TAPHONOMIC EFFECTS OF VULTURE SCAVENGING

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ABSTRACT

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From July through September 2007, three pig carcasses (*Sus scrofa*), weighing between 60 and 140 pounds were placed outside in a grassy area in central Texas. A surrounding fence was built to prevent entrance by terrestrial scavengers, while allowing avian scavengers unrestricted access. Modification of the pig carcasses was recorded through the use of two motion-sensing digital cameras and daily on-site observations. Two species of vultures, the American black vulture (*Coragyps atratus*) and turkey vulture (*Cathartes aura*), both waited approximately 24 hours before beginning to scavenge and did not feed at night. They completely skeletonized the pig carcasses in 3 to 26 hours of feeding. Vultures were observed manipulating the carcasses, and their activity left scratches on the bones, which can be utilized as specific indicators of vulture scene modification and body alteration. The accelerated rate of decomposition and the signature markings on the bones are important factors to consider when interpreting taphonomic events and determining an accurate postmortem interval at vulture modified scenes.

KEYWORDS: Forensic science, taphonomy, scavenging, vultures

CHAPTER I

INTRODUCTION

As Haglund and Sorg (1997:13) define it:

> ...forensic taphonomy is that part of forensic anthropology which focuses on reconstructing events during and following death by collecting and analyzing data about the depositional context, discriminating peri- and postmortem modification of the remains, and estimating the postmortem interval.

When deceased individuals are not discovered immediately, they are often subjected to events after death that can complicate later time since death interpretations. As the above definition indicates, forensic investigations are mainly concerned with the period surrounding death, the perimortem interval, as well as the period extending to the time of discovery, the postmortem interval. Estimation of a postmortem interval, or PMI, often proves difficult, and any observation that can be utilized to distinguish the passage of time should be explored. Evidence of animal scavenging has been shown to aid in the estimation of PMI (Willey and Snyder 1989; Schoenly et al. 1991; Goff 1993; Haglund 1997a; Klippel and Synstelien 2007), as scavengers are known to modify rates of decomposition and insect colonization, alter bone itself, and disperse elements from their original deposition site (Haynes 1983; Morse et al. 1983). Thus, it is important in a forensic context to isolate the effects of different animals with regard to their alteration of flesh and bone, and the patterning and timing of their activities. It is also imperative that forensic anthropologists are able to distinguish between man-made and animal-produced signatures on bone.

While the analysis of animal scavenging on bone is a relatively recent line of inquiry in forensic anthropology, the study traces its roots to paleoanthropological analyses of fossil hominids. Recent reexamination of the Taung child (*Australopithecus africanus*) and other fossil specimens has revealed possible predatory bird damage (Berger 2006). The author analyzed modern crowned hawk eagle (*Stephanoaetus coronatus*) feeding behavior and examined the taphonomic signatures they leave behind. These signatures include distinctively punctured floors of primate eye orbits and cranial punctures or fractures. Similar defects were noted in the Taung child (Berger 2006). Modern analyses of animal predation and scavenging behavior may be applicable to archaeological sites as well as forensic cases.

While the effects of unlikely animals such as the domestic golden hamster (*Mesocricetus auratus*) (Ropohl et al. 1995) and sunflower sea star (*Pycnopodia helianthoides*) (Anderson and Hobischak 2004) have been investigated in forensic contexts, some of the most obvious scavengers have not. For centuries, vultures have been known consumers of flesh, including that of humans. In 1536, after the Spanish defeated the Incas in what is now modern Peru, so many natives lay slain that the battlefield was overwhelmed with feeding vultures. This historical event inspired the Cusco Coat of Arms, which depicts 8 vultures in honor of this battle.

In some cultures, vultures have played an esteemed role. For example, one of the preferred methods of burial among Tibetan Buddhists is a so-called sky or celestial burial (Malville 2005). In this practice, the body is cut up and fed to vultures, which are regarded as sacred birds. This premise of exposure of human bodies to scavengers is an early practice as well, as researchers have uncovered murals in the ancient settlement of Çatal Hayuk (5800 B.C.) that depict vultures pecking at corpses (Malville 2005).

Historically, vultures are known scavengers and have been known to consume human flesh, although little research has been conducted on the topic. The purpose of this research is to isolate and analyze the taphonomic effects of vulture scavenging on decomposition rates and bone modification. For the purposes of this study, the decomposition rate is analogous to the time taken to skeletonize after death. In creating a research design, it was the intention of the author to establish a secure locality where vulture activity could be monitored and video-recorded with minimal interference by human activity and mammalian scavengers. Because of the wide range of their habitats, growing population sizes, and increasing ability to adapt to urban environments, it is important to determine what specific effects vulture scavenging can have on human remains. 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.

CHAPTER II

LITERATURE REVIEW

Mammalian Scavenging

Thus far, scavenging research has largely focused on mammalian scavengers such as dogs (Haglund et al. 1989; Willey and Snyder 1989; Haglund 1997a), cats (Haynes 1983; Pickering and Carlson 2004), bears (Haynes 1983; Merbs 1997; Carson et al. 2000), hyenas (Haynes 1983), and rodents (Haglund 1992).

Some of the most frequent scavengers of human remains are domestic dogs (*Canis familiaris*) and coyotes (*Canis latrans*) (Willey and Snyder 1989). They are known to modify and consume tissues, disarticulate elements, modify bone, scatter remains, and alter both scene and evidence (Haglund 1997a). Many of these alterations have forensic implications. The consumption of tissues accelerates the rate of decomposition and affects the interpretation of time since death. In the case of a suspicious death, canid modifications could mask, destroy, or even mimic markings inflicted perimortem. For example, dogs are known to chew and consume the ends of long bones. This destruction of context and evidence complicates the interpretation and reconstruction of the scene. Thus, it is imperative that forensic anthropologists be aware of the impact of these potentially confounding factors.

Differentiating human from non-human bone modification is also an important consideration with regard to animal scavenging. Results of canid scavenging have been detailed in many sources, extending into the archaeological literature (Haynes 1983; Haglund et al. 1989; Willey and Snyder 1989; Haglund 1997a). Tooth markings can leave impressions categorized as pits, furrows, punctures, or scoring (Haglund 1997a). These types of markings have been documented, described, photographed, and published so that investigators can distinguish these impressions from others such as blunt force or sharp force trauma that occurred perimortem. Researchers have also determined a pattern of consumption and disarticulation of mammalian carcasses meant to aid in the estimation of PMI. These stages, developed by Haglund et al. (1989:589) are as follows:

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
4 = total disarticulation and scattering, with only cranium and assorted skeletal elements or fragments recovered

The sequence of disarticulation as a result of vulture scavenging could be examined and compared to these stages.

Rodent gnawing has also been studied, and a general understanding of the taphonomic effects of rodent scavenging has emerged (Haglund 1992; Klippel and Synstelien 2007). Markings left by rodents are characterized by straight parallel grooves, which are the imprints of their incisors (Haglund 1997b). Rodents are often agents of scene modification, because they hoard elements and may carry smaller ones to their nests or burrows (Brain 1981; VanDevender et al. 1984). Porcupines (*Hysterix africaeustralis*) are most noted for their hoarding behaviors and often collect many more dry bones to gnaw than they can possibly use to maintain their incisors (Brain 1981).

Vulture Background Information

While there has been much research with regard to mammalian scavenging, there are relatively few mentions of avian scavenging in the forensic context. Vultures are primarily carrion eaters, and some vulture species are rapidly expanding their already extensive home ranges and becoming more urbanized. It is likely that forensic anthropologists will be presented with increasing numbers of cases from vulture modified scenes.

Although their possible role in the decomposition and bone modification process has not previously been isolated in the forensic literature, there have been some experiments that outline vulture feeding behaviors (Coleman and Fraser 1987; Prior and Weatherhead 1991) and carrion location techniques (Houston 1986; Buckley 1996).

Questions about animal scavenging require knowledge of animal behavior, diet, and territory size (Haglund and Sorg 1997). In the New World, there are seven vulture species including the turkey vulture (*Cathartes aura*), lesser yellow-headed vulture (*Cathartes burrovianus*), greater yellow-headed vulture (*Cathartes melambrotus*), American black vulture (*Coragyps atratus*), king vulture (*Sarcoramphus papa*), California condor (*Gymnogyps californianus*), and Andean condor (*Vultur gryphus*) (Hoyo et al. 1992).

The two species most abundant both in population and home range territories in the Americas are the American black vulture (Figure 1) and turkey vulture (Figure 2).

Figure 1: American Black Vultures.

Figure 2: Turkey Vultures.

Adult American black vultures are about 56-58 centimeters (cm) in length, weigh approximately 1100-1900 grams (g), have wingspans ranging from 137-150 cm (Hoyo et al. 1992), and in captivity can eat up to 600 g per day (Rabenold 1987). They inhabit the southern United States and can be found throughout most of South America. Because of their relatively warm range of inhabitance, they do not migrate seasonally. American black vultures do not have a sense of smell, and often rely on the turkey vulture for carrion location in areas of low ground visibility such as forests and regions with dense underbrush (Hoyo et al. 1992; Roen and Yahner 2005). American black vultures are closely associated with human activity, urban environments, and have often been noted frequenting markets, fish docks, garbage dumps, and other waste disposal areas (Hoyo et al. 1992). These birds are also known to be dominant over turkey vultures, especially in large groups, and often displace them from a carcass (Buckley 1996).

Adult sized turkey vultures range from 64-81 cm in length, weigh 850-2000 g, have wingspans of approximately 180-200 cm (Hoyo et al. 1992), and in captivity have been reported to consume 140 g per day (Prather et al. 1976). They inhabit the borders of southern Canada and can be found throughout South America ranging to the southernmost tip at Tierra del Fuego. Some turkey vultures that inhabit the northern parts of North America often migrate south for the winter (Hoyo et al. 1992).

As may be inferred from the wide region in which they are found, turkey vultures inhabit extreme ranges of habitats including deserts, grasslands and savannas, tropical rainforests, and temperate woodlands (Hoyo et al. 1992). Partial success in inhabiting many of these areas can be attributed to their highly developed olfactory lobe, which is the eighth largest of 108 avian species reported by Bang and Cobb (1968). The highly developed olfactory lobe provides them with a keen sense of smell and the ability to detect carrion not visible from the air (Smith and Paselk 1986). This ability may also be why some researchers report that turkey vultures often feed on smaller-sized carrion (Coleman and Fraser 1987; Prior 1990). The turkey vultures' olfactory advantage, ability to locate smaller carrion in forested areas, and tendency to forage individually (Buckley 1996) may contribute to why they are easily displaced from feeding sites by American black vultures. According to the numbers provided by Rabenold (1987) and Prather et al. (1976), American black vultures also consume much more food per day than do turkey vultures, 600 g versus 140 g respectively. This may also be a reason for dominance of one species over another at a food source.

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 (Rabenold 1989; Weidensaul 1996). Kiff (2000) suggests that the northward range expansion may be reflective of a positive response to global warming. Other reasons for the increase in population include the expansion of open habitat by logging and rural development, reduced human persecution, increases in carrion availability on roadways, and general results of an expanding human population (Wilbur 1983; Kirk and Mossman 1998). As their numbers continue to grow, vultures will be found increasingly in human environments and may begin to play a larger role in forensic contexts.

All vultures are carrion eaters, and consume the meat of dead animals as the major component of their diet (Palmer 1988). American black and turkey vultures generally do not kill for food, although American black vultures have been known to kill and consume small animals such as nestling birds and hatching sea turtles (Hoyo et al. 1992). For the most part, however, these vulture species are not good hunters because they do not have strong feet and talons like predatory birds. Their feet are non-specialized with short, blunt nails instead of curved talons, and many vultures cannot completely close their foot in a grasping motion (Weidensaul 1996). During feeding, vultures often stand upon the carrion with their feet and then tear away meat with their beaks, which is usually the extent of their use of feet as a feeding tool. Vulture beaks and nails are made of a keratin layer grown over a core of bone that continues to grow throughout life and is sharpened through constant wear (Weidensaul 1996). While the beak can be used to tear away tough tendons and sinews, it can also be used to delicately retrieve all morsels of edible flesh.

Another characteristic of all vulture species is their featherless heads. The lack of feathers on their head and necks prevents soiling of their plumage as they insert their heads into the cavities of carcasses. The bald head may also serve a thermoregulatory function, especially during high altitude flight, although this is still incompletely understood (Hoyo et al. 1992).

Vultures are adapted for soaring flight and have very large wingspans. They use rising air currents to gain altitude rather than continuously flapping their wings (Mandel and Bildstein 2006). This technique also conserves energy, allowing them to cover more ground while searching for carcasses to exploit, with only minimal energy expense. Carcasses are often sparsely located, so vultures must cover large areas in an effort to locate food sources (Rolando 2002). When vultures are seen circling overhead, it will not always indicate the presence of a carcass, as vultures must use updrafts to gain flight altitude.

Avian Scavenging

Because vultures are mostly indiscriminate consumers of carrion, they have been noted at sites of human decomposition. They have been observed feeding on human remains at the Anthropology Research Facility at The University of Tennessee, Knoxville (M.D. Hamilton, personal communication, January 15, 2008). In one published instance, Übelaker and Scammell (1992) share an anecdote about a cattleman who noticed several vultures in the sky, followed the birds to where they were landing, and discovered a human body. Thus, vultures both in the sky and on the ground may be indicators of decomposition, and this could be of assistance to investigators when trying to locate remains.

Vulture presence or evidence of their presence may also help when determining time since death of an individual. As an experiment by Houston (1986) indicates, when given a choice, vultures prefer day-old carrion to fresh or rotten carrion. It is still unknown why vultures prefer carrion after 24 hours, however, it has been suggested that perhaps vultures prefer carrion in a "ripened" state, after minimal decomposition, and they are wary of putrid carcasses that may contain too many harmful bacteria and/or toxins (Houston 1986).

Morton et al. (2006) conducted an experiment in which small pig carcasses were placed both on the surface and in shallow burials of a wooded area in Virginia. Their aim was to determine the taphonomic effects with regard to decomposition, scavenging, and bone scattering. Video recordings were utilized to observe activity at the site. Over the course of the experiment, many animals were observed using the remains as a food source. Turkey vultures were one of the species noted regularly feeding at the site. Morton et al. (2006) note that the turkey vultures were aggressive in their scavenging behavior and the remains were consumed within 5 days, mostly as a result of their daily consumption. Turkey vultures were only active during daylight hours. In another instance they report turkey vultures removing a carcass from a burial and consuming all of the soft tissue by the next day. In their conclusions, Morton et al. (2006) indicate that they noted "beak marks" on the recovered bones, however, these markings are neither shown nor described.

Asamura et al. (2004) outline two cases of postmortem injuries caused by crows. In both cases, the bodies were damaged by fire and partially charred. The postmortem injuries caused by the crows are characterized as a frayed and "fluffy" appearance of the nerve fibers, tendons, and ligaments (Asamura et al. 2004:3). The frayed appearance of the tissues is a result of pecking and pulling from the crows' beaks. Because crow scavenging is rarely seen, the authors suggest that crows may simply prefer charred bodies. The authors do not mention any defects left on the bones themselves as a result of the crow scavenging.

A study carried out by Hockett (1991) discovered beak marks and talon punctures only on one side of leproid (cottontail and hare) bones. The beak and talon marks they refer to were created by raptors (birds of prey that capture live animals). Although vultures are not likely to create the same talon marks due to the differences in foot morphology, the beak morphology and markings may be similar. Hockett indicates that the beak or talon punctures were found on the innominates and vertebrae, and some ilia showed “shearing or scissoring-like damage” (1991:672). There are no further descriptions of the specific markings, which make it difficult to interpret exactly what the researchers observed.

CHAPTER III

MATERIALS AND METHODS

Research was conducted at the Freeman Ranch, a mixed usage research and agricultural property owned by Texas State and located less than 10 miles west of San Marcos, Texas. The specific site of the experiment was a secluded, grassy area with no overhead foliage. On this site, a square fence was constructed of four heavy-duty welded livestock panels measuring 16 feet long, 5 feet tall, with 4 inch by 4 inch spacing of one gauge wire rod (Figure 3).

Figure 3: Fenced Area at Freeman Ranch.

The four panels were secured by wire to 8 metal T-post supports that were driven into the ground to a depth of approximately 1 foot. The fence was designed to prevent access by terrestrial scavenging animals.

Although human cadavers are preferable for conducting this experiment designed to assess vulture impact on outdoor scenes, access to human cadavers was not possible and domesticated pigs (*Sus scrofa*) were utilized instead. The internal anatomy, fat distribution, lack of thick 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 (Goff 1993; Schoenly et al. 2006). The pig carcasses used in this experiment were chosen so that their body weights would be as comparable to adult human body weights as possible. A total of four pig carcasses were utilized in this experiment and were obtained from a domestic pig breeder who routinely eliminated animals that were not show-quality.

The first trial encompassed 26 days from July to August of 2007. Two pig carcasses weighing approximately 100 pounds (45kg) each were acquired immediately after death and placed on site within 2 hours of death. One of the pig carcasses was placed in the center of the open square fence to allow exposure to avian activity (Figure 4).

Figure 4: Trial 1 Exposed Pig Carcass.

The second carcass was placed in a wire cage (4 feet long, 2 feet wide, and 3 feet tall) with additional 1½ inch chicken wire wrapping to prevent all vertebrate scavenging activity (Figure 5). This carcass served as a control for 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. The vulture-exposed carcass was collected after 26 days, while the control carcass was collected after 61 days.

Figure 5: Trial 1 Unexposed (Control) Pig Carcass.

For the second trial, the largest carcass at 140 pounds (63kg) was placed in the center of the fenced area within 2 hours of death, although it was acquired late in the evening and placed just before sundown (Figure 6). The carcass was exposed for a total of 8 days in August 2007. Daily onsite observations were conducted, and upon collection, the skin was cut away from the rest of the skeleton with gardening root clippers.

Figure 6: Trial 2 Exposed Pig Carcass.

The third trial encompassed 10 days in August 2007. An 80 pound (36kg) goat (*Capra aegagrus hircus*) died unexpectedly elsewhere on the ranch, and the goat carcass was used as an extra trial for the research project (Figure 7). The carcass was placed on site approximately 18 hours after death and was monitored daily.

Figure 7: Trial 3 Exposed Goat Carcass.

The fourth trial encompassed 12 days in September 2007. A 60 pound (27kg) pig carcass was acquired and placed at an alternate location on the ranch for 24 hours before placing it at the site and exposing it to vultures (Figure 8).

Figure 8: Trial 4 Exposed Pig Carcass.

The 24-hour delay in the placement of the pig was designed to elicit any further information regarding vulture behavior, in terms of carrion location regarding 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. One camera was a Wildview 2.0 Megapixel Digital Toggle-Switch Scouting Camera. The camera took one photograph every time it sensed motion and was on a 1-minute time delay between each photograph. Even at night, the camera could sense motion through an infrared sensor, and would take a picture using the 15-foot flash. The second camera was a Moultrie 4.1 Outfitter Cam Digital Scouting Camera. The Moultrie camera has a date, time, temperature, and moon phase feature, which it stamps 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 second 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, 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 from a weather station located nearby 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 and skeletonized and were no longer attractive to vultures, 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.

CHAPTER IV

RESULTS

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

Trial 1

Several vultures were observed flying overhead at the time of deposition, but it was not until approximately 24 hours later that 3 American black vultures descended upon the 100 pound (45kg) carcass. Within an hour, 25 vultures were within camera range, 4 of which were turkey vultures. Vultures stayed until dark (9:07pm), left the scene, and returned at first light (6:19am) the following morning. After less than 12 total hours of feeding, the exposed pig was reduced to bones, skin, and hooves (Figure 9). Some strong connective tissue continued to articulate some of the elements.

Figure 9: Exposed Carcass After Less Than 12 Hours of Feeding.

The mandible was the first element to be disarticulated from the exposed carcass, followed by the cranium and front limbs. Vultures continued to visit the site daily for 20 days, except during one day of extremely heavy rain. After Day 7, their presence was reduced and often fewer than 5 vultures were on the scene. 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. These elements were covered with fire ants and were placed back in the enclosure for further observation. With time, skeletal elements became increasingly scattered and disarticulated, although most of the flesh had been consumed 24-48 hours 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. The motion sensors on both cameras were activated and pictures were taken in the dark. There was no evidence that the opossum fed at the site.

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 (Galloway 1997) and some of the intestines had burst through the abdomen (Figure 10).

Figure 10: Unexposed (Control) Pig Carcass in Bloat Stage.

Fly activity could be heard and observed, as many flies were on and around the control carcass, although no maggot activity was yet visible. It took more than 2 weeks for the control carcass to skeletonize, although the warm temperatures caused much of the skin to mummify and even after 2 weeks, some skin and tissue remained. The remains of the control carcass were finally collected after 61 days.

Trial 2

The 140 pound (63kg) pig carcass was acquired in the evening and was placed on site just before dusk. As it was very close to dark, it was unlikely that the vultures could have located 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 prevented access by nighttime scavengers such as coyotes, which may have been among the first to gain access to the carcass.

Vultures descended upon the carcass approximately 36 hours after deposition, and almost exactly 24 hours from first light, which likely would have been the first chance for vulture detection. Eleven American black vultures were the first to arrive. Again, the mandible was the first element to be disarticulated, and this occurred within 2½ hours of feeding. During peak feeding sessions, approximately 30 vultures were in camera frame. However, upon approach of the researcher on Day 2, 92 vultures were observed flying in the sky. A picture was taken as the birds were startled, and the image was later enlarged and the birds were counted (Figure 11).

Figure 11: 92 Vultures above Trial 2.

This particular visit to the site interrupted feeding for approximately 1 hour during physical visitation and 2 hours of subsequent non-visitation by the vultures. However, the visit was necessary to rearrange the cameras, as the vultures had significantly displaced the carcass from the original viewing area.

Temperatures during the week of exposure for Trial 2 often reached over 100°F (38°C), 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 done 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 hours of deposition (Figure 12).

Figure 12: Exposed Carcass 72 Hours After Deposition.

By morning on Day 8, the mandible, cranium, and front limbs were torn away from the rest of the body, although the vertebral column and hind legs remained encased in the mummified shell of skin. Upon collection, the skin was cut away from the rest of the skeleton (Figure 13).

Figure 13: Mummified Shell of Skin Being
Removed from Skeleton.

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 evidence that either of the birds joined in the feeding.

<u>Trial 3</u>

The third trial was purely opportunistic in nature, and involved the use of a goat that unexpectedly died on the premises. The 80 pound (36kg) goat was placed onsite approximately 18 hours after death, and 3 American black vultures arrived approximately 8½ hours later, 26 hours after death. Fewer vultures fed on this carcass, and the number of vultures present was usually between 5 and 15, as opposed to the larger numbers observed for the previous 2 trials. The fewer number of vultures in this trial may have been related to the cause of death of the animal. The goat carcass was skeletonized approximately 96 hours after death, 78 hours after exposure to vultures, and after 26½ total hours of feeding (Figure 14).

Figure 14: Goat Carcass 96 Hours After Death.

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 (Figure 15) and then standing on it, all within 1 minute on Day 4.

Figure 15: American Black Vulture Carrying Goat Scapula.

After Day 5, less than 5 vultures were present at the same time. However, on Day 7, an American black vulture was observed attempting to move and possibly fly away with a whole limb (Figure 16). The limb was held together by strong connective tissue that had mummified, and the bird did not succeed in flying away with the limb.

Figure 16: American Black Vulture Carrying Goat Limb.

During a visit to the ranch, approximately 1 mile from the research site, the researcher observed several grounded vultures. The vultures seemed reluctant to leave their food source and only did so as the distance between bird and human closed considerably. Upon closer inspection, it was observed that the vultures had been feeding on a deceased juvenile goat. The ranchers were not yet aware of the death, although vulture presence acted as a signal that an animal had died.

<u>Trial 4</u>

The 60 pound (27kg) pig was exposed to vultures after being deceased for 24 hours. The first trial demonstrated that the vultures descended upon the carcass approximately 24 hours after death and placement. The second trial demonstrated that vultures descended upon the carcass approximately 24 hours after their first chance to locate the carcass, and the third trial demonstrated that vultures descended upon the carcass approximately 24 hours after death of the goat. This 24-hour period appeared to be important for the vultures. In an effort to determine whether the practice was more behavioral or olfactory related, the decision was made to first expose a pig carcass which was not fresh, but had died 24 hours previously.

Vultures descended upon this carcass approximately 7½ hours after placement or 31½ hours 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 (approximately 3 hours) and by then the carcass had already been reduced to skin, bones, and hooves (Figure 17).

Figure 17: Trial 4 Pig Carcass Skeletonized After 3 Hours of Feeding.

Table 1 summarizes vulture arrival, feeding, and time they took to skeletonize a carcass. The "total time spent feeding" was calculated by examining the array of time stamped photos for each trial. These numbers represent the amount 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.

Table 1: Summary of 4 Trials and Vulture Feeding Duration.

Subject	Weight lbs/kg	Date/time of deposition	Date/time of vulture arrival	Date of skeletonization	Total time spent feeding
Pig Trial 1	100/45	07/10/07 4:15pm	07/12/07 4:44pm	07/13/07	11 hours 21 minutes
Control Trial 1	100/45	07/10/07 4:15pm	N/A	08/05/07	N/A
Pig Trial 2	140/63	08/06/07 8.03pm	08/08/07 8:14am	08/10/07	24 hours 39 minutes
Goat Trial 3	80/36	08/14/07 8:50am	08/14/07 5:29pm	08/17/07	26 hours 45 minutes
Pig Trial 4	60/27	09/09/07 9:40am	09/09/07 5:18pm	09/09/07	2 hours 39 minutes

Observations common to all 4 trials included the invertebrate activity of blowflies, beetles, and fire ants. Maggots were rarely observed on the exposed carcasses, as the vultures were quick to devour the flesh before their colonization. Fire ants and beetles were observed most often on greasy bones and mummified tissues.

Vultures were also known to leave physical evidence of their presence at the scene. Many bones were covered in vulture scat, as was the surrounding area. Their large feathers were also often shed at the site and left behind. Paths around the enclosure were also noted, as vulture activity wore down the surrounding vegetation.

Bone Modification

Examination of all collected skeletal remains indicated that vultures leave slight evidence of their scavenging behavior on bone itself. Two types of markings are observed: First, relatively shallow scratches ranging from 1-4 centimeters in length are observed most frequently on the crania and mandibles, although they are also noted less frequently on scapulae, ribs, long bones, and vertebrae. These scratches penetrate the surface of the bone and are relatively linear, although they are irregularly shaped (they are not usually a perfectly straight line) (Figure 18).

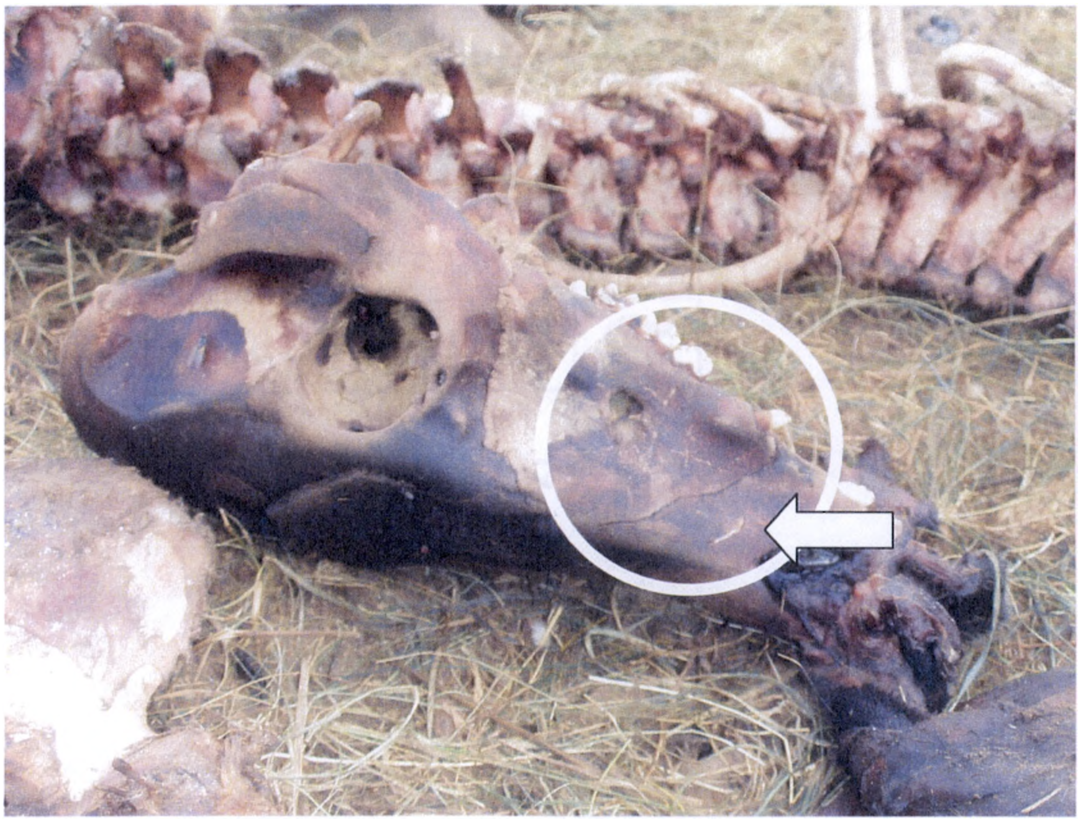

Figure 18: Shallow Penetrating Scratches.

Because these markings are so shallow, it may be the case that as the bones weather, the flaking of bone distorts or eliminates their presence. The irregular shape and imprecise definition of fresh scratches may prevent them from being misinterpreted as sharp force trauma, as they look more similar to the effects of root etching on bone, or tooth furrows created by mammalian carnivores.

The second type of marking noted is a linear surface scratch, without depth (Figure 19).

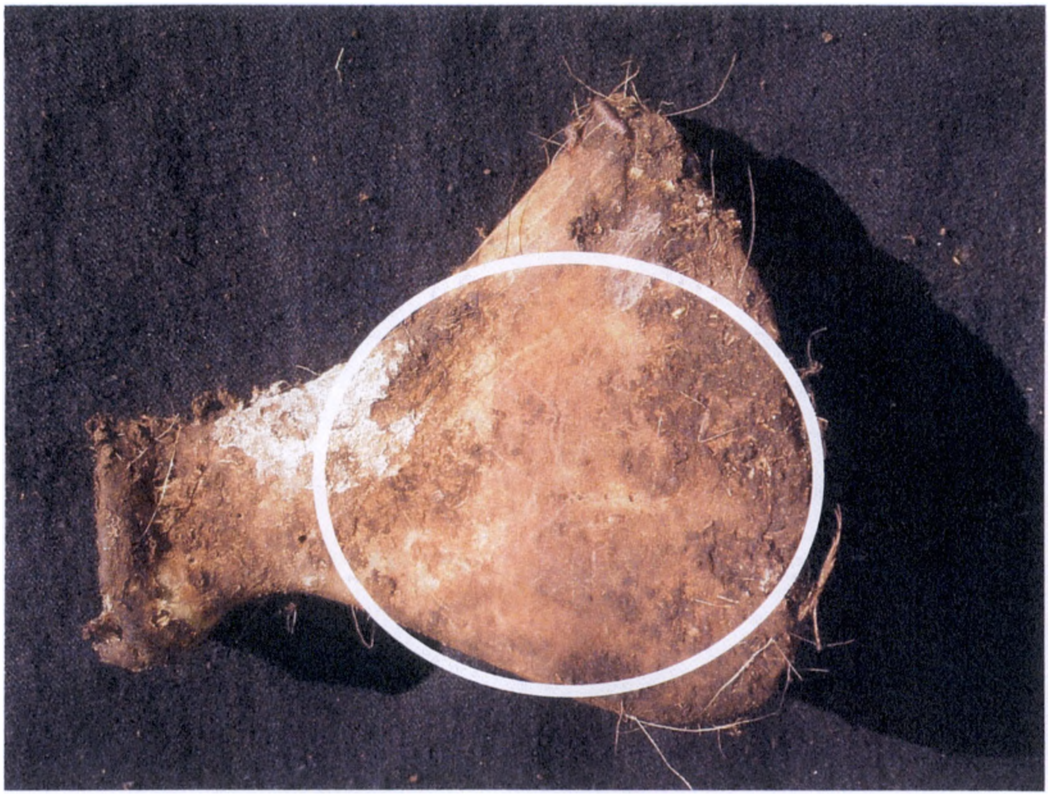

Figure 19: Non-penetrating Scratches.

These markings are characterized by a change in color on the surface of the bone. It is possible that these scratches can be washed away as dirt and decomposition residues are removed, or they may remain as a stain pattern on the bone. Both types of markings are best viewed macroscopically; however, a microscope may help to determine whether or not the scratch penetrates the surface of 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. Instead, vultures use them to gain leverage, as they stand on parts of a carcass to hold it down as they tear away flesh with their beaks (Figure 20).

Figure 20: American Black Vultures Using Their Feet for Leverage.

Therefore, it is difficult to say with any certainty which markings were the result of beaks or talons; however, it is most likely that their sharp beaks created most of the markings. Their beaks do not always leave traces on bones, as vultures were observed carrying elements, which when inspected, did not appear to have any of these characteristic markings. Eye orbits of all crania also showed very little damage or markings, and this was somewhat unexpected, since anecdotal reports often reference vultures pecking out eyes. While they can use their beaks to vigorously rip flesh from bone, vultures were often observed using their beaks in a very delicate manner.

CHAPTER V

DISCUSSION

The purpose of this research was to determine what effects vulture scavenging had upon decomposition rates and bone modification. Results of this research demonstrated that vultures leave identifiable markings on bone, and it is important to identify any patterns that differentiate vulture activities from markings produced by humans. The two digital hunting cameras proved beneficial in documenting all activity day or night, and provided a clear picture as to length of vulture presence and the specific bones manipulated by vultures.

From this research, it is clear that vultures significantly accelerate the rate of decomposition. Only turkey and American black vultures were observed feeding on the carcasses. No other avian or terrestrial scavengers were observed using the carcasses as a food source. Because of the camera monitoring, it is evident that vultures alone significantly accelerate the rate of decomposition. The result of the first trial is especially effective in demonstrating the difference in decomposition rate between the exposed and unexposed (control) carcass. The unexposed carcass was still in the early decomposition stage (Galloway 1997) or bloat stage (Payne 1965) while the exposed carcass had already been skeletonized. All exposed carcasses were skeletonized within 96 hours of death, with the majority of flesh removed 24-36 hours after death. The significant acceleration of flesh loss caused by scavenging is important when determining an accurate postmortem interval at vulture-modified scenes.

This research also revealed that although vultures can leave identifiable markings on bone, they do not always do so. 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 produced 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 estimation of the PMI.

Although vultures have been seen feeding on human remains in both recent and historical contexts (Übelaker and Scammell 1992; Malville 2005; M.D. Hamilton, personal communication, January 15, 2008), the specific effects of vulture scavenging on human remains are still unknown. It is not clear whether the patterns noted in this experiment follow for humans, although it is expected. Recent research regarding the odors (Vass et al. 2004) and volatile organic compounds (Statheropoulos et al. 2005) released during decomposition may be the key to determining exactly which compounds turkey vultures are able to detect. Smith and Paselk (1986) in their study of turkey vulture olfaction determined that turkey vultures are able to detect butanoic acid, ethanethiol, and trimethylamine. Butanoic acid, specifically, is listed by Statheropoulos et al. (2005) as a volatile organic compound associated with the decomposition of two experimental human cadavers. The ability of turkey vultures to detect odors associated with human decomposition suggests that they are able to locate human remains.

Examination of human versus other animal decomposition by-products would be useful for determining whether vultures discriminate between carrion despite their ability to locate it.

The present experiment has confirmed some previously conducted research regarding vulture behavior. As Houston (1996) reported, vultures seem to prefer day or day-and-a-half old carrion over fresh carrion. They also appear to monitor a potential food site for 7-12 daylight hours before descending, and are not active at night. It is still unclear whether this behavior is due to olfactory cues, security reasons, a combination, or other reasons altogether.

Additionally, in all four trials, American black vultures always arrived first at the site. It may be that they are able to detect carrion based solely on visual cues, or that they are attracted to the site by the presence of turkey vultures not in view of the digital cameras. In any case, the American black vultures appear dominant over the turkey vultures, and are always present first, and in larger numbers.

The disarticulation sequence of the pig carcasses is similar to that outlined by Haglund et al. (1989) in their work with canid scavenging. 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 this sequence follows the Stage 1 designation of Haglund et al. (1989), which includes the removal of the scapulae and upper extremities. Stage 2 involves the separation of the lower extremities, which often overlaps with Stage 1 with regard to this experiment. Over the course of vulture feeding, the front limbs are usually disarticulated before the hind limbs, although the hind limbs quickly follow. Figure 21 depicts the general disarticulation sequence noted, labeled 1-6, earliest to latest.

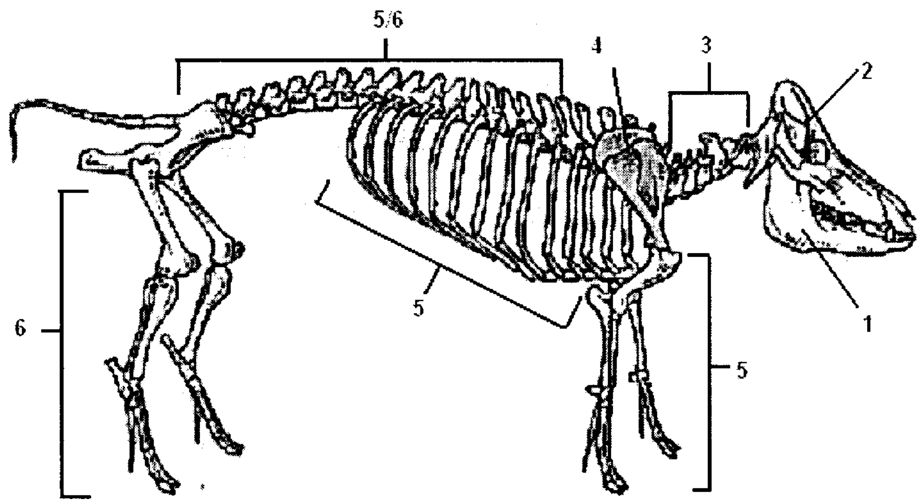

Figure 21: General Disarticulation Sequence of Pig Skeleton.
(http://www.dkimages.com/discover/previews/856/20217983.JPG)

While the stages follow relatively closely to those laid out by Haglund et al. (1989), the timing of these sequences with reference to vultures is radically accelerated.

CHAPTER VI

CONCLUSIONS

Vultures inhabit all but the northernmost reaches of the Americas, feed almost entirely on carrion (Palmer 1988), and are becoming increasingly associated with human activity (Hoyo et al. 1992). The preliminary study presented here suggests that the scavenging activities of vultures greatly alter both the carcass and the scene. This could have significant implications when applied in a forensic context. In summer in Central Texas, a fully skeletonized body (100 or more pounds) scavenged by vultures can be expected in as little as 2 days. The extreme rate with which vultures are able to deflesh a corpse and the predictable disarticulation sequence is important to consider when estimating time since death. Vultures also leave clues as to their presence at a scene. Over the course of feeding on a large carcass, vulture feces and feathers often accumulate at the scene. The results of this study show that vultures leave identifiable markings on bone, which can be utilized for determining whether a scene is modified by vultures, and in turn, affect PMI estimations. 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. This future research should focus on the effects of vulture scavenging with regard to different environments and seasons, tree cover versus open fields, disguised or hidden carcasses, and even shallow burials. Also, further analyses of the markings vultures create, the degree of bone scatter, and recovery of specific bones might yield more important information about vulture modified scenes.

APPENDIX A

SELECTION OF ADDITIONAL PHOTOGRAPHS


83F
07/17/07
04:22 PM
N REEVES


98F
07/23/07
04:18 PM
N REEVES


93F
09/09/07 05:18 PM N REEVES


86F
09/09/07 07:46 PM N REEVES

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