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Canid Scavenging/Disarticulation Sequence of Human Remains in the Pacific Northwest

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ABSTRACT: Greater understanding of animal scavenging of human remains can assist forensic science investigators in locating and recovering dispersed skeletal elements, in recognizing damage produced by scavengers, and in making more informed estimates of the postmortem interval. The pattern of skeletal damage can indicate whether the body was scavenged while intact or at some time after other natural processes of disarticulation had begun.

This study analyzed thirty partially to fully skeletonized human remains with respect to scavenging at the time of body discovery in order to determine if a patterned consumption sequence existed. The scavengers were primarily coyotes *(Canis latrans)* and domestic dogs *(C. familiaris)*. Sixteen non-carnivore-scavenged remains were also examined and contrasted with the carnivore-scavenged sample.

Observed postmortem intervals from death to recovery ranged from 4 h to 52 months. Results demonstrate that canid scavenging of human remains takes place in sequential stages: Stage 0 = no bony involvement; Stage 1 = ventral thorax damaged and one or both upper extremities removed; Stage 2 = lower extremity involvement; Stage 3 = only vertebral segments remain articulated; and Stage 4 = total disarticulation. Results revealed a clear correspondence between observed stages of disarticulation and the postmortem interval.

KEYWORDS: physical anthropology, musculoskeletal system, taphonomy, scavenging, carnivore, disarticulation

Because carnivore scavenging may significantly alter human remains and can produce damage which obscures or confounds interpretation of antemortem artifacts and the cause of death, fuller understanding of such activity can prove invaluable in forensic science investigations [*1,2*]. It has been suggested that investigation of scattering and damage to skeletons by animals may aid in establishing the postmortem interval [*3,4*] and also may reflect ecological and environmental conditions under which disarticulation occurred [*5,6*]. Morse further suggests that information from such investigations might aid in locating scattered bones [*3*].

Scavenging results in disarticulation, which in turn produces easily transportable units of single bones or bone groups which can be removed from a site by animals, or geological vectors such as water [*7-11*]; influences the pattern of bone dispersion [*5,12,13*]; and ex-

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poses bones to damage such as weathering [*5,14-16*]. In addition, dismemberment and disarticulation alter insect succession of the body [*17*] and render bones vulnerable to trampling and sedimentation [*7,18,19*] and to root damage [*20,21*].

Anatomical characteristics considered most influential to the sequence of the disarticulation process are the type of joint and amount of interlocking that is present at the articular surface and the relative amounts of easily decomposed versus more resistant tissue surrounding the joint [*2,5*].

Normal decomposition of soft tissue, leading to skeletonization and disarticulation, is considered the result of bacterial and enzymatic action [*22-25*]. Toots [*22*] suggested the following stages for the "normal" disarticulation of coyote *(Canis latrans)* skeletons deposited on the surface of the semi-arid Wyoming grasslands: skull, including the atlas, and some limbs become disarticulated; ribs become loosened and the thorax collapses; limbs begin to disarticulate into smaller units until only isolated bones remain (at this time, the lower jaw may separate from the skull); and often overlapping the previous stages, the vertebral column starts to disarticulate. Before complete separation of the vertebral column in this final stage, bones begin to weather, splinter, and gradually disintegrate. This sequence of events is assumed to take place without significant scavenger intervention, although Toots does not state so explicitly. Agreement with this general scheme has been reported by other investigators [*5,12,21*].

Modifications in the "normal" disarticulation process are found under various circumstances [*5,22*]. Considerable attention has been given to the role insects play in decay rates leading to skeletonization [*26-32*]. Insects may even cause rotation and dislodgment of bones [*33,34*]. Sedimentation and other forms of full or partial burial fix the position of skeletal elements and retard the rate of decomposition [*23-25,35*]. Bodies floating in water disarticulate differently than those on land. Observations of drifting marine mammals in open water indicate that loss of head and limbs occur first. Bones disarticulate from the distal portion of the extremities and proceed proximally [*5,33,35*]. Disarticulation of humans in water somewhat conforms to this pattern.[4] Mummification not only limits decomposition, but also acts to retain skeletal elements by holding them in anatomical position [*5*]. Saponification provides an embedding matrix for skeletal parts even though complete disarticulation may be present in such remains. Finally, when remains are scavenged by animals, they come apart at variance with the normal disarticulation sequence [*3,5,12,22*].

To date, no systematic study of the effects of scavenging of human remains has appeared in the forensic science literature; however, related investigations on animal carcasses have been carried out by several authors. A general scheme for the consumption of soft tissue and bone for various African prey by a variety of animals such as hyenas, lions, and vultures has been proposed by Blumenschine [*36,37*]. Haynes [*12,18*] and Binford [*21*] have provided information about artiodactyl carcasses fed upon by various carnivores, most notably wolves. Willey's recent observations of road-killed deer scavenged by confined wolves support those of the previous authors [*21*]. These investigations of carnivore-scavenged carcasses have demonstrated that certain groups of bones are likely to be removed and recovered in association. As summarized by Haynes, the most common associated groupings of bones removed or recovered or both include head with the first and second cervical vertebrae; rib cage with some cervical and thoracic vertebrae, including the sternum; the scapulae and upper extremities; and the lumbar vertebrae, pelvis, and lower extremities, particularly the tibia and fibula [*12*]. This suggests that carcasses utilized by larger scavengers are taken apart in predictable patterns which make certain groups of bones available for transport together.

This study is an extension of a previous report on animal tooth-mark artifact damage to bones and survivability of bones of scavenged remains [*4*]. It examines a general sequence of consumption and disarticulation of exposed, carnivore-scavenged human remains. Analysis

[4] W. D. Haglund and D. T. Reay, personal observations, 24 June 1982 and 20 June 1987.

is based on the condition of the remains at the time of body discovery, with special emphasis on damage to bone and soft tissue and on disarticulation and scattering of bones. Variables affecting consumption and disarticulation and their relationship to scattering and the postmortem interval are discussed.

Materials and Methods

The present study examines 46 partially to fully skeletonized human remains recovered between 1979 and 1988 from the Seattle-King County area of the Pacific Northwest. This is an area of 35.57-in. (90.35-cm) annual precipitation, with annual mean high and low temperatures of 59.2 and 43.96°F (15.1 and 6.64°C), respectively [*38*].

Recovery efforts in outdoor locations generally included shoulder-to-shoulder walk-through of the area surrounding the principal skeletal discovery site and denuding the area of vegetation, followed by hands-and-knees search for bones. Multiple screens, graduating to 1/16-in. (1.6-mm) mesh, were used to sift soil and debris at primary discovery sites. Scene observations were augmented by reports written by the police, physical anthropologists, and the Medical Examiner's Office. A Medical Examiner representative, experienced in recognition of human skeletal material, was present at all scenes except Case 30.

Only positively identified cases in which the postmortem interval of exposure was known were considered for inclusion in the study. This interval was estimated as the time from the last date the individual was known to be alive to the date of recovery. Human population density was based on 1986 census tract figures presented in the 1986 King County Annual Growth Report [*39*].

Cases were divided into those demonstrating no carnivore activity and those showing carnivore scavenging. Carnivore-scavenged remains were assigned a whole number value of 0 to 4, ranging from least to most completely scavenged based on the condition of the remains at the time of their recovery. The stages of scavenged remains were developed by the author (WDH) and derived in part from the work of Toots [*22*], Hill [*5*], and Haynes [*40*]. These stages are

- 0 = removal of soft tissue with no disarticulation,
- 1 = destruction of the ventral thorax characterized by absence of the sternum and damage to distal ribs, accompanied by evisceration and removal of one or both upper extremities, including scapulae and partial or complete removal of clavicles;
- 2 = fully or partially separated and removed lower extremities;
- 3 = nearly complete disarticulation with only segments of vertebral column articulated; and
- 4 = total disarticulation and scattering, with only cranium and assorted skeletal elements or fragments recovered.

Atypically scavenged remains, not corresponding to one of the above defined scavenging stages, were designated by a letter "A." Species of animal responsible for scavenging was determined by presence of scat deposits and tracks, as well as sightings of the species at the scene. Major scavengers were coyotes *(Canis latrans)* and domestic dogs *(C. familiaris)*.

Simple regression and cluster analysis was performed on the University of Washington VAX1 computer using the SPSSX statistical package. Ward's Method of clustering, a technique to optimize minimum variance within clusters, was employed to test clustering of individual cases with the hypothesized scavenging stages [*41*].

Results

Table 1 presents an overview of the human remains which formed the basis of this study. They are listed in two groups: Cases 1 through 30 consist of carnivore-scavenged remains and 31 through 46 of those bodies which were not carnivore-scavenged. Each group is listed

TABLE 1—*Summary of carnivore-scavenged and non-carnivore-scavenged human remains.*

CARNIVORE-SCAVENGED HUMAN REMAINS

Case	Sex/Age	Human Population Density	Month of Death	Environment	Elapsed Time Exposed	Stage of Disarticulation	Maximum Diameter of Scatter, ft[a]	Evidence of Antemortem Physical Trauma
1	F/29	4	Dec.	industrial suburban	4 h	0	none	GSW[b] to head
2	M/22	4	Aug.	wooded suburban	5 days	0	none	none
3	F/49	5	Feb.	indoors	8 days	0	none	none
4	F/77	6	Jan.	indoors	14 days	0	none	none
5	M/22	1	Feb.	evergreen	22 days	1	none	stabs to chest
6	F/16	1	Aug.	wooded and brushy	28 days	1	none	none
7	F/22	1	Dec.	evergreen forest	2 months	2	none	none
8	F/22	1	April	wooded and brushy	2 months	3	240	blunt head
9	F/19	1	Dec.	evergreen forest	2.5 months	1	none	none
10	F/16	5	Sept.	brushy suburban	4-5 months	2	10	none
11	F/19	4	May	evergreen forest	4-5 months	A[c]	30	none
12	M/49	1	Aug.	evergreen forest	6 months	3	200	GSW to head
13	F/26	1	Sept.	evergreen forest	8 months	3	5	none
14	M/46	1	Sept.	evergreens, sparse	8 months	3	300	GSW to head
15	F/22	1	April	evergreen forest	9 months	A	75	none
16	F/18	5	Oct.	bushes	10 months	A	18	none
17	M/29	1	April	evergreen forest	11 months	3	300	none

18	F/25	1	April	evergreen forest	12 months	4	100	none
19	F/18	4	April	wooded	12 months	4	30	none
20	F/18	1	May	evergreen forest	17.5 months	4	4	none
21	F/36	1	July		21 months	A	100	none
22	M/19	3	April	swamp, brush	21 months	4	150	GSW to head
23	F/16	4	March	swamp	24 months	A	15	none
24	F/22	3	April	wooded	24.5 months	A	600	none
25	M/18	1	Jan.	evergreen forest	25 months	A	300	
26	F/15	1	Sept.	wooded	31 months	4	300	none
27	F/7	1	Sept.	brush	32 months	A	50	none
28	F/19		Oct.	wooded	34 months	4	300	none
29	F/17	1	May	brush	51 months	4	NA	yes
30	F/17	1	Dec.	evergreen forest	52 months	4	NA	yes

NON-SCAVENGED HUMAN REMAINS

Case	Sex/Age	Human Population Density	Month of Death	Environment	Elapsed Time Exposed	Scatter of Recovered Bones, ft[a]	Evidence of Antemortem Physical Trauma
31	F/29	5	Aug.	inside parked vehicle	10 days	none	stabbing trunk
32	F/68	4	Aug.	suburban, bushes	14 days	none	none
33	F/21	1	Aug.	evergreen forest	30 days	none	head trauma
34	F/15	5	Feb.	brushy suburban	1.5 months	none	none
35	F/14	1	Aug.	evergreen forest	47 days	none	none
36	F/19	4	Sept.	wooded	2 months	none	none
37	F/20	4	June	brushy	4 months	none	none

TABLE 1—*Continued.*

NON-SCAVENGED HUMAN REMAINS

Case	Sex/Age	Human Population Density	Month of Death	Environment	Elapsed Time Exposed	Scatter of Recovered Bones, ft[a]	Evidence of Antemortem Physical Trauma
38	F/24	4	April	wooded	5 months	none	none
39	F/77	5	July	suburban	5.5 months	10	none
40	F/18	5	May	wooded	10 months	none	none
41	F/32	4	July	brushy	10 months	none	none
42	F/17	4	March	wooded	11 months	75	none
43	F/4	6	Feb.	brush	11 months	none	unknown
44	F/17	4	April	wooded	11.5 months	none	none
45	F/16	5	Feb.	wooded	19 months	none	none
46	F/16	4	Aug.	wooded	20 months	none	none

[a]1 ft = 0.3 m.
[b]GSW = gunshot wound.
[c]A = atypically scavenged remains.

in order of increasing elapsed time of postmortem exposure. Information is also provided for sex, age, human population density of the area from which the remains were recovered, month of death, environment of the deposit site, elapsed time of exposure, stage of disarticulation (for scavenged remains), and maximum diameter of the area from which bones were recovered. Population densities are defined in Table 2. Those deaths in which the cause of death was due to invasive trauma such as gunshot, stabbing, or blunt trauma are noted.

Thirty-nine cases (85%) were female and seven (15%) were male. Ages ranged from 4 to 77 years, with a majority (65%) female between the ages of 15 and 25 years of age (Table 3). This age bias is due to a serial homicide case in the region of study, publicly known as the "Green River Murders" and characterized by the death of young women [42]. Elapsed time from death to recovery ranged from 4 h to 52 months. Forty-four cases were recovered from outdoor locations, including one in a parked vehicle (Case 31). Two bodies were confined with family pets in residences (Cases 2 and 3).

Figure 1 represents an inventory of bones recovered undamaged, recovered damaged, or not recovered for individual cases. (Incomplete recovery of hand and foot elements is indicated as recovered damaged.) Case numbers correspond to those in Table 1.

TABLE 2—*Human population density of census tract where remains were discovered (1 = 1-200 persons/square mile;[a] 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).*

Number Census Tract	Human Population per Square Mile	Carnivore Scavenged	Not Carnivore Scavenged
1	1-200	19	2
2	2001-1000	0	0
3	1001-1500	2	1
4	1501-3000	4	8
5	3001-5000	3	5
6	5001-6000	1	1
Totals		29	17

[a]1 square mile = 1.6 km^2.

TABLE 3—*Summary age and sex distribution of human remains in this study.*

Age	Female	Male	Total
5-9	1	0	1
10-14	1	0	1
15-19	21	2	23
20-24	8	2	10
25-29	3	1	4
30-34	2	0	2
45-49	1	2	3
75-79	2		2
Totals	39	7	46

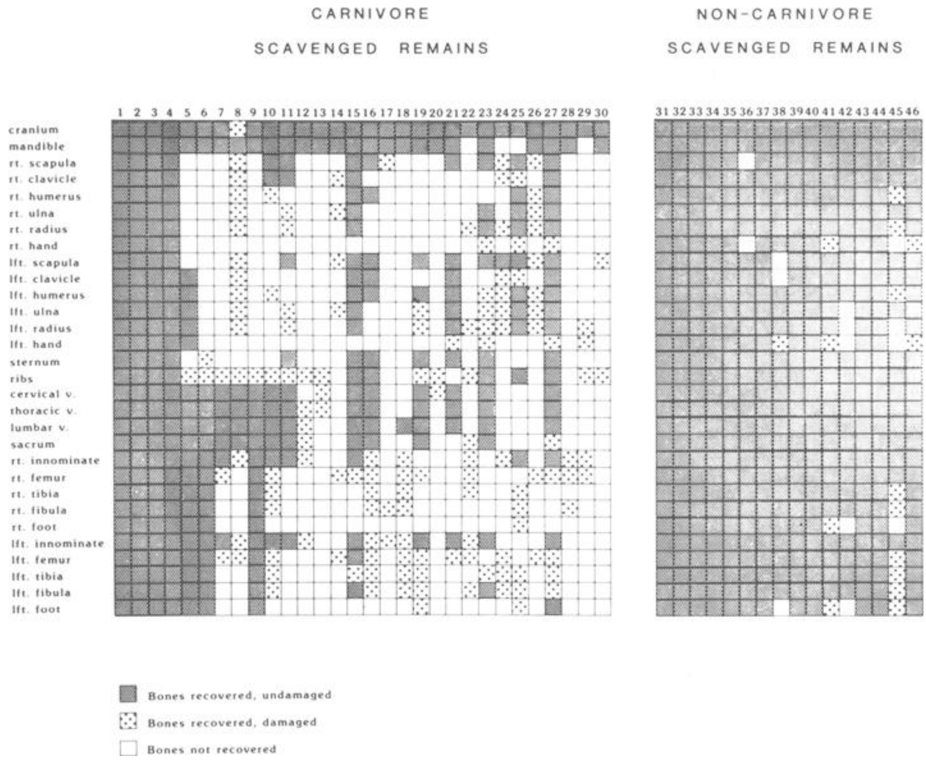

FIG. 1—*Skeletal inventories of bones present and undamaged, present but damaged, and bones not recovered for carnivore-scavenged and non-carnivore-scavenged remains (Cases 1-30 and 31-46, respectively).*

Remains Not Scavenged by Carnivores

Sixteen remains (Cases 31 to 46) showed no evidence of carnivore scavenging. Upon discovery they were arrayed in relative anatomical order with lack of significant scattering. Complete to nearly complete skeletons were recovered (Fig. 1). Missing bones usually included distal phalanges of hands and feet. Any non-carnivore animal damage to bones generally could be attributed to rodent activity as attested by tooth marks. The majority of these sixteen cases (81%) were discovered in areas of transitional to high human population density (Table 2).

Stages of Carnivore Scavenging/Disarticulation

The remaining thirty cases (1 to 30) were carnivore-scavenged. Twenty-two scavenged cases corresponded to the defined stages of scavenging with the number of cases in each stage as follows: Stage 0 = 4, Stage 1 = 3, Stage 2 = 2, Stage 3 = 5, Stage 4 = 8. Eight cases were atypical of defined stages and were designated by a letter "A." A case example representing each stage of scavenging/disarticulation is presented below. A summary of those skeletons of the atypical (A) category is also presented.

Stage 0—This stage is limited to early removal of soft tissue with no disarticulation. It is represented by 4 cases (1, 2, 3, and 4) with postmortem intervals ranging from 4 h to 14 days, respectively (Fig. 2).

Case 1 (Fig. 3) was that of a 29-year-old female who died as a result of a homicidal gunshot wound to the head. She died in the early hours of a December morning and was discovered approximately 4 h later. A medium-sized dog was seen at the remains at the time of the body's discovery. The deceased was clad only in a sweater, which had been cut up the front. She was supine, in a sprawled position, with legs, genitalia, and lower abdomen exposed.

Skin, hair, and major muscles of the head had been removed. Both eyes were missing. Carnivore tooth damage to bone consisted of a 1/8-in. (3.175-mm) diameter circular puncture defect in the superior margin of the left orbit and chewed margins of the bony nasal orifice. All skin and musculature, including vascular structures of the neck, were absent to the level of the thoracic inlet. Residual ends of vessels emanated from the arch of the aorta. The tips of four cervical transverse processes were missing. Damage to the skin and musculature extended over the anterior chest to the approximate level of the nipples and exposed the surface of the ribs. Areas of absent skin were circumscribed by chewed, irregular margins, which exhibited a serrated appearance. Numerous linear abrasions were present on margins of skin adjacent to areas of soft tissue damage. Chewed bits of tissue were entangled in the knit of the sweater, and the cut in the sweater had been enlarged by scavenger or scavengers of the anterior chest area.

Stage 1—This stage demonstrates destruction of the ventral thorax characterized by absence of the sternum, destruction of sternal rib extremities, evisceration, and absence of one or both upper extremities, including the scapula and partial or complete clavicle. The three cases representing this stage had been exposed for periods ranging from 22 days to 2½ months (Cases 5, 6, and 9, Fig. 2).

Case 5 (Fig. 4) was a 25-year-old male, whose death was attributed to blunt impact to the head and stab wounds to the back. He had been deposited in a rural area of evergreen forest the third week of February. He was discovered in the second week of March for a total period of exposure of 22 days. He had been lightly clad in a shirt and jeans at the time of disappearance. When discovered, his pants had been partially pulled off and his shirt was found 35 ft (11 m) from the remains. When alive he weighed 135 lbs (61 kg) and at autopsy, 53 lbs (24 kg).

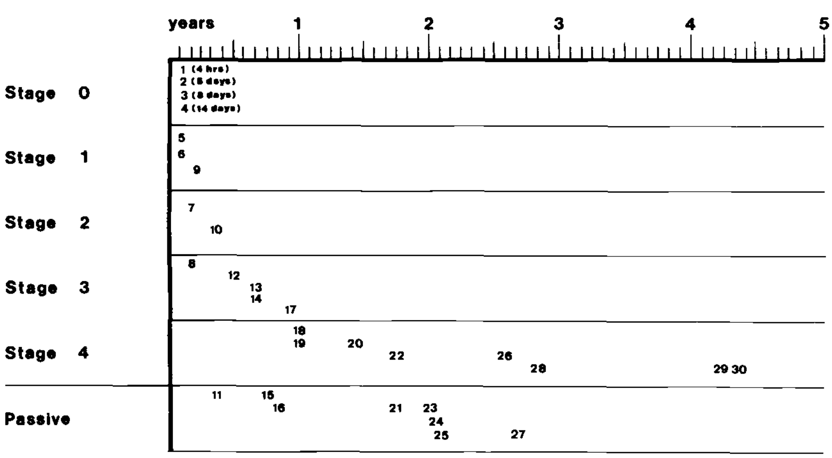

FIG. 2—*Elapsed time interval (weeks, months, or years) from death to discovery is correlated with the stage of carnivore scavenging at the time of body discovery. Numbers indicated in the time axis for each scavenger stage correspond to numbers of individual cases.*

FIG. 3—*Stage 0: Initial stage of animal scavenging involving destruction of soft tissue. Represented by Case 1 with an elapsed postmortem interval of 4 h before discovery.*

Damage to the head consisted of absence of the tip of the nose, masseter muscles, and skin of the mid to lower face, resulting in exposure of the mandible to the level of the ear (Fig. 4*a*). Skin margins were irregular. All viscera, except for the prostate gland, had been removed, including tongue and neck organs. Sternum and costal cartilages were missing, as well as both clavicles. The right upper extremity, including the scapula, was missing and not recovered. The left upper extremity was defleshed to the level of the hand, which was relatively intact (Fig. 4*b*). This limb was attached to the body by a tag of skin at the shoulder. The proximal ribs remained only as remnants and were extensively gnawed to 1 1/4 to 4 in. (3 to 10 cm). The remainder of the axial skeleton was intact, including muscles and skin on the back. Skin edges were irregular, and short distances from the margins exhibited characteristic V-shaped defects made by the canine teeth of carnivores (Fig. 4*c*). Both femurs were exposed. The skin over the right lower leg and dorsum of the right foot was present, as well as skin over the lateral and posterior aspect of the left lower leg.

Stage 2—In addition to the attributes present in Stage 1, Stage 2 involves the lower extremities. In Case 7, both upper extremities are detached and the lower extremities were also removed, along with the fully articulated pelvic girdle and sections of lower spine. Two cases (7 and 10), with postmortem intervals of 2 and 4.5 months, respectively, correspond to Stage 2 disarticulation (Fig. 2).

Case 7 (Fig. 5) was a 19-year-old woman reported missing in late December and discovered in mid-February in a wooded area 20 yd (18 m) off a main road. She was found partially beneath some fallen trees. The mandible was found approximately 20 ft (6 m) from the rest of the body. The skull and entire axial skeleton were present and articulated; only the coccyx was absent. Ribs were extensively gnawed at their proximal ends. Both upper extremities were missing, including both clavicles and scapulae. Lower extremities were missing from below the distal condyles of the femur, which had been gnawed through. Gnawing damage was present at the subpubic angle, although the superior pelvic rim was intact. Wet ligament and muscle tissue was present along the entire spinal column and pelvic region. At the time of autopsy the remains weighed 16 lbs (7 kg); in life the woman weighed 120 lbs (54 kg).

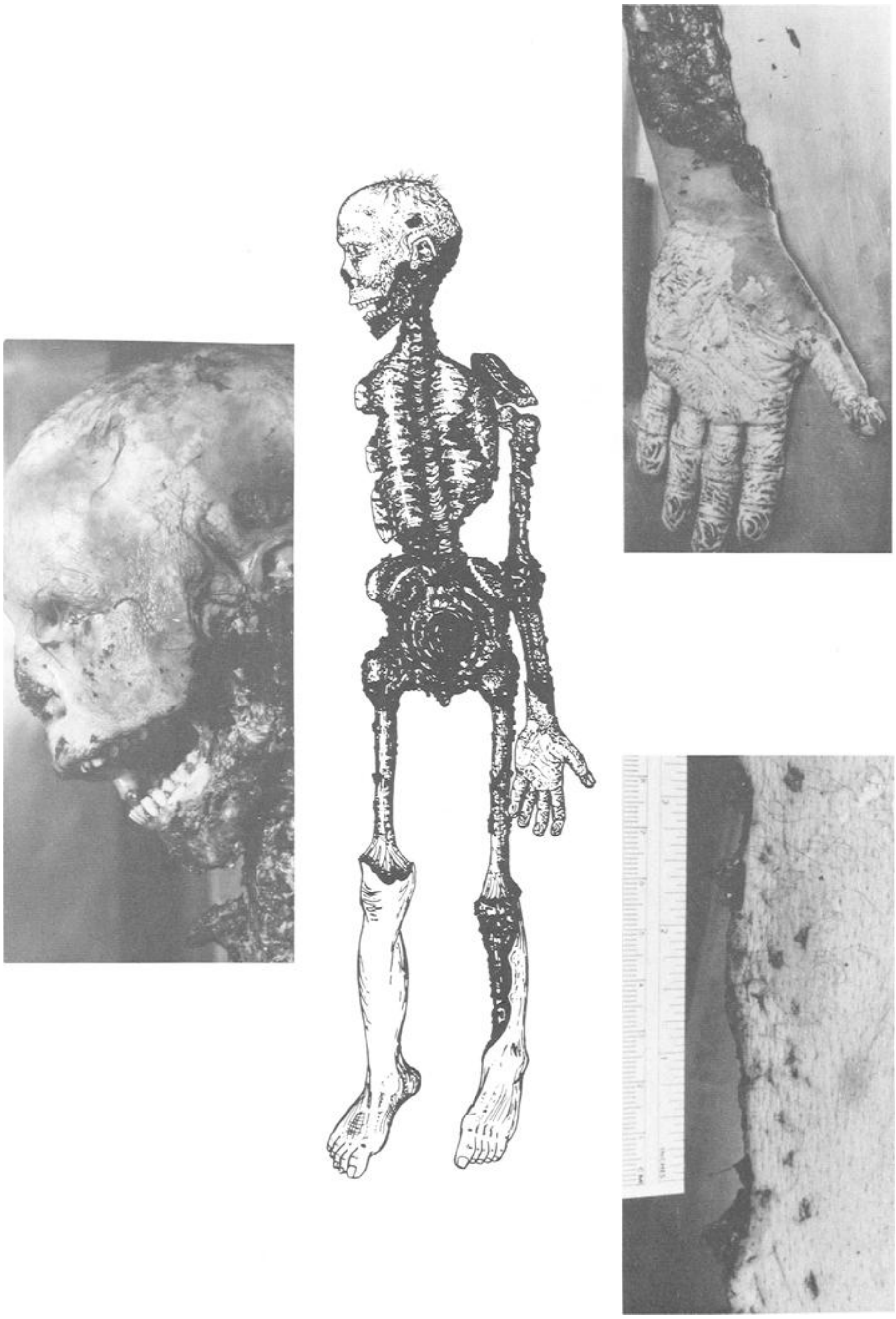

FIG. 4—*Stage I: Case 5 recovered from a rural, forested area after being exposed 22 days. Overall depiction of remains showing evisceration and destruction of ventral thorax accompanied by missing upper extremity.* (a) *Damage to head and neck, showing decomposition as well as results of animal activity.* (b) *Hand of deceased. Note irregular margins of damaged area at level of the wrist.* (c) *Skin margins from lateral right lower leg. Note V-shaped tooth defects characteristic of carnivore canine teeth.*

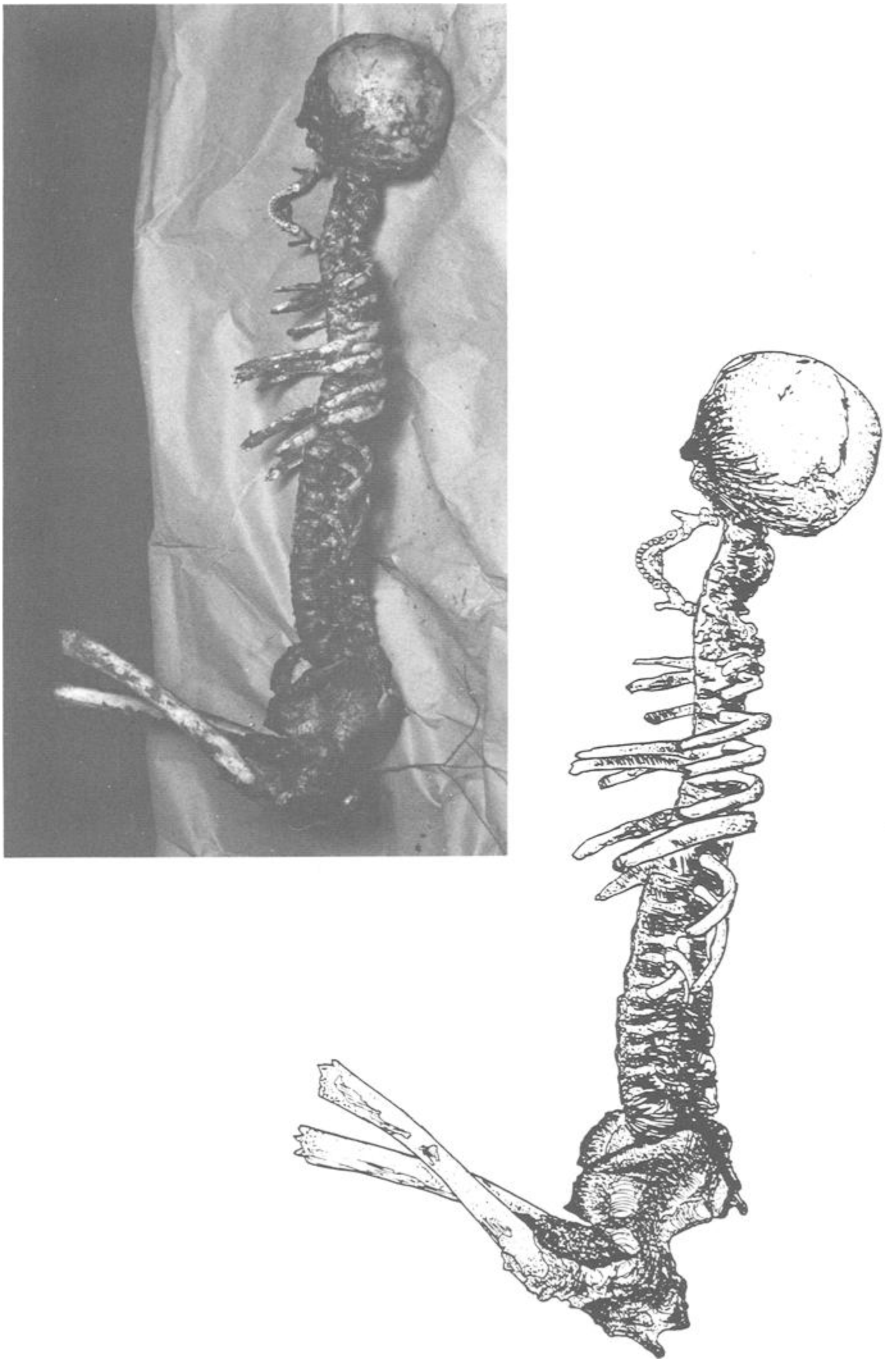

FIG. 5—*Stage 2 represented by Case 8 exposed in extremely rural area for 2½ months.*

Stage 3—In this stage, all skeletal elements, except for articulated sequences of vertebrae, were separated and either absent or extensively damaged. Bones were widely scattered over areas of 10 ft to 100 yd (3 to 91 m). Recovered long bones were damaged at both ends and bones from a single extremity were frequently found close by. The range of exposure for cases in this stage was 2 to 11 months and involved Cases 8, 10, 12, 13, 14, and 17 (Fig. 2).

Case 12 typified Stage 3. This 49-year-old male was known to be alive in late August and was discovered the following April. His remains were exposed for a period of slightly over 6 months. He was discovered in a rural area at the fringe of dense evergreen forest. Death was due to a gunshot wound to the head.

Two sections of vertebral column remained articulated: the sacrum with ten lumbar and thoracic vertebrae and thoracic vertebrae one through seven. The latter segment had one rib fragment attached. All transverse processes and one spinous process showed damage typical of carnivore gnawing. All remaining skeletal elements were disarticulated and scattered. There was soft tissue absence on the head, but the skull and mandible were minimally damaged. Both first ribs, both innominates, and the left femur were extensively damaged by gnawing animals. Skeletal elements were scattered over approximately 200 ft (61 m).

Stage 4—This stage consists of complete disarticulation and scattering with cranium and assorted bones or bone fragments recovered. Elapsed time of exposure ranged from 6 to 52 months and included Cases 18, 19, 20, 22, 26, 28, 29, and 30 (Fig. 2).

Case 26, typical of Stage 4, was a 19-year-old female deposited in September and discovered over 2½ years later in an area of dense evergreen forest. The remains were recovered from three general locations. The skull, mandible, and both femora shafts were within 20 ft (6 m) of each other. Bones of the right upper extremity consisting of the scapula and shafts of the humerus, radius, and ulna were approximately 30 ft (9 m) in one direction, while the same bones of the left upper extremity were 282 ft (86 m) in the opposite direction.

Atypically Scavenged Remains

Eight carnivore-scavenged skeletons (Cases 11, 15, 16, 21, 23, 24, 25, and 27) did not correspond to scavenging stages as defined above. These skeletons differed from those previously discussed in that bones damaged or not recovered were atypical of those expected in the defined sequence of scavenging. Four were in areas of low human population density (Cases 15, 21, 25, and 27), but were in sheltered circumstances which prevented complete exposure to scavengers. In addition, Case 20 was heavily clothed, Case 15 was wrapped in a plastic tarp, and both Cases 25 and 27 were in shallow graves. The remaining four cases (11, 16, 23, and 24) were discovered in areas of transitional to high human population density (Table 1) and had minimal carnivore tooth damage. They were found in relative anatomical order with little or no scattering at the time of discovery.

Cluster Analysis of Scavenging Stages

The results of cluster analysis are shown in Fig. 6. The clustering matrix was derived by assigning a whole number value to the information presented in Fig. 1 (undamaged bones were assigned a score of 3, those present but damaged a score of 2, and those absent a score of 1). In the resulting dendrogram, Stage 0 clusters separately. (Stage 0 also clusters with non-scavenged remains. This is predictable since both categories have minimal to no bones damaged or missing.) Stages 1 and 2 each form separate clusters. Stages 3 and 4 form a combined cluster as expected since scoring consideration was given to presence or absence of articulation, the defined difference between Stages 3 and 4. Atypical cases are randomly scattered throughout the various clusters. A notable exception to the expected clustering is Case 8.

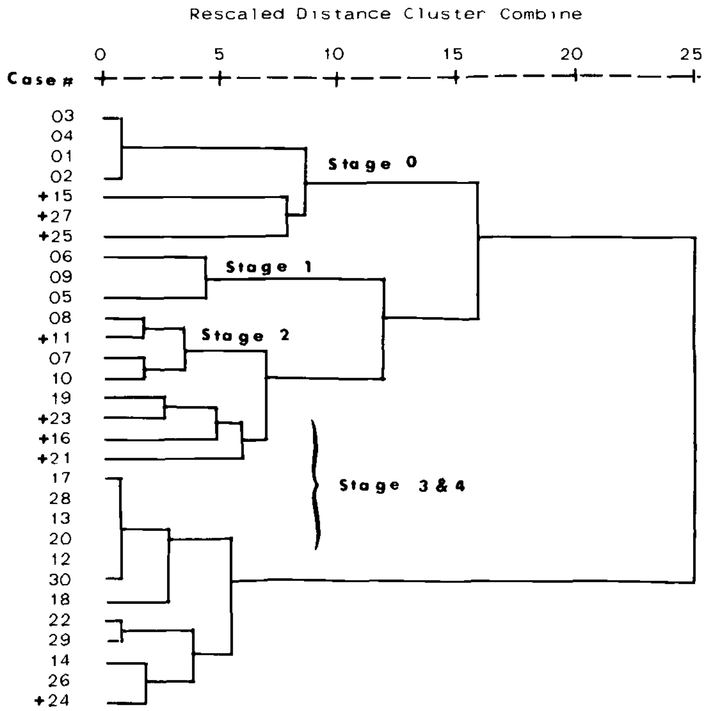

FIG. 6—*Dendogram (Ward Method) based on scoring for bones present and undamaged, present and damaged, or bones absent for scavenged cases (+ indicates atypical cases).*

Carnivore Scavenging and the Postmortem Interval

Figure 2 summarizes the elapsed postmortem interval from time of death to time of discovery for each stage of scavenging, as well as for atypical cases. Next, the relationship between number of bones recovered and length of postmortem exposure was examined for carnivore-scavenged remains (Fig. 7). For each skeleton, the presence or absence of bones was inventoried. Inventoried bones included the skull, mandible, clavicles, scapulae, humeri, ulnae, radii, sternum, vertebral column, sacrum, ribs, innominates, femora, tibiae, and fibulae for a total of 70 bones. Three regressions are shown for the number of bones recovered over time. They include all carnivore-scavenged remains of this study, all carnivore-scavenged remains minus those which were in the atypically scavenged category, and only those carnivore-scavenged remains which were discovered in a census tract area of 1 in which human population density was 1 to 200 persons/square mile (2.6 km^2). As shown for cases discovered in areas of population density less than 200 persons per square mile, the recovered number of bones shows a strong trend to decrease over time.

Discussion

Sequence of Carnivore Scavenging and Disarticulation

Medium-sized canid consumption and disarticulation of human remains takes place in a relatively consistent sequence. This is especially true for bodies scavenged while completely

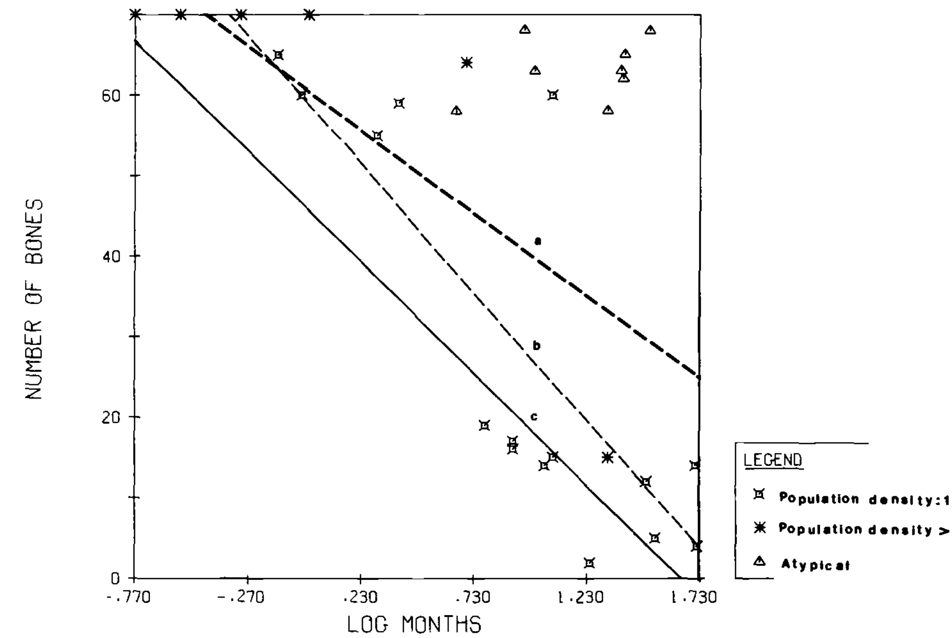

FIG. 7—*Relationship between number of bones recovered and log 10 months elapsed time of postmortem interval.* (a) *Regression for all carnivore-scavenged remains of this study (*$r = 0.5250$, $p < 0.0035$, *y intercept* $= 3.5900$, *slope* $= -0.525$*).* (b) *Regression for carnivore scavenged remains (minus atypical cases) coinciding with defined stages of atypical scavenging (*$r = -0.8588$, $p < 0.0035$, *3.5665, y intercept* $= 3.57$, *slope* $= -0.859$*).* (c) *Regression for carnivore-scavenged remains coinciding with defined stages of disarticulation where body was discovered in a census tract area of 1 (= population density of 1-200 persons/square mile) (*$r = 0.8318$, $p < 0.0001$, *y intercept* $= 3.49$, *slope* $= -0.832$.

intact and prior to previous disarticulating modifications due to decomposition and insect activity.

Removal of skin and muscle from the face and neck, accompanied by removal of neck organs, were the first actions of scavengers. Feeding activity progressed to the thoracic inlet and was followed by destruction of bony structures of the ventral thorax, including the sternum, sternal ends of ribs, and clavicles. Overlapping or subsequent to this stage, one or both upper extremities were removed along with the scapula and, at times, the remaining portions of the clavicles. Upper limb removal was a natural sequel to consumption of the pectoral muscles and separation of the clavicle from the thorax. This leaves the upper limb with minimal soft tissue connection dorsally. These disarticulated upper extremities are often transported away from the remains. Consumption of viscera accompanies this stage.

By Stage 2, most muscle has been eaten from the thorax and pelvic region as well as the thigh. Lower limbs may be removed by gnawing through the distal femoral condyles. Lower extremities are also removed in association with the complete pelvic girdle and various levels of lumbar and thoracic vertebrae. This occurs when breaks of spinal articulation occur. By Stage 3, remaining segments of the axial skeleton may still be articulated, but have been transported from the main body site. Isolated bones are usually scattered and heavily damaged. In the final stage of disarticulation, all recovered bones are disarticulated, extensively gnawed, and scattered over a wide area.

Variables Affecting Sequence of Scavenging

The sequence of canid scavenging is modified in areas of high human population density and when remains are in sheltered circumstances (Cases 25 and 27). This is consistent with previously published findings of damage to and survivability of skeletal elements of carnivore scavenged remains [*4*]. Body position can also alter the sequence of carnivore consumption and is demonstrated by a bias of body parts missing from the remains (Case 19). Cause of death, especially when involving invasive trauma, may significantly accelerate the scavenging sequence. This is exemplified in Cases 1 and 8, in which death was due to gunshot injuries to the head and extensive blunt trauma to the head, respectively. Although not evidenced in this study, extensive trauma to portions of the body other than the head might well detract from the normal sequencing of consumption by a scavenger.

Variations in anatomy relating to bony architecture, ligamentous attachments, and amounts and types of tissue surrounding joints have a great deal to do with the ease with which certain bones and body parts can be removed by scavengers. For instance, upper limbs, with their relatively loose girdle attachments and limited bony connections, are easier to remove than the lower extremities. Moreover, the articulated head of the femur is in a joint protected by a deep bony recess as well as quantities of surrounding tissue. This renders it relatively inaccessible. This may be why smaller carnivores such as coyotes may remove the lower extremity at the cancellous portions of the distal femoral condyles, as in Case 7. If the femur were detached at the hip joint, one might expect damage to the acetabular rim. Most recovered disarticulated innominates showed no damage to the rim of the acetabulum; even so, the proximal end of the femur had been completely destroyed. This suggests that the separation occurred after the remains were in a stage of advanced decomposition and at a time when the femur was easily pulled from the joint.

It is well-documented that natural body orifices or sites of invasive injury provide primary ports of entry for insects [*30*]. Natural orifices have also been noted as sites of access to animal carcasses by non-anthropod scavengers. Blumenschine specifically mentions vultures initiating their feeding via anus, genitals, ears, eyes, and mouth, citing their limited ability to gain access to flesh beneath the skin, except through these openings [*36,37*]. Of individual remains representing Stage 0 scavenging in this study, only two had fully exposed genitals (Cases 1 and 3). In both instances, scavenging was initiated at the lower face and neck region; however, gunshot trauma to the head was present in Case 1. Initiation of feeding at the head might well have a sound anatomical basis. Soft tissue with subjacent bone is relatively more susceptible to blunt force trauma [*43*] and is a factor that may well contribute to smaller, weaker carnivores feeding on the head of human remains rather than other parts of the body. The multiple planes and edges of the face may also aid smaller, weaker scavengers in consumption. Blumenschine also mentions hide thickness as a barrier for certain carnivores [*36,37*]. The tough parchment-like skin of mummified remains provides a similar barrier to scavengers, especially in hot dry climates such as in the southwestern United States.

Scene Information: Effects of Scavenging

Establishing the original site of the remains, as well as recovering transported body parts, is crucial to forensic investigations. Complete remains may be moved by animals. Animal movement of a body can be inferred by drag marks or disturbed ground cover, and sprawled attitude of the body may often be in evidence. Previous resting places of a body may be marked by discolored areas caused by body fluid leakage. The presence of insect larvae, or pupae casings and strong odor may also give indications of a resting site. This was true for Case 6, where the skeleton, minus both upper extremities, was 30 ft (9 m) from where the body had been originally deposited. In Case 21, the deceased's location at the time of death was marked by a revolver with which he had killed himself. Movement of his entire thorax by animals was indicated: clearly, scavengers were responsible. The remains of Case 5 were positioned on its back. Scavenging coyotes had moved the body about, but had not turned it over, as attested by undamaged skin present over the back.

Dispersal of body parts by animals can be dramatic, affecting both distance of scattering and associations of recovered bones. One mandible was found 1/4 mile (0.4 km) from the rest of the skeleton and had been transported by a domestic dog. Rodriguez has demonstrated that medium-sized dogs are capable of transporting human skulls [44]. Associations of recovered bones also demonstrate the disarticulation/dismemberment process. In Case 26, one upper extremity, consisting of the shafts of the humerus, radius, and ulna, was discovered over 200 yd (183 m) from where the skull, mandible, and tibias were found. The constituent elements of the other upper extremity were found in association with each other 30 ft (9 m) in the opposite direction from the remains.

In general, the most likely sites of recovery of skeletal material is in the immediate vicinity of the initial body location and along animal trails which provide access to the area. Isolated teeth were recovered by screening areas considered to be the original resting place of the body and areas between the original body location and the location where the mandible and cranium were recovered. This was true especially in areas where sediment was responsible for covering remains. Some smaller elements of hands and feet were recovered from rodent tunnels during the screening process. One femur shaft was found in a hollowed-out portion of a tree trunk. Dependent upon the scavenging species and their behavior, teeth and bone fragments may be recovered from scat deposits in latrine areas or near den entrances. Some scavengers cache food, which may involve shallow burial in soil or brush debris. No reliable information is available on caching by coyotes [45]. Of course, vectors other than animals are also responsible for movement of bones. Disarticulated bones have a propensity to roll down inclines and be moved by surface drainage.

Animal Scavenging and the Postmortem Interval

Scavenging opportunities might take place at any time before, during, or after other natural skeletonizing phenomena are in progress. Scavenging may be initiated, abandoned, and initiated again. Various scavengers may have a preference for various states of freshness or decay of carcasses they consume. For instance, in warmer weather, scavenger-assisted disarticulation is most certainly affected by decomposition and insect activity. Depending upon the state of decay at the time of scavenging, these other phenomena might contribute to considerable modification of the expected sequence of disarticulation by the scavenger. In such cases, bones which are missing or damaged may be atypical of bones expected when intact remains are scavenged. Case 11 is such an example. The radius and ulna were damaged at their distal and proximal ends, whereas the humerus was intact. In Case 23, a complete right radius, ulna, and scapula were intact and unmarred by tooth artifacts when recovered. The right humerus was missing, and bones of the left upper extremity and both lower extremities were either damaged or missing. Such atypical patterns of disarticulation might also be dependent on the body position at the time of scavenging. This limited scavenging of bodies, in advanced disarticulation due to decomposition and insects, may result in skeletal remains staying in relative anatomical position. It has been pointed out that scavenging may significantly alter expected rates of insect succession; this occurs when scavengers consume insect larvae along with body parts [17]. Elapsed time for various stages of scavenging are subject to wide and overlapping time intervals.

Estimation of postmortem intervals using regression equations, in which the number of bones recovered is treated as the independent variable, is risky for it requires uniform recovery efforts by experts qualified in recognition of human skeletal material. Recovery of skeletal material, in turn, is dependent on terrain and thoroughness of recovery techniques. Authorities in skeletal recovery stress the absolute necessity that qualified experts be involved in the recovery efforts of skeletons from outdoor scenes [6,46,47].

Conclusions

As shown in this study, variables affecting scavenging and disarticulation by animals are human population density of the area in which the remains are discovered, circumstances which protect the remains from scavengers, position of the remains, and the cause of death. Other factors which will affect scavenging are behaviors of the scavenging species, season of year, amount of food available, number of individuals feeding, and size relationship of scavenger to carcass. Any assessment of postmortem interval is extremely area-dependent and does not depend on a single criterion. Knowledge of the species of scavenger is critical to any estimation of postmortem interval.

In the Pacific Northwest, a fully skeletonized body with both upper extremities missing may be produced in as little as 28 days. Disarticulation and scattering of all bones, except for segments of vertebral column, can be expected in as little as two months. For elapsed times of exposure beyond one year, coyote-scavenged human remains are fully disarticulated and may be widely scattered, resulting in many bones not being recovered.

Limitations of sample size have not allowed inferences regarding scavenging relative to season. Research in the future needs to assess the effects of scavenging in various environments, seasonal variations in scavenging, species, and their numbers. The manner of death also deserves consideration when assessing scavenged remains. Analysis of animal scattering of bones as well as which bones are recovered associated are further areas which might yield important information.

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