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Taphonomic Effects of Vulture Scavenging*

ABSTRACT: From July through September 2007, three pig carcasses (*Sus scrofa*), weighing between 27 and 63 kg were placed outside in a grassy area in central Texas. A surrounding fence prevented entrance by terrestrial scavengers, while allowing avian scavengers unrestricted access. A fourth pig carcass served as a control for the rate of decomposition and was placed in a cage that prevented terrestrial and avian animal access. Modification of the carcasses was recorded through the use of two motion-sensing digital cameras and daily on-site observations. American black vultures (*Coragyps atratus*) and turkey vultures (*Cathartes aura*) waited *c.* 24 h before beginning to scavenge and completely skeletonized the carcasses in 3 to 27 h of feeding, leaving scratches on the bones. The accelerated rate of decomposition and the signature markings on the bones should be considered when interpreting taphonomic events and determining an accurate postmortem interval at vulture-modified scenes.

KEYWORDS: forensic science, forensic anthropology, taphonomy, postmortem scavenging, vultures, postmortem interval, time since death, decomposition, bone modification

A better understanding of the effects of animal scavenging on human remains can provide forensic investigators with the information necessary to properly assess a scene, as well as make more accurate estimations of the postmortem interval (PMI). Previous studies have demonstrated that evidence of animal scavenging can aid in the estimation of PMI, as scavengers are known to physically alter bone (1–5) and disperse elements from their original deposition site (4–6) in specific ways. Many of these previous studies have focused on the effects of mammalian scavengers, while the effects of avian scavengers, such as vultures, have not been widely investigated. The research presented here focuses on vulture scavenging and highlights the fact that in addition to modifying the scene, altering bone, and dispersing elements, animal scavenging can also significantly alter the rate of decomposition.

Vultures are known for their carnivorous diet and have been observed feeding on all types of carrion, including human remains. Two of the most common New World vulture species are the turkey vulture (*Cathartes aura*) and the American black vulture (*Coragyps atratus*). The turkey vulture can be found from the southern border of Canada to the southernmost tip of South America inhabiting deserts, grasslands, savannas, tropical rainforests, and temperate woodlands (7). Turkey vultures have bald red heads and are known to possess a keen sense of smell and a large olfactory bulb (7,8), making them able to locate food sources in many environments. Unlike turkey vultures, American black vultures lack a highly developed sense of smell (8–10). However, these birds are closely associated with urban development, have benefited greatly from human activity, and are often observed feeding at garbage dumps, road kills, markets, and fish docks. American black vultures are found in the southern United States and throughout most of South America living in cities, lowland areas, and in open country (7).

Over the past few decades, both American black and turkey vultures have rapidly expanded their normal geographic ranges northward, probably as a result of increases in their population (11,12) due to the expansion of open habitat by logging and rural development, illegality of killing vultures without a migratory bird depredation permit, increases in carrion availability on roadways, and general results of an expanding human population (13). As their numbers continue to grow, vultures will be found increasingly in human environments and will be likely to play a larger role in forensic contexts.

This study examines whether vultures significantly retard or accelerate the rate of decomposition, what types of signature markings they leave on bones, and how they alter the site during the course of feeding. These factors could confound PMI estimations and are important considerations when analyzing human remains from vulture-modified scenes.

Materials and Methods

Research was conducted at the Freeman Ranch, a mixed usage research and agricultural property utilized by the Forensic Anthropology Center at Texas State University in San Marcos as an outdoor decomposition laboratory. The specific site of the experiment was a secluded, grassy area with no overhead foliage. A square fence was constructed of four heavy-duty welded livestock panels measuring 16 ft long, 5 ft tall, with 4" × 4" spacing of one gauge wire rod. The fencing was designed to prevent access by terrestrial animals.

In order to assess vulture impact on outdoor scenes, domesticated pigs (*Sus scrofa*) were utilized. The internal anatomy, fat distribution, general lack of fur, and omnivorous diet of pigs are closely analogous to those of humans, and for this reason they are generally accepted as an experimental alternative (14,15). The four pig carcasses used in this experiment were chosen so that their body weights would be comparable with adult human body weights.

The first trial encompassed 26 days from July to August of 2007, and included two pig carcasses weighing *c.* 45 kg or 100 lbs each, which were acquired immediately and placed on site within 2 h of death. One of the pig carcasses was placed in the center of the open square fence to allow exposure to avian activity. The second carcass was placed in a wire cage (4 ft long, 2 ft wide, and 3 ft tall) with additional 1½" chicken wire wrapping to prevent all vertebrate scavenging activity. This carcass served as a control for

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the rate of decomposition. Both of the carcasses were exposed to the same flora, natural elements, and insects, and were monitored daily for the duration of exposure. An extended period of observation for the control carcass precluded the use of additional controls for Trials 2–4.

For the second trial, the largest carcass at 63 kg (140 lbs) was placed in the center of the fenced area within 2 h of death, although it was acquired late in the evening and placed just before sundown.

The third trial encompassed 10 days in August 2007. A 36 kg (80 lbs) goat (*Capra aegagrus hircus*) died unexpectedly elsewhere on the ranch, and the goat carcass was used as an extra trial for the research project. The carcass was placed on site *c.* 18 h after death and was monitored daily.

The fourth trial encompassed 12 days in September 2007. A 27 kg (60 lbs) pig carcass was acquired and stored at an alternate location for 24 h before placing it at the site and exposing it to vultures. The 24-h delay in the placement of the pig was designed to elicit any further information regarding vulture behavior, in terms of carrion location ability with reference to visual, olfactory, or safety cues.

Two motion-sensing digital cameras were secured to the fence and directed at each of the exposed carcasses to capture all movement and animal activity. The first camera (Wildview 2.0 Megapixel Digital Toggle-Switch Scouting Camera, Wildview, Grand Prairie, TX) took one photograph every time it sensed motion, and was on a 1-min time delay between each photograph. At night, the camera sensed motion through an infrared sensor, and took pictures using the 15-foot flash. The second camera (Moultrie 4.1 Outfitter Cam Digital Scouting Camera, Moultrie Feeders, Alabaster, AL) had a date, time, temperature, and moon phase feature, which it stamped on each picture taken. The date and time stamps were crucial when creating timelines of vulture presence, activity, and feeding behavior. This camera took a burst of two pictures each time it sensed motion, and was on a 30-sec delay between trigger points. Pictures in the dark were made possible due to the infrared motion sensing and a 30-foot flash. Both cameras were rearranged as necessary to keep the carcass in view.

Additional photographs were taken with a handheld Nikon digital camera (Nikon Inc., Melville, NY), and individual observations were recorded via daily visits for the duration of the project. Weather and atmospheric data including temperature and relative humidity were compiled daily from a weather station on the ranch. These data were provided as a service of the Environmental Physics Program of the Department of Soil and Crop Sciences at Texas A&M University.

After the remains were scavenged, skeletonized, and vultures were no longer visiting the site to feed, bones with any remaining soft tissue or dirt were placed in warm water and scrubbed with a soft bristle toothbrush. The carcass from Trial 2 was macerated. All markings left by vulture scavenging activities were analyzed and recorded after their retrieval from the site.

Results

Results of the four trials are reported separately and will include information as it relates to vulture arrival, feeding behavior and duration, rate of decomposition, patterns of carcass disarticulation, and bone modification.

Trial 1

Several vultures were observed flying overhead at the time of deposition, but it was not until *c.* 24 h later that three American black vultures descended upon the 45 kg carcass. Within an hour, 25 vultures were within camera range, four of which were turkey vultures. Vultures stayed until dark, left the scene, and returned at first light the following morning. After less than 12 total hours of feeding, the exposed pig was reduced to bones, skin, and hooves (Fig. 1). Some strong connective tissue continued to articulate some of the elements.

The mandible was the first element to be disarticulated from the exposed carcass, followed by the cranium and front limbs. Late afternoon on Day 7, pictures were captured of an American black vulture carrying a vertebra in its beak. Cameras also captured the rapidity with which vultures are able to feed, flip, and manipulate a carcass in an effort to gain access to edible parts. Upon arrival on Day 8, a scapula, radius, and ulna were observed outside of the fenced area. No observable evidence of mammal scavenging was present. Although these elements were covered with fire ants, they were placed back in the enclosure for further observation. With time, skeletal elements became increasingly scattered and disarticulated, although the majority of the flesh had been consumed after a total of 24–48 h after placement of the carcass. The only known mammalian presence was that of an opossum (*Didelphis marsupialis*), which entered the site during the night between Day 6 and 7, but did not feed or otherwise manipulate the carcass.

By the time the exposed pig had skeletonized, the control pig (of the same size and placed at the same time) was in the bloat stage of early decomposition (16) and some of the intestines had burst through the abdominal wall (Fig. 2). It took more than 2 weeks for the control carcass to skeletonize, although the warm temperatures caused much of the skin to mummify. The remains of the control carcass were finally collected after 61 days, when it was determined that the soft tissue decomposition process had ceased.

Trial 2

The 63 kg pig carcass was acquired in the evening and was placed on site just before dusk. As it was very close to dark, it was expected that the vultures would not have been able to locate the carcass before nightfall. The placement just before sundown was intended to mimic the disposal of a human body near dark or at dark (although the research design for this experiment prevented access by nighttime scavengers such as coyotes, often among the first to gain access to the carcass).

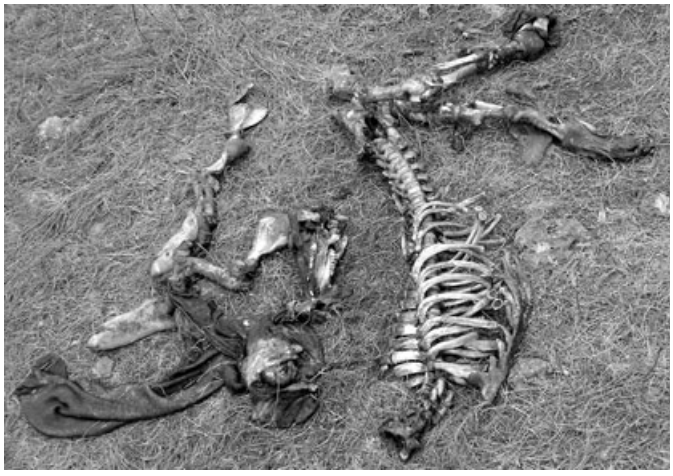

FIG. 1—*Exposed carcass from Trial 1 after less than 12 h of feeding.*

FIG. 2—*Unexposed (control) pig carcass in bloat stage of decomposition.*

FIG. 3—*American black vulture* (Coragyps atratus) *carrying goat scapula.*

Vultures descended upon the carcass *c.* 36 h after deposition, and almost exactly 24 h from first light, which likely would have been the first chance for visual detection. Eleven American black vultures were the first to arrive. Again, the mandible was the first element to be disarticulated, and this occurred within only 2½ h of feeding. During peak feeding sessions, *c.* 30 vultures were in camera frame. Upon approach of the researcher on Day 2, a total of 92 vultures were observed flying in the sky over the carcass.

Temperatures during the week of exposure for Trial 2 often reached over 38°C (100°F), which caused the uneaten skin of the carcass to mummify by Day 4. The vultures were unable to strip the skin from the carcass as they had in the first trial. Instead, the vultures were able to use the natural orifices as well as a few small holes they were able to peck to consume all of the soft tissue inside the mummified shell. Vultures were observed sticking their heads deep inside all openings. Aside from the skin, most of the soft tissue was consumed within 72 h of deposition.

No mammalian visitors were observed during the 8 days of exposure. A red-tailed hawk (*Buteo jamaicensis*) was observed on Day 2, and a Crested Caracara (*Polyborus plancus*) was noted on Day 4 outside of the enclosure. There is no photographic evidence that either of the birds joined in the feeding.

Trial 3

The third trial was purely opportunistic in nature, and involved the use of a goat that unexpectedly died on the premises. The 36 kg goat was placed onsite *c.* 18 h after death, and three American black vultures arrived *c.* 8½ h later, 26 h after death. Fewer vultures fed on this carcass, with the number of vultures present usually between five and 15, as opposed to the larger numbers observed for the previous two trials. The goat carcass was skeletonized *c.* 96 h after death, 78 h after exposure to vultures, and after 26½ total hours of feeding.

Heavy rain on Day 2 prevented normal feeding behavior. Vultures were seen feeding on the carcass during light rain, leaving the site during heavy rain, and returning when the rain lifted. Again, the mandible was the first element disarticulated. An American black vulture was observed carrying a scapula in its beak (Fig. 3) on Day 4.

Trial 4

The 27 kg pig was exposed to vultures after being deceased for 24 h. The first trial demonstrated that the vultures descended upon the carcass *c.* 24 h after death and placement. The second trial demonstrated that vultures descended upon the carcass *c.* 24 h after their first chance to visually locate the carcass, and the third trial demonstrated that vultures descended upon the carcass *c.* 24 h after death of the goat. This 24-h period appeared to be important for the vultures. In an effort to determine whether the practice was behavioral or olfactory related, the decision was made to expose a pig carcass that was not fresh, but had died 24 h previously.

Vultures descended upon this carcass *c.* 7½ h after placement or 31½ h after death. Between 25 and 35 vultures were observed feeding on the relatively small carcass at one time. The majority of the vultures were American black vultures, while turkey vultures often numbered less than five. The vultures fed until dark (*c.* 3 h) and by then the carcass had already been reduced to skin, bones, and hooves.

Table 1 summarizes vulture arrival, feeding, and length of time they took to skeletonize each carcass. The "total time spent feeding" was calculated by examining the array of time stamped photos for each trial. These numbers represent the quantum of time vultures were observed on the site. Hours when vultures were not present, during the night or during heavy rain for example, were not included in this number.

All four pig skeletons were disarticulated in a patterned order always beginning with the mandible and followed by the cranium and front limbs. Vultures were also observed leaving physical evidence of their presence at the scene. Many bones were covered

TABLE 1—*Summary of four experimental trials.*

Subject	Weight, kg/lbs	Date and Time of Deposition	Date and Time of Vulture Arrival	Date of Skeletonization	Total Time Spent Feeding
Pig Trial 1	45/100	7/10/07, 4:15 PM	7/12/07, 4:44 PM	7/13/07	11 h 21 min
Control Trial 1	45/100	7/10/07, 4:15 PM	N/A	8/05/07	N/A
Pig Trial 2	63/140	8/06/07, 8:03 PM	8/08/07, 8:14 AM	8/10/07	24 h 39 min
Goat Trial 3	36/80	8/14/07, 8:50 AM	8/14/07, 5:29 PM	8/17/07	26 h 45 min
Pig Trial 4	27/60	9/09/07, 9:40 AM	9/09/07, 5:18 PM	9/09/07	2 h 39 min

N/A, not applicable.

in vulture scat, as was the surrounding area. Their large feathers were also often shed at the site and left behind. Trampled paths around the enclosure were also noted, as vulture activity wore down the surrounding grass.

Bone Modification

Examination of all collected skeletal remains indicated that vultures may leave slight evidence of their scavenging behavior on bone. Two types of markings were observed: first, relatively shallow scratches measuring up to 4 cm in length were observed most frequently on the crania and mandibles, although they were also noted on scapulae, ribs, long bones, and vertebrae. These scratches penetrated the surface of the bone and are relatively linear, although irregularly shaped (Fig. 4). Because these markings were so shallow, it may be the case that as the bones weather, exposure and the flaking of bone would distort or eliminate their presence. The irregular shape of fresh scratches should prevent them from being misinterpreted as sharp force trauma, as their appearance was more similar to the effects of root etching on bone.

The second type of marking noted was a linear surface scratch without depth (Fig. 5). Microscopic analysis showed these markings were characterized by a change in color on the surface of the bone, with very little to no surface depth. It is possible that these ephemeral scratches can be washed away by rain or intentional cleaning of the element, but they may remain as a stain pattern on the bone.

From digital photographs, it is clear that vultures use both their beaks and their feet as tools when feeding on a carcass, although their feet are weak and relatively useless for grasping and manipulating (12). Instead, vultures use them to gain leverage, as they stand on parts of a carcass to hold it down and tear away flesh with their beaks. Therefore, it is difficult to say with any certainty which markings were the result of beaks or talons; however, photographic evidence shows it is more likely that their beaks created most of the markings. Their beaks do not always leave traces on bones, as vultures were observed carrying elements, which when

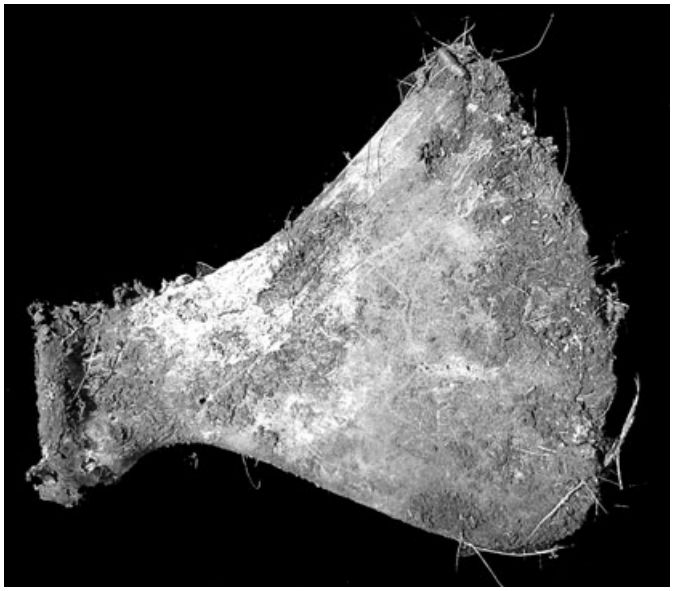

FIG. 5—*Nonpenetrating scratches noted on surface. The scapula has not been cleaned, and the white areas depict vulture scat.*

FIG. 4—*Shallow penetrating scratches caused by vulture scavenging. Area of interest is circled.*

FIG. 6—*A feather and scat (circled) deposited at site.*

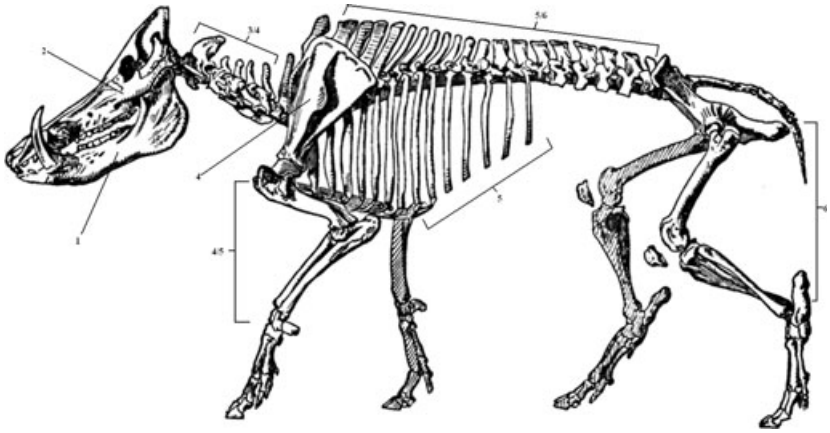

FIG. 7—*General disarticulation sequence of pig skeleton* (Sus scrofa).

inspected, did not have any of these characteristic markings. Eye orbits of all crania also showed very little damage or markings, and this was somewhat unexpected as anecdotal reports often reference vultures pecking out eyes and damaging fragile orbital bones. While they can use their beaks to vigorously rip flesh from bone, vultures were also observed using their beaks in a very delicate, deliberate manner.

Discussion

The preliminary study presented here demonstrates that the scavenging activities of vultures greatly alter both the carcass and depositional scene. This could have significant implications when applied in a forensic context (i.e., in the summer in Central Texas, a 45 kg/100 lbs body scavenged by vultures can become skeletonized in as little as 2 days).

From this research, it is clear that American black and turkey vultures significantly accelerate the rate of skeletonization. All exposed carcasses were skeletonized within 96 h of death, with the majority of flesh removed in the 24–36 h period after death. The significant acceleration of flesh loss caused by scavenging vultures is important when estimating an accurate PMI at vulture-modified scenes.

Vultures also leave evidence of their presence at a feeding site. Over the course of feeding on a large carcass, vulture feces and feathers often accumulate at the scene (Fig. 6). Also, vultures can leave identifiable markings on bone, which can be utilized for determining whether a scene is modified by vultures, and in turn, how this might affect PMI estimations. While these markings are linear, they are too irregular to be confused with sharp force trauma. This type of information is important when assessing human-inflicted injuries versus animal markings (i.e., carnivore-produced punctures or scores). These shallow scratches noted on the bones also serve as a clear indicator of vulture modification at a scene. When observing this type of modification of bone in a forensic case, an accelerated rate of decomposition should be considered, which will affect the overall estimation of the PMI.

The disarticulation sequence of the pig carcasses is similar to that outlined by Haglund et al. (5) in their work with canid scavenging of human remains. In the present experiment, however, the mandible was always the first element to be disarticulated, followed by the cranium, scapulae, and front limbs. With the exception of the mandible, the rest of the disarticulation sequence parallels that demonstrated by Haglund et al. (5). The initial stage includes the removal of the scapulae and upper extremities, while the separation of the lower extremities shortly follows. Figure 7 depicts the general disarticulation sequence noted, labeled 1–6, from earliest to latest. While the stages follow relatively closely to those previously described, the timing of these sequences with reference to vultures is radically accelerated and can occur within 1 week.

It is imperative that investigators understand the effects of all scavenger species within the environment in which a body is deposited. Further research may provide more details about the intricacies of vulture behavior and their role in the forensic context, and future research should focus on the effects of vulture scavenging with regard to differential environments and seasons, tree cover versus open ground, disguised or hidden carcasses, and even shallow burials. Also, further analyses of the markings vultures create, the degree and patterning of bone scatter, and the specific bones recovered might yield more important information about vulture-modified scenes.

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