VULTURE SCAVENGING OF CHILD-SIZED PIG CARCASSES IN CENTRAL FLORIDA: UTILIZING GIS TO ANALYZE SITE VARIABLES AFFECTING SKELETAL DISPERSAL

by

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ABSTRACT

Scavengers can significantly alter a forensic scene and consume, modify, disarticulate, and disperse bodies. However, little research exists regarding scavenging in Central Florida, specifically scavenging involving Black and Turkey Vultures (*Coragyps atratus, Cathartes aura* respectively). The purpose of this study is to examine the effects of vulture scavenging on consumption, disarticulation, and dispersal of child-sized carcasses in the Central Florida region. The research sample consisted of four pig (*Sus scrofa*) carcasses weighing approximately 25kgs that were deposited in two distinct sites (shaded and unshaded) at the Deep Foundations Geotechnical Research Site located on the UCF campus. Two field cameras were placed at each site to record the scavenging, decomposition, and dispersal. The dispersal data was mapped and analyzed using ArcGIS v. 10.2.2 spatial analyst tools. Additionally, the scavengers recorded during the research period were noted, and their effect on disarticulation, consumption and dispersal were analyzed. Overall, while the canopy at the shaded sites did not impact vulture scavenging, grass height, the site perimeter fence, and the ground surface foliage density impacted vulture dispersal patterns. The majority of elements were dispersed within 6m of the initial carcass deposition. Through analysis of recorded video it was determined that vultures were able to completely skeletonize a child-sized carcass in approximately 8 hours of feeding time. In addition to vulture activity, opossums were recorded further dispersing and modifying skeletal remains after vulture activity had ceased.

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LIST OF ACRONYMS

ADD = Accumulated degree-days

ATP = Adenosine triphosphate

°C = Degrees Celsius

cm = Centimeters

DNA = Deoxyribonucleic acid

DOP = Dilution of precision

°F = Degrees Fahrenheit

GIS = Geographic Information System

GPS = Global Positioning System

HD = High definition

IR = Infra-red

kgs = Kilograms

lbs = Pounds

m = Meters

PMI = Postmortem interval

TBS = Total body score

TSD = Time since death

VOC = Volatile organic chemicals

WAAS = Wide Area Augmentation System

CHAPTER 1: INTRODUCTION

The decomposition of an organism is influenced by many factors, such as temperature, humidity, soil acidity, and rainfall. How these factors and others interact form the taphonomic process unique to a specific geographic region (Klepinger 2006). Knowledge of how decomposition progresses in specific regions is imperative to accurately determine time since death (TSD) as well as post mortem interval (PMI) in a medicolegal forensic context. One of the greatest factors in determining time since death, and which also has a huge impact on PMI, is the amount of scavenging activity that takes place in a region (Klepinger 2006). Heavy animal scavenging can drastically alter PMI by progressing decompositional processes well beyond their expected PMI. With the remarkable ability to alter forensic contexts, it is essential that forensic anthropologists are familiar with local scavengers as well as their scavenging practices (Pokines 2014).

Many commonly encountered animals contribute to the scavenging and disarticulation of forensic remains. Coyotes are endemic throughout the continental U.S., and are voracious scavengers. They have been known to accumulate at sites of carrion and can consume and cache much of the soft tissue of a carcass, advancing the decomposition process, and altering TSD assumptions (Pokines 2014). Coyotes will also gnaw on bones and can scatter and disarticulate forensic remains when feeding as a pack. Rodents, too, are very common in the continental U.S. and have a biological need to grind their teeth on hard objects like bone and wood. Additionally, some rodents engage in osteophagy in order to acquire minerals that rarely occur in nature, like phosphorous,

and zinc (Carlson 1940; Coventry 1940). While coyotes, and rodents are familiar consumers of carrion, vultures are capable of having the largest impact on TSD and PMI due their ability to access vertebrate remains that terrestrial scavengers cannot, including hanging victims (Komar and Beattie 1998) as well as areas enclosed in fences. In addition to their ability to fly, vultures have been known to feed in large groups (Wallace and Temple 1987; Reeves 2009; Spradley et al. 2012) and, according to Spradley et al. (2012), vultures can skeletonize a fully fleshed cadaver in approximately five hours, where normally progressing decomposition can take up to four months before skeletonization occurs. Due to the keen sense of smell of some New World vulture species, the powerful eyesight of others, and their collective ability to fly, the likelihood of vultures discovering forensic remains is greater than that of coyotes or other terrestrial consumers of carrion. This exemplifies the type of problems that vulture scavenging can have on determining accurate TSD and PMI. With increasing black vulture (*Coragyps* atratus) and turkey vulture (*Cathartes* aura) populations in Florida (Avery 2004) one can assume that vulture contact with decomposing forensic remains will also increase, making expanding knowledge of how vultures specifically affect TSD and PMI in Central Florida a priority.

Objectives

The purpose of this project is to determine the type of avian scavengers active in Central Florida, including but not limited to vultures, and to measure their effect on PMI,

TSD, and the dispersal of remains in both open, and heavily shaded environments in Central Florida. Similar studies have been conducted on elements of this project in other areas of the country (Table 1) e.g. (Beck et al. 2015; Houston 1986; Klippel and Synstelien 2007; Reeves 2009; Ricketts 2012; Roen and Yahner 2005; Spradley et al. 2012, Sorg et al. 2012; Thomaides et al. 1989;), however they are either environments not analogous to Central Florida, or they do not cover the same range of measurable factors as this project.

Table 1: Summary of Research Details Used in Research Where Scavenging Was Observed On a Carcass in a Unique Microenvironment

Study	*Study Sample*	*#*	*Duration*	*Location*	*Scavenger Species*	*Deposition*
Spradley et al. *(2012) Spatial patterning of vulture scavenged human remains*	Human (*Homo sapiens*)	1	Nov 19 - June 10	San Marcos, TX (Central Texas)	Black Vultures (*Coragyps atratus*) Turkey Vultures (*Cathartes aura*)	Grassland, no tree cover
Beck et al. *(2015) Animal Scavenging and Scattering and the Implications for Documenting Border Crossers in the Sonoran Desert*	Pig (*Sus scrofa*)	2	June 15 – July 17	Arivaca, AZ	Black Vultures (*Coragyps atratus*) Turkey Vultures (*Cathartes aura*) Dogs (*Canis familiaris*) Cats (*Felis catus*) Ravens (*Corvus corax*)	Desert, one in shade, one in direct sunlight
Houston *(1986) Scavenging Efficiency of Turkey Vultures in Tropical Forest*	Chicken (*Gallus domesticus*)	74	5 days	Barro Colorado Island, Panama	Turkey Vultures (*Cathartes aura*) Black Vultures (*Coragyps atratus*)	Tropical Rainforest
Reeves *(2009) Taphonomic effects of vulture scavenging*	Pig (*Sus scrofa*) Goat (*Capra aegagrus*)	5	26 days for pigs 1 and 2 No duration for pig 3 10 days for the goat 12 days for the pig 4	San Marcos, TX (Central Texas)	Turkey Vultures (*Cathartes aura*) Black Vultures (*Coragyps atratus*)	Grassy, no overhead foliage
Ricketts *(2012) Scavenging Effects and Scattering Patterns on Porcine Carcasses in Eastern Massachusetts*	Pig (*Sus scrofa*)	28	Aug 8 - Oct 14 for pig one 25 days for pig two 30 days for pig 3 6 days for pig 4 6 days for pig 5	Holliston, MA (Eastern Mass.)	Turkey Vultures (*Cathartes aura*) Black Vultures (*Coragyps atratus*) Opossum (*Didelphis virginiana*) Fisher (*Martes pennanti*) Raccoon (*Procyon lotor*)	Grassy, forested, wetland, buried, submerged. All with tree cover

Study	*Study Sample*	*#*	*Duration*	*Location*	*Scavenger Species*	*Deposition*
Roen and Yahner *(2005) Behavorial Responses of Avian Scavengers in Different Habitats*	White-tail deer (*Odocoileus virginianus*)	36	Jan 2000 - Mar 2000 Dec 2000 - Mar 2001 at 18 sites	Gettysburg Park, PA	Turkey Vultures (*Cathartes aura*) Black Vultures (*Coragyps atratus*) American Crows (*Corvus brachyrhynchos*) Blue Jays (*Cyanocitta cristata*)	Habitats put in three categories: Open, Edge, Wooded
Sorg et al. *(2012) Taphonomic Impacts of Small and Medium-sized Scavengers in Northern New England*	Pigs (*Sus scrofa*)	9	1 year	Maine	Turkey Vultures (*Cathartes aura*) Bears (*Ursus americanus*) Coyotes (*Canis latrans*) Crow (*Corvus brachyrhynchos*) Fisher (*Martes pennanti*) Raccoon (*Procyon lotor*) Bobcat (*Lynx rufus*)	Various, forested
Klippel and Synstelien *(2007) Rodents as Taphonomic Agents: Bone Gnawing By Brown Rats and Gray Squirrels*	Human (*Homo sapiens*)	10	16 months to >30 years	Knoxville, TN	Gray Squirrel (*Sciurus carolinensis*) Brown Rat (*Rattus norvegicus*)	Temperate environment

In an effort to fully comprehend the effects that vultures and other scavengers have on the decomposition process in Central Florida, four pig (*Sus scrofa*) carcasses were deposited in a regulated, fenced-in area and continually observed throughout the decomposition process until advanced skeletonization occurred. Since vulture activity was the primary desired scavenging the fence provided an advantage by restricting access of large terrestrial scavengers within the site. By observing the decomposition process as it progressed unhindered, it can be inferred that an accurate log of when scavengers, specifically vultures, encountered the remains. This included what interactions they had with the remains, including dispersal as well as how they affected PMI and TSD estimations. In addition, the effects of tree cover on scavenger behaviors was also tested, since an important aspect of determining how PMI and TSD estimation is affected, is understanding likelihood of scavenger interactions with remains. In the case of avian scavengers, most rely on sight to locate carcasses; however, many other carrion-consuming species have been known to follow turkey vultures (Stewart 1978; Wallace and Temple 1987), which use a specialized sense of smell instead of sight to locate carcasses (Stager 1964). The three main objectives of this research project include the following:

1. To determine the type of scavengers, particularly avian scavengers, commonly interacting with vertebrate remains within a fenced-in area in Central Florida.

2. To determine the effects scavengers, particularly avian scavengers, have on taphonomy and dispersal of remains in Central Florida

3. To determine what affect environment has on disarticulation, scavenging, and dispersal of remains.

The following chapters will cover the background information necessary to understand the mechanisms behind human decomposition and TSD and animal scavenging and dispersal of remains in a forensic context, as well as those fauna and their scavenging tendencies that are commonly encountered in Central Florida. Additionally, the materials and methods utilized in this research will be listed and explained, followed by the results of the research. The resulting data will be discussed in the context of similar research, and then a final conclusion and future considerations will be drawn.

CHAPTER 2: BACKGROUND

In order to conduct this research, it was necessary to review the background literature regarding decomposition and TSD, animal scavenging and dispersal of vertebrate remains in a forensic context, as well as scavenging behaviors of fauna located in Central Florida that have been known to interact with remains during the decomposition process. Specifically, animal modification of soft-tissue and skeletal elements was included to provide further detail on what taphonomic processes might be encountered, in addition to which of these Central Florida scavengers were most likely to encounter the sample carcasses.

Human Decomposition

The study of the changes in biological materials from the point of death until the point of recovery and examination is known as taphonomy. Taphonomy was a term first coined by Efremov in 1940 and is defined as "the science of burial". The interest in taphonomic changes in remains and the necessity of knowledge surrounding this process for medico-legal purposes spurred the formation of the forensic taphonomy subfield. Forensic taphonomy is the “study of these changes in biological remains from the time of death until their recovery and analysis” (Pokines 2014). In other words, forensic anthropologists study processes like, decomposition, disarticulation, scavenging, and dispersal of remains.

Decomposition begins immediately following death, which is defined by Perper (1993) as "the irreversible cessation of the brain, respiratory, and circulatory abilities, causing internal biochemical reactions in response to the depletion of oxygen in tissues." Once these systems cease to function, the body can no longer stave off the processes that occur during decomposition. At this point, decomposition occurs on a continuum, where the different stages are determined based mainly on gross tissue change, as well as underlying chemical and physical reactions that occur after the point of death. On this continuum are five main stages of decomposition: fresh, bloat, active decay, advanced decay, and skeletonization(Table 2) (Clark et al. 1997). Furthermore, Casper's Rule states that when all variables are equal, and there is access to air, a body decomposes twice as fast as a body immersed in water, and eight times as fast as a body buried in the ground (Madea et al. 2007).

Table 2: Summary of Decomposition Stages

Decomposition Stage	*Time of Onset*	*Summary*	*Change*
Fresh	At time of death	No discoloration, mortis triad	Mortis Triad
Bloat	24 h – 48 h	Decomposition releases gas that are contained in the carcass	Carcass will change colors and can appear to be much larger than at time of death
Active Decay	24 h – 2 Weeks	Majority of soft-tissue loss, color change, odor is given off	Carcass will be reduced to connective tissue and bones and will progress through multiple color changes
Advanced Decay	2 Weeks – 4 Months	Greasy bones with some soft-tissue adhered to remains, could include mummified skin	Bones will begin to dry out, skin and remaining soft tissue with dry or be consumed by dermestid beetles
Skeletonization	4 Months -	Dry bones are weathered by the elements	Bones continue to dry, can stain from algae, sun exposure, etc. Cortical bone exfoliates, bone will erode

The fresh stage of decomposition begins the moment after death. As oxygen flow ceases, autolysis occurs in the cells. Autolysis is caused by the mitochondria of the cells expanding and rupturing the cell as a response to lack of oxygen. Similarly, cellular death initiates the breach of the lipoprotein membranes of lysosomes that contain high concentrations of enzymes, like lipases and proteases, which cause the deconstruction of intestinal protein, lipids, carbohydrates and DNA (Evans 1963). As a result of the lack of oxygen, adenosine triphosphate (ATP) cannot be produced (Love and Marks 2003), which will result in further decompositional processes.

Also immediately following death, algor mortis begins with modification of normal human body temperature (37°C, 98.6°F) to ambient temperature (Dix and Graham 2000). A cooling rate of 1.5°F per hour is generally accepted as normal, however, there are many internal and external variables that affect the rate. Still, algor mortis as a tool for time since death estimation is generally applicable within the first 10-12 hours postmortem (Dix and Graham 2000).

As a result of gravity, the blood in the body pools in the low-lying body tissues, resulting in a reddish-purple color. This is referred to as liver mortis. The subcutaneous pooling of blood may become evident as soon as 20 minutes after death (Perper 1993). The blood pools can be blanched early on during the process, however, over time, the lividity becomes fixed, and blanching is no longer possible. This occurs approximately 8-12 hours after death and can also be used to assist determination of time since death (Di Maio and Di Maio 2001).

Rigor mortis is a result of the decrease of cellular ATP (Perper 1993). ATP is necessary for proper muscle function, and when ATP cannot be created, the actin and myosin of the muscle bridges cannot function resulting in the muscles binding in a contractile form (Perper 1993). Rigor mortis can occur as early as 2-6 hours and can persist for up to 48 hours (Clark et al. 1997).

Autolysis initiates the bloat stage of decomposition, by breaking down the biomolecular components of the body. Microbial activity results in carbon dioxide and other volatile compounds that become trapped in the skin of the neck, scrotum, and abdomen (Vass et al. 1992). Bloating depends on physical trauma to the body, as gashes, and cuts will cause the volatile organic chemicals (VOC) to dissipate rather than become trapped under the skin, thus decreasing the amount of time the cadaver is bloated. Bloating can last as long as chemical decomposition and anaerobic microbial activity occurs (Vass et al. 1992)

Active decay is an ongoing process that occurs during autolysis and lasts throughout the decomposition until soft-tissue quantities are decreased and entomological specimens retreat from the corpse to pupate. The same components of decomposition that result in bloating contribute to the color change of the soft-tissues, as greens, blacks, and browns occur throughout the progression of tissue decomposition by microbes as they proliferate and a build-up of biliary acids occur (Clark et al. 1997). As these processes continue, the body's tissues are liquefied and drain from the orifices and wounds created by maggots feeding on the tissues. The skin slips off the corpse in sheets, around the

hands and feet as the cells degenerate. Eventually, active decay ceases, and the process of decomposition converts into the next stage.

Advanced decay occurs usually with the help of weather and microbial decomposition of the bones and remaining soft tissue. Bones are largely exposed to the elements from pervasive insect activity and animal scavenging. The last soft-tissues to remain are the dense connective tissues of the joint surfaces (Stewart 1979).

Often the transition between advanced decay and skeletonization is subtle, as the minerals and chemicals in the bones are still being utilized by the environment, and the bones are almost entirely dry and exposed. This is the longest stage of decomposition with no demarcated end. During this stage, the bones can be used by animal scavengers for tooth honing and grinding, as well as a source of minerals (Carter et al. 2007; Swift et al. 1979). The bones are subjected to the elements and can change color and shape depending on the intensity of the sun, resulting in bleaching, and cracking of the bones. At the most extreme level of skeletonization, the bones are crumbling in situ as a result of the environment, whether it be rain, sun exposure, acidity of the soil, or other factors (Damann and Carter 2014).

For decades, forensic anthropologists scored the many intricate and continuous stages of decomposition typologically and qualitatively. The inaccuracy of this method, however, has forced forensic anthropologists to design more effective means of ranking, grading, and scoring general forensic progression, both in the soft tissue and in the skeletal material. Further details on these scoring methods are covered in Chapter 3:

Materials and Methods.

Time Since Death

Estimating the amount of elapsed time since the death of an individual is extremely important, because it can eliminate individuals from the pool of possible decedents, confirm or refute alibis given to police from suspects, and sometimes provide important details surrounding the circumstances of the individuals death. Determining TSD usually entails estimating the probable rate of decomposition and chronologically working backward. There are several methods often utilized to establish decomposition rates and TSD, such as accumulated degree-days (ADD), entomological data, the mortis triad, as well as environmental conditions.

Accumulated degree-days is the representation of thermal energy units that are available to facilitate biological processes like bacterial proliferation or fly larva growth (Megyesi et al. 2005). Calculation of ADD requires that a base temperature be subtracted from the daily average temperature, and all these average temperatures be added together for the approximate amount of days that decomposition has occurred to the point in time one is trying to calculate for (Vass et al 1992). Most often a base temperature of 0C is used due to the fact that while some bacterial proliferation may be occurring, temperatures below freezing significantly retard biological processes which require energy (Vass et al 1992). The temperature recorded in Celsius is then recorded over the

period of time intended for measurement, and then added together to produce the ADD for that temporal period.

When using entomological data to make TSD determinations it is not uncommon to utilize ADD in conjunction with the life cycle of a known recorded species of insect, most often a species of fly. Flies come in contact with the body within a few hours after death when the subject dies in an aerobic environment (Gennard 2007). At this time, flies lay eggs on the carcass which hatch into larva that feed on the carcass and grow at a rate specific to each species. Insects require thermal radiation to progress through their life cycle, with each species having a unique base temperature. Therefore, entomological data recovered from a carcass can be compared to ADD and, when moving in reverse temporal direction, can determine at what time eggs were deposited on the carcass (Gennard 2007). If time of oviposition is determined, it can be deduced that the subject died close to that time.

Determining the TSD is usually much more accurate, as it is measured in hours or days when dealing with a short postmortem interval. This is because algor, liver, and rigor mortis all occur within the first 12 hours of death, so encountering one of these processes is directly indicative of a recent death (Dix and Graham 2000). These early postmortem changes usually occur with less variation, making predicting time since death easier than when encountering heavily decomposed or skeletal remains (Clark et al. 1997). Extensive decomposition is much more variable and is affected by many intrinsic

and extrinsic factors. These longer postmortem interval ranges are placed in weeks, months, or years, and usually given in a large range (Klepinger 2006).

Depending on the environment of deposition, cause of death, and many other factors, decomposition can occur rather quickly over the course of a few weeks, or over a longer period of time better measured in months (Klepinger 2006). The primary determinant of soft tissue decomposition is temperature, which accounts for 80% of the variation (Megyesi et al. 2005). This is largely due to the temperature's effect on bacteria proliferation as well as the lifecycle of insects involved in the decomposition process.

Other factors affecting the rate of decomposition vary widely by location and include, humidity, moisture, pH, the depositional environment, presence and extent of animal modification, presence and extent of perimortem trauma, body weight, and presence of chemicals (Pokines and Symes 2014). These factors in addition to temperature must be deliberated when estimating PMI, which emphasizes the importance of understanding as much of the scene and context as possible.

As a direct result of this range of decompositional factors, decomposition varies immensely amongst geographical regions. The information pertaining to decomposition in the dry, arid environment of Arivaca, Arizona (Beck et al 2015), cannot be applied with any medico-legal accuracy to the temperate, forested region of Southern Illinois (Dabbs et. al 2013). With regional data available on decomposition rates as it pertains to a specific location and its many factors, predicting the PMI becomes more realistic,

which results in more accurate police work. Once PMI can be determined with precision, the pool of potential decedents and perpetrators will likely become narrower.

Animal Scavenging and Disarticulation

Forensic taphonomy includes all the interactions forensic remains have with their environment up until their collection and analysis, which includes any interactions remains might have with local fauna. Since deceased vertebrate carcasses, or carrion, are "enormous temporary boosts in consumable resources" (Pokines and Symes 2014) it comes as no surprise that there are thousands of organisms, both decomposers and consumers, which have evolved to exploit these resources as efficiently as possible. In addition to providing soft-tissue for consumption, carrion serves as a natural resource of vitamins and minerals, and as a hard surface to grind teeth. Therefore, markings on bone can be the result of gnawing, predation, dismemberment, teeth honing or grinding, and don't always occur as a byproduct of soft-tissue consumption (Table 3).

Table 3: Causes of bone modification

Modification	*Damage*	*Animal Type*	*Location*	*Cause*
Gnawing	Crushing of the bone and incising	Rodents, Scavengers, Carnivores, Osteophages	All locations	Result of predation, dismemberment, incisor sharpening
Dismemberment	Crushing and incising, furrows, pits, scores	Scavengers, Carnivores	Synovial Joints of the appendicular	Result of feeding

Modification	*Damage*	*Animal Type*	*Location*	*Cause*
			skeleton	
Teeth honing/Grinding	Parallel furrows and incising	Rodents	All locations	Result of rodent honing of incisors
Predation	Pits, scores, furrows, crushing	Carnivores	Axial skeleton	Damage to the bones ribs and verts as a result of trauma

Bone gnawing is defined as destructive crushing or incising of the bone in order to consume parts of the bone or hone and grind teeth (Pokines 2014). Bones are gnawed for multiple reasons: as a result of predation, in dismemberment of prey, in obtaining grease content, to obtain nutrients from mineral content, and for rodent incisor sharpening (Pokines 2014). The act of predation usually has minimal effects on the skeleton of adult vertebrates as large predators kill by disembowelment or by directing attacks towards the throat (Kruuk 1972, 2002). As a result, the bones most often affected by predation are the bones of the vertebral column and the ribs (Pokines 2014).

Dismemberment of prey is associated with feeding. Species like canids and other decomposers that feed in large groups may disarticulate limbs from the carcass and drag them away from the pack to consume alone as a response to interspecies competition for food (Hudson 1993; Kent 1981). For example, Spradley et al. (2012) documented vultures dispersing remains up to 51 feet as a result of interspecies competition.

Being a valuable resource of fat that is so rare in the wild, long bones are oftentimes scavenged and gnawed in order to access the nutritionally valuable marrow

located in the medullary cavity. This sort of gnawing behavior is common in many larger North American predatory mammals (Pokines 2014). In addition to large, predatory mammals gnawing on skeletal remains, rodents express a biological need to grind their continuously growing incisors and often use bones to achieve this.

Many rodents have been known to consume bone during gnawing, most-likely in an effort to consume dietary sodium (Roze 2009) or other minerals rarely occurring in nature like calcium phosphate (Klippel et al. 2007). These include Old World porcupines, gophers, and both eastern grey and fox squirrels. Brown rats have even been known to consume and gnaw bone in an effort to obtain nutrients in the form of fats (Klippel et al 2007). Additionally, multiple ungulate species, like sheep (Brothwell 1976) and deer (Sutcliffe 1973, 1977), have been recorded engaging in osteophagia as a response to limited environmental resources of minerals. Rodent incisor sharpening is a commonly encountered form of scavenger gnawing. Rodents have been known to gnaw on many different hard materials in addition to bone in order to hone their continuously growing incisors. These gnaw marks are characterized by parallel grooves. In comparison, vertebrate carnivores can produce several different types of postmortem bone trauma that could be encountered during research.

Generally, the direct tooth marks left on bone by carnivore and scavenging activity are tooth pits, tooth punctures, tooth scores, and tooth furrows (Table 4). Circular or irregular-shaped depressions in the cortical bone that do not penetrate into the cancellous bone of the interior are referred to as tooth pits (Pokines 2014). These pits are

caused by the apex of carnivore teeth slightly penetrating the bone during gnawing and consumption and generally have a maximum length no more than three times the maximum width (Pokines 2014).

Table 4: Types of tooth marks

Tooth Marks	*Depth*	*Length*	*Width*	*Cause*	*Shape*
Tooth Pits	Shallow, do not penetrate cancellous bone	No more than 3x width	short	Result of gnawing and consumption	Circular, irregular-shaped depression
Tooth Punctures	Penetrate into cancellous bone	No more than 3x width	short	Predation	Can preserve shape of tooth with crushed margins
Tooth Scores	Shallow, do not penetrate cancellous bone	Much longer than width	Very short width	Tooth honing, gripping, consumption	Run length of bone, may be parallel
Tooth Furrows	Penetrate into cancellous bone	Much longer than width	Medium to short	gnawing	Irregular, often obliterated during excessive gnawing

Tooth punctures are similar to tooth pits; however, punctures are deeper penetrations that continue through the cortical bone and deep into the cancellous bone within the diaphysis (Pokines 2014). The margins tend to be crushed or broken in form, further differentiating tooth pits from tooth punctures (Pobiner 2007). Tooth punctures can sometimes preserve the shape of the tooth which may be used to potentially identify the scavenger (Pokines 2014). Tooth punctures are more often encountered in cases

where the deceased was killed by the predator, as a result of the predator forcefully biting the individual and holding onto the individual in an attempt to cut off the airway or inflicting lethal damage to organs or the spine (Kruuk 1972, 2002).

Tooth scores are striations that have the same penetrative form of tooth pits, but instead run the length of the bone and are usually three times longer in maximum length than width (Pokines 2014). They are sometimes cut in a parallel manner by multiple teeth dragging across the periosteum of the bone and are sometimes referred to as gripping marks (Pokines 2014).

In the same way that tooth punctures are deeper forms of tooth pits, tooth furrows are essentially tooth scores that penetrate deeper into the cancellous bone (Pokines 2014). Furrows are often obliterated by continued gnawing, as cancellous bone is destroyed in order to get access to the marrow within the long bone diaphysis (Pokines 2014). Tooth marks can be so extensive that individual marks cannot be determined. In this case the damage is grouped into the broader term of gnawing damage. Still, sometimes individual marks can be preserved past the margins of the gnawing damage and can be identified (Pokines 2014).

In addition to terrestrial scavenging carnivores, vultures and other avian scavengers can leave markings on bone that are likely to be encountered during research (Hamilton and Spradley 2011, Reeves 2009). Birds use their sharp beaks to shear soft tissue from bone. Reeves (2009) identified two varieties of markings left by vultures (primarily black) on pig and goat carcasses: shallow, irregular linear scratches found

most often on skulls, and incredibly shallow scratches mostly evident as a change in color on the surface of the bone and very rarely preserved over the course of feeding and scavenging events. On animals that must be flensed, damage to thin cortical areas is sometimes encountered (Baker 2012, Bochenski and Tornberg 2003). This includes punctures to the skull, scapulae and long bone diaphyses (McGraw et al. 2006).

Size of bone markings, in conjunction with overall damage to the bone, can be used to distinguish between small and large scavenger species, but due to the infinite number of ways to attack bone, there is no way to unequivocally determine which scavenger leaves what marks without the aid of other forms of evidence like scat, feathers or fur (Einarsen 1956, Gilmour and Skinner 2012, Murad 1997). Field cameras can be utilized to provide a second line of evidence for use in identifying scavenger activity.

Bone Dispersal

While bone dispersal is oftentimes a side effect of animal scavenging, it can also be caused by normal environmental processes. Both large and small animals are capable of dispersing bones away from initial deposition (Haynes 1982, 1983). This is referred to as a primary dispersal, which is defined by Pokines (2014) as "bone movement away from their point of initial deposition, without any prior movement of the entire, intact mass of remains as a unit". This type of dispersal is likely caused by animal feeding and downslope wash (Pokines 2014). For instance, the feeding behavior of large scavenging birds has been known to disperse skeletal remains for many reasons. Large numbers of

birds often feed simultaneously, which increases chances of osseous dispersal. Intraspecies competition can force less dominant individuals to grab whatever they can and retreat a great distance to consume the food unmolested. Vultures specifically have been known to carry bones as large as adult goat scapulae in their beaks and transport them through the air (Reeves 2009). Some species of vultures have even been known to reconcentrate osseous remains at roosts (Pokines 2014).

In addition to competition, skeletal material can be altered or moved during the feeding process (Pokines 2014). The sharp beaks and talons of many avian scavengers can incise and damage bone, as the animals attempt to flense soft tissue from bone. However, the damage to bone caused by avian scavengers is often far less than most terrestrial scavengers that rely on teeth to crush and break bone to fully exploit soft tissues (Pokines 2014). Often, when attempting to consume the most accessible tissues, large avian scavengers can rotate, shift, and move an entire carcass. Spradley et al. (2012) determined that some of the dispersal is dependent on terrain, however vultures were able to disperse human skeletal remains over 83.6m^2.

More advanced dispersal is usually the result of terrestrial animal scavenging and flowing water channels. Heavy dispersal likely involves multiple species either scavenging the bones at different times during the PMI, or as a result of interspecies and intraspecies competition. It can be assumed that taphonomic alterations to the bone increase as PMI and amount of dispersal both increase (Pokines 2014).

Secondary dispersal is defined by Pokines (2014) as "occurring when remains have been moved, largely intact, from the point where initial deposition occurred to another location. From this secondary deposition point, secondary dispersal will then proceed". This type of dispersal is largely the result of transportation of murder victims however, it can also be the result of large predators transporting a carcass, or "caching" (Pokines 2014). It's also been confirmed that scavengers can revisit osseous remains to scavenge remains long past initial skeletonization, which has been known to lead to secondary dispersal (Pokines 2014). Spradley et al (2012), Reeves (2009), and Dabbs et al (2013), all experienced secondary dispersal via the agency of vultures or coyotes. Because it is very rare for an entire carcass to become devoid of consumable soft-tissue in a single scavenging event, it’s very common for secondary dispersal to occur.

Central Florida Scavengers

Not all of the above mentioned scavenging, and dispersal behaviors are exhibited by the carrion-eaters of Central Florida. Central Florida is home to common carrion-eating species such as coyotes, black vultures, turkey vultures, crows, raccoon and opossums with generally well-understood interactions with carcasses in forensic literature. However, there are scavengers unique to Central Florida, some more likely to interact with the cadavers than others, that need to be referenced. These include the crested caracara, the armadillo, the bald eagle, the fish crow, the American alligator, the black bear, the bobcat, the Florida panther and the feral pig (Table 5).

Table 5: Species of scavengers endemic to Florida

Scavenger	*Binomial Nomenclature*	*Likelihood of Contact*	*Type of consumer*	*Family*	*Range*
Coyote	(*Canis latrans*)	Medium	Predator, Scavenger	Canidae	Contiguous US
Black Vulture	(*Coragyps atratus*)	High	Scavenger	Cathartidae	Southern US
Turkey Vulture	(*Cathartes aura*)	High	Scavenger	Cathartidae	Contiguous US
Crow	(*Corvus brachyrhynch*)	High	Scavenger	Corvidae	Contiguous US
Raccoon	(*Procyon lotor*)	High	Omnivore, Scavenger	Procyonidae	Contiguous US
Opossum	(*Didelphis virginiana*)	High	Omnivore, Scavenger	Didelphidae	Contiguous US
Crested Caracara	(*Caracara cheriway*)	Medium	Predator	Falconidae	Southern US, Coastal
Bald Eagle	(*Haliaeetus leucocephalus*)	Medium	Predator	Accipitridae	Contiguous US
Fish Crow	(*Corvus ossifragus*)	Medium	Scavenger	Corvidae	Southern US, Coastal
American Alligator	(*Alligator mississippiens*)	Low	Scavenger, Predator	Alligatoridae	Southeastern US
Black Bear	(*Ursus Americanus*)	Low	Predator, Scavenger	Ursidae	Contiguous US
Bobcat	(*Lynx rufus*)	Low	Predator, Scavenger	Felidae	Southern US
Florida Panther	(*Puma concolor*)	Low	Predator	Felidae	Southeastern US
Feral Pig	(*Sus scrofa*)	Low	Omnivore, Scavenger	Suidae	Southern US
Armodillo	(Dasypus novemcinctus)	Medium	Insectivore	Dasypodidae	Contiguous US

Coyotes (*Canis latrans*) are common in all the states of the contiguous US. They are roughly 20 - 50 pounds and live as familial packs or lone wanderers (Smith and Dunn 2011). Coyotes are extensively omnivorous, and will eat almost anything. While most of their hunting is restricted to wild and domestic animals about the size or smaller than a sheep, they play a very important role as a decomposer in their ecosystem (Smith and

Dunn 2011). Not much is known about their scavenging behavior other than what is known in regards to pack eating hierarchy. However, coyotes are crepuscular and are opportunistic feeders, meaning they do most of their scavenging at dawn or dusk and are likely to scavenge any carcass they come across (Smith and Dunn 2011). Coyotes are uncommon south of the Florida Panhandle, however they are very comfortable living in close contact with humans (Smith & Dunn 2011).

After population declines in the 1990's and 2000's, black vultures (*Coragyps atratus*) and turkey vultures (*Cathartes aura*) have become prolific throughout the contiguous US, including the entire state of Florida. Vultures of both species are so prevalent in the Central Florida region that the University of Central Florida used the vulture as an unofficial mascot during the early 1970's. Black vultures as well as turkey vultures are the primary carrion-eaters in most regions (Dabbs et al. 2013). Turkey vultures are the larger of the two species (1.6-1.8 m wingspan) and have been found to exist in all habitats within the contiguous US (Sibley and Monroe 1990). In contrast, black vultures are smaller (1.3-1.6 m wingspan) and are more common in the American South (Sibley and Monroe 1990). Turkey vultures are unique in that their bald heads are red, in stark contrast with their jet-black body plumage. When compared with black vultures' black head and black body, the two can be easily distinguished from each other. In addition to visual differences, the two vultures also differ physiologically. Turkey vultures have a unique olfactory bulb in their brain that allows them to detect VOCs commonly released during the decomposition process, which assists the birds in locating carcasses (Dabbs et al. 2013). Black vultures do not have this heightened sense and

generally rely on eyesight alone to locate food. In fact, black vultures use their eyesight to locate not only carcasses, but turkey vultures as well, and consistently follow them to carcasses (Stolen 2000). Once a black vulture finds turkey vultures feeding, the black vulture bullies away the competition, and with the help of large numbers, will muscle Turkey Vultures away from the carcass (Pokines 2014). A flock of vultures has been known to skeletonize a fully fleshed adult human being in roughly 5 hours (Spradley et al. 2012) which indicates they have a dramatic impact on decomposition.

Crows belong to the family of birds called Corvids. Crows and other Corvids are commonly encountered in every US state, and have been found to live in most habitats (McGowan 2001). They are highly intelligent and have been known to cache food and return to feed multiple times (Pokines 2014). Komar and Beattie (1998) have even noted Corvids as being capable of osseous dispersal, after a magpie was recorded transporting a pig metatarsal more than 600 meters to a nest. Crows are opportunistic feeders and will eat most anything, and subsequently, carrion does not make up a consistent percentage of their diet (McGowan 2001). In addition to consuming the soft tissue of a carcass, crows are likely attracted to decomposition because of the entomological activity that occurs during the decomposition process.

The common raccoon (*Procyon lotor*) can be found in every US state. They are omnivorous, and therefore have a high level of dietary plasticity, allowing them to consume energy however it becomes available (Zeveloff 2002). Understandably, raccoon scavenging has been noted in many forensic cases and research experiments. Their small

size, dexterous forepaws, and ability to climb make them efficient scavengers (Zeveloff 2002). Raccoon are largely nocturnal and do the bulk of their scavenging at night (Zeveloff 2002). For this reason, they avoid competition with crepuscular scavengers like coyotes, and diurnal scavengers like vultures. Raccoon are generally solitary animals (Zeveloff 2002), so it is unknown how much of an impact they have on PMI estimates, since they lack the numbers needed to rapidly skeletonize carcasses, in the same manner of coyotes and vultures.

The common opossum (*Didelphis virginiana*) is an omnivorous scavenger similar to the common raccoon in size and prevalence. Like the raccoon, they are nocturnal, solitary, and have a high level of dietary plasticity (Krause and Krause 2006). They've been known to consume carrion in similar capacities to that of the raccoon. Their ability to climb allows them access to forage and scavenge areas other scavengers would not be able to access. Unique to opossum, is a mandible much larger than expected for its body size (Krause & Krause 2006). This may result in the opossum being able to damage osseous material more severely than raccoon. Unfortunately not much research has been conducted on the opossum and its scavenging behaviors (Krause & Krause 2006).

The crested caracara belongs to the falconidae family of birds with other falcons and hawks. They are roughly the same size as black vultures, and, like black vultures, rely on sight rather than olfaction to locate carrion (Layne 1996). Their diet consists mostly of carrion, however they have been recorded hunting small mammals and reptiles

(Morrison 1996). While the crested caracara is located in Central Florida, they are generally uncommon in the southern U.S. (Layne 1996).

The bald eagle is also encountered in Central Florida. While the birds of prey aren't known as carrion-eaters, they are opportunistic hunters, and have been seen eating fresh road-kill. There is not much research done on their scavenging behavior, however the possibility remains that they may interact with sample carcasses (Personal communication with Audubon Center for Birds of Prey, Winter Park, FL).

Like the American crow, the fish crow is also prevalent in Central Florida. As well as belonging to the family Corvid, fish crows also behave very similarly to American crows. They eat carrion, are slightly smaller than American crows, and have been known to return to caches of food multiple times (McGowan 2001). Both the American crow and the fish crow are very common in Central Florida, with the fish crow being a unique species of crow to the southeastern states.

The American alligator (*Alligator mississippiensis*; hereafter Alligator) is abundant in Central Florida. While not much has been written about the alligator's role in forensic scavenging, they are known to be opportunistic carnivores (Rice et al. 2007). The stomach contents of alligators in Central Florida reveal a diverse diet with an extraordinary range in frequency of animals indicating alligators will consume almost anything smaller than themselves (Delany and Abercrombie 1986). Furthermore, a study on crane predation and nest scavenging by alligators (Folk et al. 2014) indicated that alligators are important species in the decomposition and removal of carcasses. Alligators

are largely aquatic reptiles, only leaving the water to nest, or sunbathe for warmth. For this reason alligators are unlikely to venture into the selected test site which contains only a single small pond. Additionally, it would be uncommon for an alligator to locate a decomposing carcass outside of the water.

Feral pigs (*Sus scrofa*) have extended populations to 38 states and are continuing to expand their ranges (Mouton 2009). Pigs are omnivorous and are well-known consumers of carrion. While pigs aren't commonly seen in the greater Orlando area, their presence must be considered. Pigs will consume all forms of carrion and are not hesitant to consume the remains of other pigs. Savaging is common among pigs (Chen et al. 2008), and willingness to consume pork is common among them as well.

Black bears (*Ursus americanus*) are considered the foremost scavenger of predator kills (Murphy et al. 1998; Murphy and Ruth 2010). Because of their size, black bears consume a large amount of food each day and have been known to monopolize carrion (Allen et al. 2015). Black bears are well-known climbers and would not hesitate to scale a barrier in an attempt to acquire carrion. Additionally, black bears have an exceptional sense of smell (Lariviere 2001) making detection by black bears in the area a strong possibility. While black bear are native to Florida, their presence is rare, and population density indicates that the likelihood a bear encounters the subject carcasses during this project is minimal.

Central Florida is home to three different species of feline that are capable of encountering the pig carcasses involved in this research. Those felids are: the bobcat

(*Lynx rufus*), the Florida panther (*Puma concolor* hereafter Panther), and the feral cat (*Felis catus*). All felids endemic to Florida are solitary carnivores, therefore it's unlikely they will have a large taphonomic effect. Feral cats have not been known to scavenge soft-tissue often and would most likely encounter the carcass accidentally. The bobcat, while sparse in Central Florida, has been seen by Arboretum staff within 3 months of the start of the research. As presented by Rippley et al (2012), extensive bobcat scavenging has been recorded previously. In Southeast Texas, a bobcat was noted as interacting with a cadaver 88 times over the course of two days, and consumed much of the flesh of the thighs, and left arm. While scavenging on remains by bobcats is not commonly documented, it is important to note that it has occurred (Rippley et al. 2012). Not much research has been done on panther feeding habits outside of stomach contents examination; however, pigs make up 50% of the diet of panthers in Florida (Maehr 1990). Behaviorally, panthers return to kill sites periodically following a kill to consume available nutrients (Maehr 1990). If a panther encounters the pig carcasses used in this research, it is possibly it may consume soft-tissue or otherwise affect the taphonomic process.

Due to the location and design of this research, some of these scavengers are more likely to interact with the subject carcasses over the course of the experiment. Specifically, black bears, opossum, raccoon, vultures, eagles, crows, cats and coyotes. Black bear are rarely seen within the city limits of Orlando, however black bear have occasionally been recorded using the UCF Arboretum as a pass-through, and tend to follow the banks of the rivers that run through Central Florida. Bear commonly interact

with humans because they are attracted to the smell of refuse. These powerful noses would likely detect the smell of decomposition if a black bear happened to be in the vicinity of the Arboretum at the time of this research. Furthermore, black bear are excellent climbers and would have no problem overcoming a six foot fence in order to gain access to a carcass. Opossum are ubiquitous and live in fringe areas where forest and human developments meet. Opossum are also good climbers, and are small enough to crawl beneath the fence as well. Raccoon are similar to opossum in that they are good climbers and reside in areas with human activity. Vultures, eagles, and crows are all noted scavengers, and their ability to fly enable them to bypass the six foot fence, thus their presence is most likely. Cats, both feral and domestic may interact with the carcasses, given that the Arboretum is located in close proximity to a residential area. Additionally, Central Florida is home to bobcats and Florida panthers, which, while rarely seen, are carnivores that could possible encounter the remains, either by accident or in an attempt to feed. Scavenging by bobcats has been noted in forensic literature. Felids are agile and would easily bypass a six foot chain link fence. Lastly, coyotes, while not common in Central Florida, are known scavengers that could easily crawl beneath the fence in an attempt to feed on carrion.

While armadillo (*Dasypus novemcinctus*) are not consumers of carrion, they are abundant in the natural lands where this research is conducted, therefore their possible interactions with the pig carcasses should be mentioned. Baker (1943) collected armadillo stomachs in order to investigate their impact on quail nests in Texas. It was concluded that armadillo subsist on a vast majority of invertebrate species (over 90%)(Baker 1943).

This is significant, because while armadillo do not consume carrion, their effect on insects and other invertebrates common among the decomposition process, may alter decomposition rate by removing decomposers, and consumers like arachnids from a carcass (Baker 1943).

CHAPTER 3: MATERIALS AND METHODS

Research Field Site

The research field site consists of a square, fenced-in area approximately two acres in size (on the UCF campus) which is known as the Deep Foundations Geotechnical Research Area (Figures 1-3). The fence is 6-foot chain-link with a padlocked entrance gate on the north side of the enclosure, with no other entrances. The area consists of an eastern half that is mainly tall grass and small shrubs with the occasional saw palm or long-leafed pine tree, and a western half that is mostly grass with tall long-leaf pines, and scattered live oak, with the occasional bush or palm. The site is generally secluded and sits several hundred yards away from the roadways and residential homes, allowing for animals to access the site unaffected by people and traffic. The soil on the site is classified by the USDA soil survey (http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm) as mainly Pomello fine sand on 0 to 5 % slopes with small areas of Smyrna-Smyrna, wet, fine sand on 0 to 2 % slopes.

The site has been the location of previous research experiments involving osteological material; therefore, the site was thoroughly searched in order to collect any remaining skeletal material in preparation for this study and to avoid any skeletal material scattered by animal scavenging intermingling with specimens from past research studies. Additionally, the area was prepared for deposition by cutting the tall grass at the location of each pig (*Sus scrofa*) carcass deposition site. This was to ensure all locations had a consistent level of growth at the start of the study and assist in locating displaced skeletal

elements as the decomposition process naturally occurred. Two pig deposition sites were chosen in open areas on the eastern half of the site, and two pig deposition sites were chosen on the western half in heavy tree cover.

The pig carcass deposition site located in the southwest quadrant of the Deep Foundations Geotechnical Research Area was labeled Deposition Site Shade #1 (S1). This site consisted of scattered long-leaf pines with intermittent deciduous foliage scattered throughout as well as tropical saw palms. The growth of long-leaf pines was relatively new growth that provided an inconsistent canopy, casting partial shade throughout the day. The ground cover was a mixture of grass, exposed soil, and pine needles, however, pine needles were the majority and provided a near-complete layer covering the ground. The site was located in a small clearing of trees near a cluster of pines, which formed a partial barrier on the West side of the deposition. Further south of the deposition, tall grass grew along the Western fence line.

The pig carcass deposition site located in the northwest quadrant of the Deep Foundations Geotechnical Research Area was labeled Deposition Site Shade #2 (S2). This site consisted of a tightly packed growth of long-leaf pines and assorted deciduous trees scattered intermittently throughout. The ground was covered in pine needles to the point that the soil was not visible. The deposition site was located in a circular clearing approximately three meters in diameter with a full canopy that provided almost complete shade through the entire day. On the north side of the deposition site, the ground was covered in scattered bushes and tall grass underneath long-leaf pines.

The pig carcass deposition site located in the southeast quadrant of the Deep Foundations Geotechnical Research Area was labeled Deposition Site Open #1 (O1). This site consisted of a wide-open field of tall grass that was partially cleared in the area between a solitary deciduous tree and the southern fence line. There was a small cluster of pines west of the deposition site, however the site had no canopy and was without shade for the majority of the day. The only time of day where shade was cast on the site was in the early morning from old-growth long-leaf pines that were outside of and south of the Deep Foundations Geotechnical Research Area. The ground was largely dirt with a small covering of dead plant material as a result of site preparation. The grass at the site was trimmed short, however, the area directly north of the deposition site consisted of waist high grass within the large field area. Tall grass was also concentrated along the southern fence line and on the east and west sides of the deposition.

The pig carcass deposition site located in the northeast quadrant of the Deep Foundations Geotechnical Research Area was labeled Deposition Site Open #2 (O2). This site consisted of a clearing among scattered and mixed foliage, mainly consisting of young long-leafed pines, various deciduous trees, and tall brush. The area north of the deposition site was characterized by tall grass and scattered foliage. The east of the site was packed trees of differing varieties. The southern side of the site was largely open with scattered high grasses and bushes. The west of the site was fairly open as well with the exception of a moderately sized oak. The ground was cleared as part of site preparation and was therefore mostly dirt with plant debris scattered throughout. This area received direct sunlight for the majority of the day with the exception of sunrise.

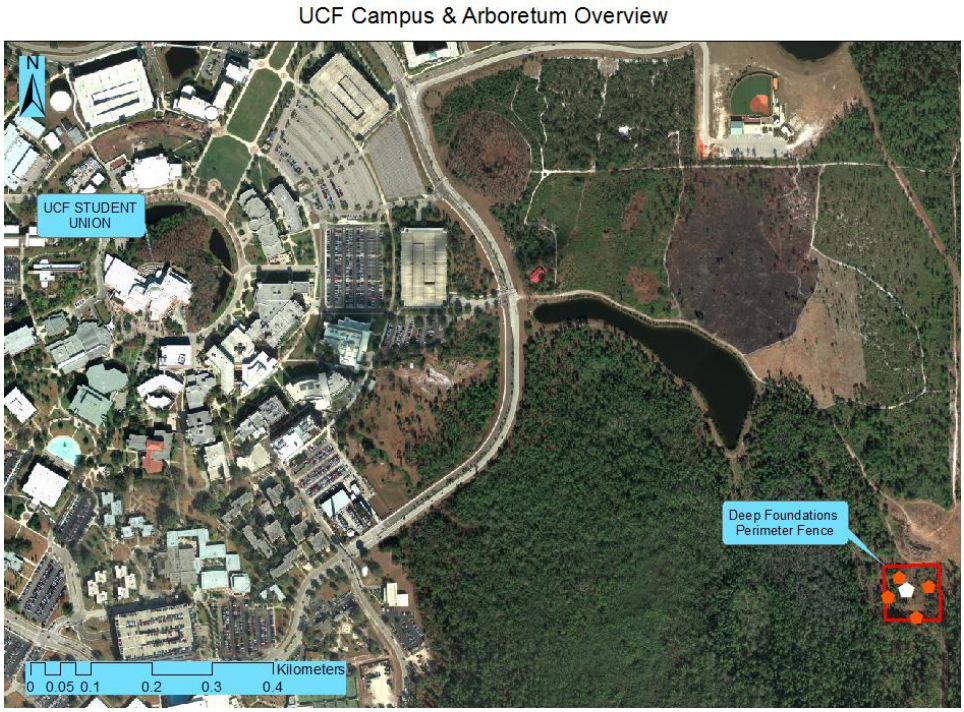


Figure 1: Largescale overview of UCF campus and Arboretum

Figure 2: Medium-scale overview of Arboretum

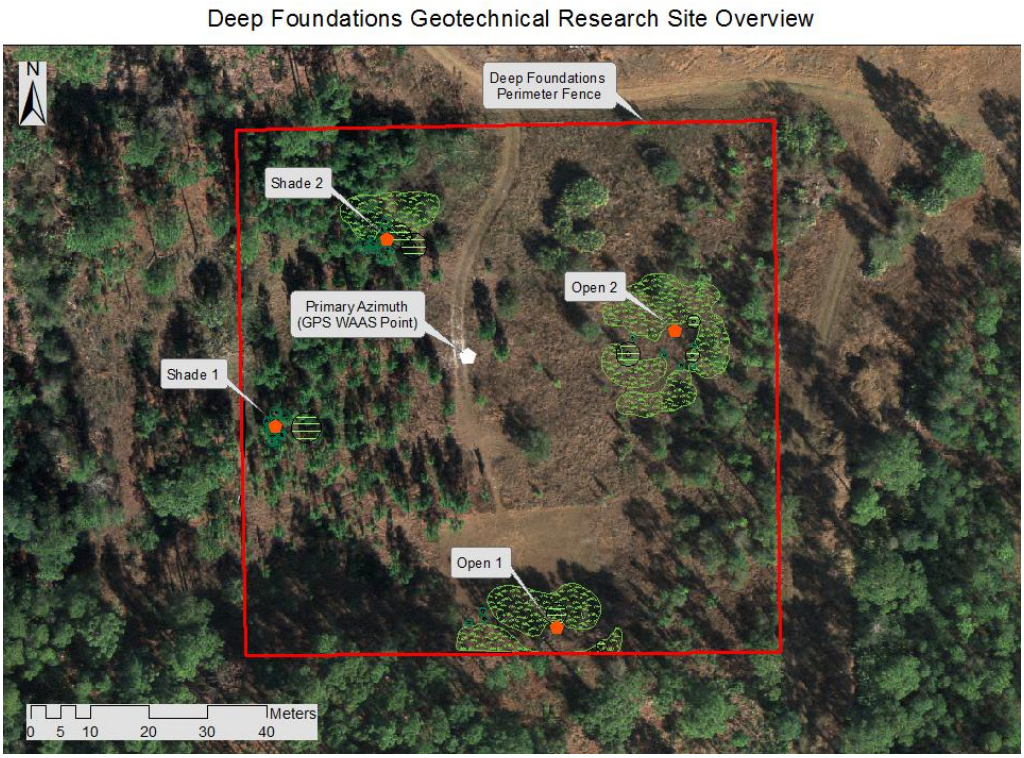


Figure 3: Overview of Deep Foundations Geotechnical Research Site

Site Preparation

Prior to acquiring the samples and conducting research, the site area was prepared for deposition. This included collecting osteological evidence already scattered around the test site, clearing each sub-site of excess flora in order to establish a consistent ground cover across sites, installing a permanent central datum post for mapping via GIS,, and prepping and installing IR video and time lapse game cameras at each site.

In order to clear each deposition site, garden shears and a grass whip cutter were employed. Sites with grass were trimmed using the grass whip cutter in order to establish

continuity throughout all sites. Garden shears were used on young trees and brush too thick to be cleared with the grass whip cutter. Garden shears were also utilized for trimming away branches and foliage obscuring game camera views of the deposition sites.

The central clearing at the Deep Foundations Geotechnical Research Area was chosen as the location for the primary azimuth for multiple reasons. The centrally located site would allow for easier and more accurate measuring of secondary azimuths and the cleared area contained no large rocks, or tall grass that would hinder installation of the primary azimuth, in this case a plastic stake, with a mallet. Most importantly, the clearing allowed for optimal satellite visibility at the site. In order to attain the most accurate GPS data, dilution of precision (DOP) must be kept to a minimum. This is achieved by holding the GPS unit one meter above the ground, make sure the GPS unit is far away from obstructions like trees and buildings, and that satellite geometry is optimal. This location offered the most accurate comparative GPS data.

Game camera locations of each deposition site were determined based on viewing angle and available structures that could support the fixture of the game camera. Site S2 featured numerous thick trees which were optimal distances away from deposition sites and would allow for limited reflection from the rising or setting sun. Any foliage obstructing the view was trimmed with the garden shears. Cameras were affixed via Master Lock Python cables, and optimal camera angles were achieved with rubber door stops placed between the back of the cameras and the structures. Site S1 also provided

adequate trees which had cameras affixed to them. Camera angles and obscured foliage was rectified similarly at Site S2. Site O1 was partially selected due to the location of the fence and the solitary tree which provided two adequate structures for camera placement. Site O2 contained two trees with direct views of the deposition site that could support the attachment of cameras. All cameras were secured and angled using the same method and materials described for Site S2.

Each site was observed by two game cameras (one Reconyx PC800, and one Browning Strike Force HD on sites S1 and S2. And one SG-990v and one Browning Strike Force HD on sites O1 and O2), with the pig placed in view of both and with measures taken to avoid camera orientation in the direction of the setting or rising sun. In total, eight cameras were used. The direction of the cameras ensure that neither sunrise nor sunset obscured the images, or trigger the IR beam. The cameras were affixed to trees of the appropriate size and location, at approximately 1 meter above ground level and angled slightly downward by using a rubber wedge doorstop. All cameras were at least one meter away from each carcass, and appropriately angled in order to properly frame each image. The Browning Strike Force HD cameras were set on infrared detection with a five minute delay to capture one minute of video whenever the IR beam was broken. The Reconyx PC800 at the S1 and S2 locations and the SG-990v at the O1 and O2 locations were set on a 24-hour, 5 minute increment time lapse in order to capture a scene image every 5 minutes.

Pig Carcass Sample

Pig carcasses were used for this decomposition study. Goff (1993) determined via entomological decomposition rates that pigs approximately 50lbs (23kgs) are the best human analogues in part, due to the similar trunk size, thickness, and tissue densities. This particularly sized carcass is child-sized in comparison to adult human cadavers, both in overall size, limb length, bone size, and ossification level of bones. It should be noted that the 23kg pig carcass is the smallest justifiable size, because smaller skeletal remains are much easier to destroy and can be consumed by scavengers.

The sample of this study consisted of four whole pig carcasses (*Sus scrofa*) ranging between 55lbs (25kgs) and 65lbs (29.5kgs) (Table 6) were purchased freshly deceased from Walliser Pork, in Wimauma, Florida. The pigs were slaughtered for human consumption in accordance to standards set by the USDA (USDAFSIS, 2003). The pigs were euthanized via .22 caliber bullet to the frontal bone of the cranium by personnel at Walliser Pork. They were allowed to exsanguinate, and were then hosed down to clean excess blood off the carcass. They were then wrapped in garbage bags for transportation to the research site after being transported approximately two hours to the UCF campus, and were then laid out in the four pre-determined sites on the same day. The cranial end was orientated northward and the tip of the nose was exactly 50cm from the secondary datum, which was installed at each site, at the time of deposition. Additionally, the only outward signs of trauma to the carcasses were the small bullet holes on the frontal bones. Since the carcasses were hosed down, there was minimal blood around the wound on the carcass.

Table 6: Pig Carcass Sample Summary

Sample #	*Animal/Weight*	*Site Location*	*# Cameras*
Sample 1	*Sus scrofa*/ 25kgs	NE Quadrant O2	2 (1 Time Lapse, 1 IR)
Sample 2	*Sus scrofa*/ 27kgs	SE Quadrant O1	2 (1 Time Lapse, 1 IR)
Sample 3	*Sus scrofa*/ 29.5kgs	NW Quadrant S2	2 (1 Time Lapse, 1 IR)
Sample 4	*Sus scrofa*/ 27kgs	NE Quadrant S1	2 (1 Time Lapse, 1 IR)

Documentation Methods

Mapping the Site

A primary datum approximately central to all four sites and in an open area was selected and recorded via wide area augmentation system (WAAS) to relate the locations and any future disarticulation and scatterings of the four pigs. WAAS GPS allows for better accuracy, integrity and availability of GPS data. Due to limitations in equipment and poor DOP at the Deep Foundations Geotechinical Research Area, WAAS GPS provided by a handheld Garmin resulted in the most accurate data that could be achieved. This data was measured in ArcGIS and accuracy was determined to be <.5m. The initial deposition of the pigs was recorded using the azimuth control-point mapping method (Dupras et al. 2012) using the central datum point as primary azimuth. From the primary azimuth, four separate secondary azimuths were set, each one 50cm from the nose directly north of each respective carcass. This was done to make azimuth measuring more efficient and ensure greater accuracy at each site since the carcasses were placed as far as possible away from each other. The secondary azimuths were recorded as follows: S1

was 3480 cm from the primary azimuth at an angle of 250° off North; S2 was 2322 cm from the primary azimuth at an angle of 328° off North; O1 was 4843 cm from the primary azimuth at an angle of 162° off North; O2 was 3519 cm from the primary azimuth at an angle of 83° off North. In addition, measurements were taken of the distance between the secondary azimuth points and the nearest fence at shortest distance at a right angle in order to measure accuracy in ArcGIS as well.

Mapping the Carcasses

Points were measured off the secondary azimuths to each pig at specific locations in order to detail the position of the depositions. The points used were the base of the tail, the most anterior point of the nose, the central point of the shoulder, the central point of the hip, the most distal end of the hind leg and most distal end of the front leg. As the carcasses decomposed and disarticulated and the remains were scattered, more points were necessary to accurately map the distribution. These points were determined after each event and were dependent on the state of the carcass. Bones were divided into two categories, articulated remains and disarticulated elements. Articulated remains were any combination of soft-tissue and skeletal elements that were still naturally articulated. These remains were recorded with multiple points, one at the proximal end, and one at the distal end, in the case of an articulated leg or multiple points to properly represent the shape of a mass of elements, such as the skin bags at some sites or articulated lower limbs and os coxae. Disarticulated elements include all individual skeletal elements or pieces of

soft-tissue and any fragments. These elements were recorded by a single point located at the centermost location of the bone or element. Maps were produced in ArcGIS detailing each specific deposition site, initial scatter, subsequent scatter events, as well as unique scattering events for each site. Throughout the duration of the project, new maps were recorded after each scattering event (as determined through examination of camera footage and in situ evidence).

Photography and Documentation

The sites were visited daily for 2 weeks at approximately the same time and photographed using a Canon Powershot S3 IS 6.0 megapixel digital camera. Upon each daily visit, the affixed cameras were checked and the images were downloaded and saved. Additionally, all weather data was recorded from the WUCF-FM weather station located on campus. This included average temperature, relative humidity, barometric pressure, and rainfall. In addition to photos, PMI was assessed using the TBS system discussed in chapter 2. Each carcass was scored independently and notes were taken on any unique changes not included in PMI determination and photographs. Entomological data was collected when applicable (Table 7).

Table 7: Summary of Data to be Collected

	Stage of Decomposition				
Data to be collected	*Fresh*	*Bloat*	*Active Decay*	*Advanced Decay*	*Skeletonization*
Photographic (DSLR)	X	X	X	X	X
Entomological	X	X	X	X	
TBS Scoring	X	X	X	X	
Photographic (Stationary)	X	X	X	X	X
Weather	X	X	X	X	X
Mapping	X	X	X	X	X

Entomology

While not the focus of this research project, entomological specimens were collected and documented based on standard protocols for possible future research. This included collecting biological samples throughout the fresh and bloat phases to ensure an appropriate range of lifecycle stages while the data was available. Additionally, two attempts to install pitfall traps occurred, however, both instances resulted in the pitfall traps being scavenged so no data were recorded.

Entomological data was collected with the help of Shawn Kelly, collection manager, and his student volunteers of the UCF Bug Closet and entomology club. Often,

insects are the first scavengers to arrive at a body postmortem. For this reason entomological data is used to estimate TSD, via evaluation of arthropod life cycles and succession of various species (Christensen et al. 2014). Insects transition through predictable life cycles that can be used to determine decomposition stage. During the maggot stage of the life cycle, insects consume much of the body mass of the remains and can have a drastic impact on PMI and ADD. For this reason, entomological biotic data were collected during the fresh and bloat stages. This includes maggots, hymenoptera present, beetles present, as well as flies that were caught. The entomological data was collected from each carcass every other day as applicable upon each visit and the subsequent material was preserved in vials of alcohol, labeled, and later identified by Mr. Kelly and his volunteers.

With collection of the different life cycle stages of various fly species, and recorded temperatures during the experiment, we were able to determine ADD and see how it correlated with the actual decomposition process. For this, the following formula for calculating ADD provided by Gennard (2012) was used:

$$\text{Time(days)} \times (\text{Temperature} - \text{base temperature}) = \text{ADD}$$

Base temperatures were obtained from online UCF weather sources after identification of entomology was completed. Entomologically calculated ADD was then compared with TBS calculated ADD.

Decomposition and Weathering Scoring

The Total Body Score (TBS) system implemented by Megyesi (2005) to estimate PMI from decomposed human remains was utilized in this research. In Megyesi's (2005) study, 68 forensic cases were assessed using the TBS system developed by Galloway et al. (1989). Megyesi then compared the TBS scores for these forensic cases with their actual PMI to quantify the accuracy of using TBS to determine ADD with special attention given to temperature. This scoring method was used in order to determine how rapidly vertebrate scavenging alters ADD and PMI. It was imperative to know when the pig carcasses transition between decomposition stages, in order to track the duration of each stage in relation to amount of scavenging activity. However, in Megyesi's (2005) study, scavenging events were so intense that decomposition stages were severely altered and some were bypassed. Each carcass was scavenged to the point of skeletonization at the point of maximum bloat, or at the beginning of post-bloat.

The TBS system is based on three different scoring tables; the head and neck, the abdomen, and the limbs (Galloway 1989). The head and neck is scored between 1 point (Fresh) and 13 points (Dry bone). The abdomen is scored between 1 (Fresh) and 12 (Dry bone). The limbs are scored between 1 (Fresh) and 10 (Dry bone), making the range of TBS 3-35; 3 being completely fresh, and 35 being completely skeletonized. In cases where limbs may have extreme differences in decomposition between left and right, or fore and hind, an average of the two scores is taken (Megyesi et al. 2005). This scoring system allows the anthropologist to score parts of the cadaver individually so that one is

not stuck typologically defining the decomposition stage of the cadaver, which provides more accurate results.

To calculate ADD, we use the formula taken from Gennard (2008):

Days X (Temperature - Base Temperature) = ADD

Because certain species of insect require different base temperatures to develop, as well as a different amount of time to reach certain life cycle stages, entomological samples can be recovered, and time can be counted backwards by examining the temperatures of the area the body was discovered over the past days to accurately determine the PMI.

Weather Data

The aspects of weather that were recorded are, temperature, relative humidity, pressure, and rainfall. All of these data were recorded daily, and could be accessed for any day within the past year from the online weather base for the University of Central Florida (http://www.wunderground.com/personal-weather-station/dashboard?ID=KFLORLAN72#history).

Weather data was especially important for accurately calculation of ADD. When combined with the TBS, an accurate ADD can be determined and then compared to the actual number of days decomposition has occurred. By comparing ADD to actual days of decomposition, we could begin to determine the effects that animal scavenging and tree cover has on the decomposition process.

Duration

The cadavers were laid out for approximately 3 months, primarily because intense scavenging led to early skeletonization of the carcasses. Initially, the cadavers were visited and studied daily, at approximately the same time. During visitation, images were taken as needed, game camera images and video were downloaded, carcasses were remapped if necessary, entomological data was recorded as necessary, weather data was recorded, and decomposition was scored and recorded. All of the data recording took between 1.5 and 8 hours depending on the amount of change that occurred over a 24-hour period. This period of daily visitation occurred for 2 weeks as decomposition occurred rapidly and skeletonization was facilitated by intense scavenging. As the carcasses progressed through the skeletonization stage, visitation was reduced to every two days for 2 weeks and then reduced to once a week as decomposition became negligible and daily recording only involved the staining and bleaching of the skeletal elements.

CHAPTER 4: RESULTS

This chapter includes the research data collected during this study: weather, entomology, gross decomposition, primary scavenging and dispersal, skeletal staining and weathering and additional scavenging events. The weather conditions over the period that data collection took place were consistent across all four sites. The data for gross decomposition, primary scavenging, dispersal, and additional scavenging will be reported by site and organized temporally. Gross decomposition was scored based on methods developed by Megyesi et al. (2005) for soft-tissue decomposition. Methods developed by Behrensmeyer et al. (1979) were used to score advanced skeletal weathering. Dispersal was mapped in situ using an azimuth control method (Dupras et al. 2012) and later electronically mapped with ArcGIS. Using in situ measurements, approximate locations of the carcass were determined in 15 minute intervals over the course of the vulture feeding period and mapped in ArcGIS in order to visualize the progression of dispersal and reduction of the carcass. This included distance traveled, approximate shape or reduction of the carcass and the bearing of the carcass.

Weather Data

Each pig carcass deposition site was placed into two distinct categories: heavily shaded and direct sunlight. Sites S1 and S2 were heavily shaded sites that were shaded

for the majority of the day, while sites O1 and O2 were in direct sunlight and unshaded for the entire day except for a brief period in the early morning.

Weather data was recorded daily for the first two weeks, every other day for the next two weeks, and then weekly until the conclusion of the study. This study spanned the months of March 2016 to June 2016. Daily average temperatures, rainfall, relative humidity, barometric pressure, and current temperature were all recorded using data collected from the WUCF-FM weather station on the University of Central Florida campus (Table 8). During this time period, temperature ranged between 79.7° and 58.9° F. Relative humidity ranged between 92% and 52%. The most precipitation over a 24 hour period occurred on March 26th, when approximately four inches was recorded.

Table 8: Summary of Weather Data

Date	*AVG Temp (°F)*	*Humidity (%)*	*Pressure (in)*	*Precipitation (cm)*	*KADD*
8-Mar	69.3	71	30.26	0	0
9-Mar	70.5	78	30.24	0	294.5389
10-Mar	73	78	30.24	0	590.4669
11-Mar	72.9	79	30.23	0	886.3391
12-Mar	72.9	82	30.15	0	1182.2113
13-Mar	74.9	79	30.03	0	1479.1946
14-Mar	77.6	77	29.99	0	1777.6779
15-Mar	78.2	71	30.01	0	2076.4946
16-Mar	77.2	74	30.03	0	2374.7557
17-Mar	74.5	80	30	0	2671.5168
18-Mar	74.2	75	29.97	0	2968.1112
19-Mar	71.2	87	29.9	0.57	3263.039
20-Mar	72.3	81	29.9	0.33	3558.5779
21-Mar	58.9	52	30.15	0	3846.6723
22-Mar	60.7	70	30.31	0	4135.7667
24-Mar	70	84	30.09	2.06	4722.7888
26-Mar	74.7	88	30.09	4.06	5313.7554

Date	*AVG Temp (°F)*	*Humidity (%)*	*Pressure (in)*	*Precipitation (cm)*	*KADD*
28-Mar	76.7	84	30.03	0	5910.6665
30-Mar	73	79	30.13	0	6502.5778
1-Apr	79.7	76	29.94	0	7100.8222
4-Apr	69.8	66	30.1	0	7985.7166
7-Apr	72.3	72	29.98	0.127	8870.5555
13-Apr	74	80	30.08	0.711	10639.6773
20-Apr	71.5	67	30.12	0	12705.9494
27-Apr	76	72	29.94	0	14784.7212
4-May	72	92	29.77	1.524	16875.2158
11-May	78.7	71	30.16	0	18948.7102
18-May	79.1	79	29.99	0.025	21044.038
25-May	78.5	62	30.24	0	23138.8656
1-June	83.1	79	30.01	0	25235.0826

The weather in Central Florida had an impact on the decompositional changes noted on the carcasses. The high average temperature and relative humidity during the first five days more than likely aided in the acceleration of the early decomposition stage and the progression to the bloat stage in two days (590.745 KADD) for the pig carcasses located in the shade (S1, S2), and in three days (886.673 KADD) for the pig carcasses located in direct sunlight (O1, O2). Additionally, the pervasive relative humidity and temperature resulted in the carcasses and skeletal elements retaining moisture, with the skin bags at sites S2 and O1 remaining moist throughout the process of data collection until their removal by scavengers. However, those remains in direct sunlight (O1, O2) dried at a slightly faster rate than those located in the shaded environments (S1, S2).

Entomology

Throughout the stages of decomposition, different insects were noted interacting with the carcasses (Table 9). Maggot activity was noted in both shaded and unshaded environments; however, the shaded group of sites displayed maggot activity near the surface of openings of the head and anus, while the unshaded group had maggot masses that tended to occur deeper in the openings of the head and anus (Figures 4 & 5). This is due to the preference of darkness exhibited by maggots (Gennard, 2007). Maggots were prevalent throughout the early and active stages of decomposition, but were not present following the mass scavenging of the carcasses by vultures. This is a result of the vultures consuming the maggots themselves as well as the majority of the soft-tissue, which is the food source of the maggots. In addition to maggots, it was noted that fire ants (*Solenopsis invicta*) (Figure 6) were prevalent in the unshaded group, likely as a consequence of the carcasses and skeletal remains with adhered soft-tissue being in direct contact with the ground surface, providing the ants greater access to soft-tissue, and the ability to incorporate the skeletal elements into their nests (Figure 7).

Figure 4: TSD 4 Days, Maggots deeply packed into mouth of pig carcass O1

Figure 5: TSD 4 Days, Maggot mass exposed in mouth of pig carcass S1

Figure 6: Fire ants swarming the remains of a lower forelimb at site O2, Day 7

For example, Figure 7 represents a pig humerus from site O2 being built into a fire ant nest within approximately one week of skeletonization. Additionally, fire ants were noted feeding on fly eggs during the fresh, and early decomposition stages in the unshaded group. No fire ant activity was noted on remains from the shaded group. Flies (*Diptera*) were common throughout the data collection process, being noted at the time of deposition (TSD 0+2h), until the end of the data collection process. The other insect order of note, was the presence of beetles (*Choleoptera*). The range of beetles noted during the data recording process includes the American carrion beetle (*Necrophila americana*) (Figure 8), burying beetle (*Nicrophorus orbicollis*) (Figure 9), hister beetle (*Histeridae*), and hide beetle (*Dermestes*). Hister beetles were documented at all four sites throughout

the active decay stages, however hide beetles were only noted from S2 during the active decay stage. Additionally, the American carrion beetle and the American burying beetle were only documented at site S1 once skeletonization had occurred. Lastly, several yellow jackets (*Vespula squamosal*) were noted on the day of deposition, and were seen consuming blood, as well as fly eggs during the early decomposition stage.

Figure 7: Humerus with fire ant nest built around it at site O2 Day 9

Figure 8: American Carrion beetle feeding on an ankle at site S2 Day 8

Figure 9: Burying beetle on an ankle at site S1 Day 11

Table 9: Entomology summary of identified insect species at sites S1, S2, O1, and O2

Site	*Fresh*	*Early*	*Bloat*	*Active*	*Skeletonization*
S1	Flies (*Diptera*), Yellow Jacket (*Hymenoptera*)	Flies (*Diptera*), maggots	Flies (*Diptera*), Maggots, Hister beetles (*Histeridae*),	Flies (*Diptera*), Maggots, Hister beetles (*Histeridae*),	Flies (*Diptera*), American carrion beetle (*Necrophila americana*), Burying beetle (*Nicrophorus orbicollis*)
S2	Flies (*Diptera*), Yellow Jacket (*Hymenoptera*)	Flies (*Diptera*), maggots	Flies (*Diptera*), Maggots, Hister beetles (*Histeridae*), Hide Beetle (*Dermestes*)	Flies (*Diptera*), Maggots, Hister beetles (*Histeridae*), Hide Beetle (*Dermestes*)	Flies (*Diptera*),
O1	Flies (*Diptera*), Yellow Jacket (*Hymenoptera*)	Flies (*Diptera*), Maggots, Fire ants (*Solenopsis invicta*)	Flies (*Diptera*), Maggots, Hister beetles (*Histeridae*), Fire ants (*Solenopsis invicta*)	Flies (*Diptera*), Maggots, Hister beetles (*Histeridae*), Fire ants (*Solenopsis invicta*)	Flies (*Diptera*),
O2	Flies (*Diptera*), Yellow Jacket (*Hymenoptera*)	Flies (*Diptera*), Maggots, Fire ants (*Solenopsis invicta*)	Flies (*Diptera*), Maggots, Hister beetles (*Histeridae*), Fire ants (*Solenopsis invicta*)	Flies (*Diptera*), Maggots, Hister beetles (*Histeridae*), Fire ants (*Solenopsis invicta*)	Flies (*Diptera*),

Gross Decomposition

All appropriate figures detailing gross decomposition for pig carcass S1 will be included in the section, Pig Carcass SI. Rather than include duplicate figures for pig carcasses S2, O1, and O2, representing the decomposition process, redundant figures will be included in specifically referenced appendices located at the conclusion of Chapter 6.

Pig Carcass S1

The pig carcass was deposited at S1 at the fresh stage of decomposition (Table 10) on March 8th, TSD of 0+2h, at approximately 2:15 PM (Figure 10). Algor mortis occurred naturally and was uninterrupted. At time of deposition, rigor mortis was beginning to occur, as the carcass presented stiff limbs when being handled. Also at the time of deposition, the pig carcass at S1 was scored with a TBS of 3, placing it in the freshest stage possible. The presence of blowflies and yellow jackets was noted at the time of deposition. Blowflies began laying eggs near the cavities of the head, as well as near the bullet hole in the frontal bone and in skin folds near the head. The carcass remained in the fresh stage for one day.

On March 9th, TSD of one day, the carcass at S1 transitioned from the fresh stage to the early decomposition stage (Table 10). This included pink-white appearance of the skin at the head and neck, marbling of the abdomen, and gray-to-green discoloration of the lower abdomen, and a pink-white appearance of the limbs (Figure 11). This period also included the proliferation of blowfly larvae at the nasal and oral cavities, and at

the bullet hole on the frontal bone. This stage lasted for one day until bloat began to occur.

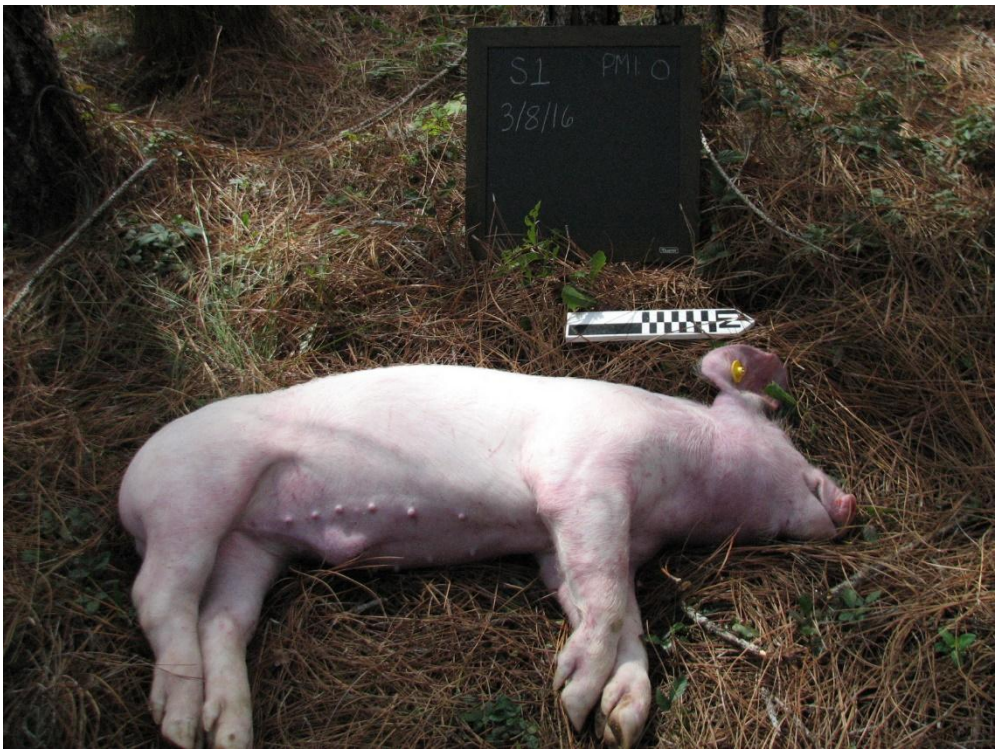


Figure 10: Carcass S1 in fresh stage of decomposition, TSD 0

On March 10th, TSD of two days, the pig carcass transitioned into the bloat stage (Table 10). The carcass remained in the bloat stage for an extended period of time (Figure 11), during which the carcass accumulated VOCs in the abdomen and neck and ballooned in size. This period also saw the green and black discoloration of the lower abdomen, the marbling and black discoloration of the abdomen, the green and black discoloration of the face and neck, and receding of the lips and gingiva. Maggot masses had expanded to pack the oral and nasal cavity as well as the ocular cavities. Maggot mass temperature was

recorded on March 12th, TSD of four days, at 8:59 AM. The current air temperature was 67.8° F and the first instar stage larval mass was 81° F which was 11° F warmer than the interface temperature of 70° F, and 13° F warmer than the ambient temperature. In response to the heavy shade, the maggots did not retract deep into the cavities of the head. In fact, they were frequently seen around the lips and teeth of the carcass and even pooled below the mouth on the ground surface in purged decomposition fluid. This stage lasted for a total of three days until decomposition was accelerated by a mass vulture scavenging event which will be discussed in the following section titled "Carcass Consumption and Scavenging".

Figure 11: Carcass S1 Bloat Stage Day 4; note the intestines rupturing the lower abdominal wall

On March 13th, TSD of five days, the carcass was drastically reduced in soft-tissue mass (Table 10), and advanced well passed the advanced decomposition stage described as moist decomposition with limited bone exposure, a TBS of 19-24, to full skeletonization, a TBS of 27-35. The carcass was reduced to skeletal elements, some with adhered soft tissue, by intensive vulture scavenging over the course of 9 h 5 m. At this point, the carcass was characterized by scattered, greasy skeletal elements with some skeletal elements retaining soft tissue. Scattering of the elements will be discussed in the following section titled "Avian Dispersal". The carcass was scored with a TBS of 29. From March 14th, TSD of six days, until June 1st the carcass progressed through the stage of skeletonization. This included the gradual desiccation of remaining soft-tissue, and the drying of skeletal elements. The carcass was scored as TBS 35, the maximum TBS score representing complete skeletonization with dry bone, on April 27th, TSD of 50, after the remaining soft-tissue was completely desiccated, and the remaining bones of the head, trunk, and limbs were completely dry.

Table 10: Pig S1 Decomposition Summary

Day	*Decomposition*	*TBS*	*Observations*	*KADD*
Day 0+2h	Fresh	3	Fly activity	0
Day 1	Early decomposition	5	Slight color change, no odor	294.5389
Day 2	Early decomposition	7	Slight bloat, color change, slight odor, slight maggot activity	590.4669

Day	*Decomposition*	*TBS*	*Observations*	*KADD*
Day 3	Active decay	12	Moderate bloat, active decay, color change, strong odor, advanced maggot activity, purging	886.3391
Day 4	Active decay	12	Significant bloat, active decay, color change, strong odor, advanced maggot activity, purging	1182.2113
Day 5	Active decay	13	Full bloat, active decay, skin slippage, purging, strong odor, advanced maggot activity, intestines burst through lower abdomen	1479.1946
Day 6	Skeletonization w/ some soft tissue	29	Slight odor, fly activity, greasy, wet remains	1777.6779
Day 7	Skeletonization w/ some soft tissue	29	Slight odor, fly activity, greasy, wet remains	2076.4946
Day 8	Skeletonization w/ some soft tissue	30	No odor, no fly activity, greasy remains	2374.7557
Day 9	Skeletonization w/ some soft tissue	30	Greasy remains, fungus and mold growth	2671.5168
Day 10	Skeletonization w/ some soft tissue	30	Greasy remains, fungus and mold growth	2968.1112
Day 11	Skeletonization w/ some soft tissue	31	Greasy remains, fungus and mold growth	3263.039
Day 12	Skeletonization w/ some soft tissue	31	Greasy remains, some dried soft tissue	3558.5779
Day 13	Skeletonization w/ some soft tissue	31	Greasy remains, some dried soft tissue	3846.6723
Day 14	Skeletonization w/ some soft tissue	31	Greasy remains, some dried soft tissue	4135.7667
Day 16	Skeletonization w/ some soft tissue	32	Greasy remains, some dried soft tissue	4722.7888
Day 18	Skeletonization w/ some soft tissue	32	Greasy remains, some dried soft tissue	5313.7554
Day 20	Skeletonization mostly dry bone	33	Bones beginning to dry	5910.6665
Day 22	Skeletonization mostly dry bone	33	Bones beginning to dry	6502.5778

Day	*Decomposition*	*TBS*	*Observations*	*KADD*
Day 24	Skeletonization mostly dry bone	34	Bones drying	7100.8222
Day 27	Skeletonization mostly dry bone	34	Bones drying	7985.7166
Day 30	Skeletonization mostly dry bone	34	Bones drying	8870.5555
Day 36	Skeletonization mostly dry bone	34	Bones drying	10639.6773
Day 43	Skeletonization mostly dry bone	34	Bones drying	12705.9494
Day 50	Skeletonization dry bone	35	Dry bone	14784.7212
Day 57	Skeletonization dry bone	35	Dry bone	16875.2158
Day 64	Skeletonization dry bone	35	Dry bone	18948.7102
Day 71	Skeletonization dry bone	35	Dry bone	21044.038
Day 78	Skeletonization dry bone	35	Dry bone	23138.8656
Day 85	Skeletonization dry bone	35	Dry bone	25235.0826

Pig Carcass S2

The pig carcass was deposited at S2 at the fresh stage of decomposition (Table 11) on March 8th, TSD of 0+2h, at approximately 2:15 PM (APPENDIX A, Figure 41). Algor mortis occurred naturally and was uninterrupted. At time of deposition, rigor mortis was beginning to occur, as the carcass presented stiff limbs when being handled. Also at the time of deposition, the pig carcass at S2 was scored with a TBS of 3, placing it in the freshest stage possible. The presence of blowflies and yellow jackets was noted

at the time of deposition. Blowflies began laying eggs near the cavities of the head, as well as near the bullet hole in the frontal bone. The carcass was scored in the fresh stage for one day.

On March 9th, TSD of one day, the carcass at S2 transitioned from the fresh stage to the early decomposition stage (Table 11). This included pink-white appearance of the skin at the head and neck, marbling of the abdomen, and gray to green discoloration of the lower abdomen, and a pink-white appearance of the limbs (APPENDIX A, Figure 43). This period also contained the proliferation of blowfly larvae at the nasal and oral cavities, as well as the bullet hole on the frontal bone. This stage lasted for one day until bloat began to occur.

On March 10th, TSD of two days, the pig carcass began to transition into the bloat stage (Table 11). The carcass remained in the bloat stage for an extended period of time (APPENDIX A, Figures 45, 46), during which the carcass accumulated VOCs and ballooned in size. This period also saw the green and black discoloration of the lower abdomen, the marbling and black discoloration of the abdomen, the green and black discoloration of the face and neck as well as the slippage of skin at the chin, and receding of the gums. Maggot masses had expanded to pack the oral and nasal cavity as well as the ocular cavities. Maggot mass temperature was recorded on March 12th, TSD of four days, at 8:36 AM. The current air temperature was 66.9° F and the first instar stage larval mass was 79° F which was 9° F warmer than the interface temperature of 70° F, and 12° F warmer than the ambient temperature. In response to the heavy shade, the maggots did

not retract deep into the cavities of the head, in fact, they were frequently seen around the lips and teeth of the carcass. This stage lasted for a total of three days until decomposition was accelerated by a mass vulture scavenging event which will be discussed in the section titled “Scavenging”.

On March 13th, TSD of five days, the carcass was drastically reduced in soft-tissue mass (Table 11), and advanced well passed the advanced decomposition stage described as moist decomposition with limited bone exposure (APPENDIX A, Figures 47, 48), a TBS of 19-24, to full skeletonization, a TBS of 27-35. The carcass was reduced to skin and bones by intensive vulture scavenging over the course of 8 h 45 m. Vulture scavenging will be discussed in the section titled “Primary Scavenging”. At this point, the carcass was characterized by scattered, greasy skeletal elements, and a large sack-like heap of skin with some adhered skeletal elements. Scattering of the elements will be discussed in the section titled “Dispersal”. The carcass was scored with a TBS of 29. From March 14th, TSD of 8 days, until June 1st the carcass progressed through the stage of skeletonization. This included the gradual desiccation of remaining soft-tissue, and the drying of skeletal elements. The carcass was scored as TBS 35, the maximum TBS score representing complete skeletonization with dry bone, on April 27th, TSD of 50, after the remaining soft-tissue was completely scavenged, and the remaining bones of the head, trunk, and limbs were completely dry.

Table 11: Pig S2 Decomposition Summary

Day	*Decomposition*	*TBS*	*Observations*	*KADD*
Day 0+2h	Fresh	3	Fly activity	0
Day 1	Early decomposition	5	Slight color change, no odor	294.5389
Day 2	Early decomposition	7	Slight bloat, color change, slight odor, slight maggot activity	590.4669
Day 3	Active decay	10	Moderate bloat, active decay, color change, strong odor, advanced maggot activity	886.3391
Day 4	Active decay	13	Significant bloat, active decay, color change, strong odor, advanced maggot activity	1182.2113
Day 5	Active decay	13	Full bloat, active decay, skin slippage, purging, strong odor, advanced maggot activity	1479.1946
Day 6	Skeletonization w/ some soft tissue	29	Slight odor, fly activity, greasy, wet remains	1777.6779
Day 7	Skeletonization w/ some soft tissue	29	Slight odor, fly activity, greasy, wet remains	2076.4946
Day 8	Skeletonization w/ some soft tissue	30	No odor, no fly activity, greasy remains	2374.7557
Day 9	Skeletonization w/ some soft tissue	30	Greasy remains, fungus and mold growth	2671.5168
Day 10	Skeletonization w/ some soft tissue	30	Greasy remains, fungus and mold growth	2968.1112
Day 11	Skeletonization w/ some soft tissue	30	Greasy remains, fungus and mold growth	3263.039
Day 12	Skeletonization w/ some soft tissue	31	Greasy remains, some dried soft tissue	3558.5779
Day 13	Skeletonization w/ some soft tissue	31	Greasy remains, some dried soft tissue	3846.6723
Day 14	Skeletonization w/ some soft tissue	31	Greasy remains, some dried soft tissue	4135.7667
Day 16	Skeletonization w/ some soft tissue	31	Greasy remains, some dried soft tissue	4722.7888

Day	*Decomposition*	*TBS*	*Observations*	*KADD*
Day 18	Skeletonization w/ some soft tissue	31	Greasy remains, some dried soft tissue	5313.7554
Day 20	Skeletonization w/ some soft tissue	32	Bones beginning to dry	5910.6665
Day 22	Skeletonization mostly dry bone	34	Bones beginning to dry, soft tissue scavenged	6502.5778
Day 24	Skeletonization mostly dry bone	34	Bones drying	7100.8222
Day 27	Skeletonization mostly dry bone	34	Bones drying	7985.7166
Day 30	Skeletonization mostly dry bone	34	Bones drying	8870.5555
Day 36	Skeletonization mostly dry bone	34	Bones drying	10639.6773
Day 43	Skeletonization mostly dry bone	34	Bones drying	12705.9494
Day 50	Skeletonization dry bone	35	Dry bone	14784.7212
Day 57	Skeletonization dry bone	35	Dry bone	16875.2158
Day 64	Skeletonization dry bone	35	Dry bone	18948.7102
Day 71	Skeletonization dry bone	35	Dry bone	21044.038
Day 78	Skeletonization dry bone	35	Dry bone	23138.8656
Day 85	Skeletonization dry bone	35	Dry bone	25235.0826

Pig Carcass O1

The pig carcass was deposited at O1 at the fresh stage of decomposition (Table 12) on March 8th, TSD of 0+2h, at approximately 2:15 PM (APPENDIX B, Figure 56).

Algor mortis occurred naturally and was uninterrupted. At time of deposition, rigor mortis was beginning to occur, as the carcass presented stiff limbs when being handled. Also at the time of deposition, the pig carcass at O1 was scored with a TBS of 3, placing it in the freshest stage possible. The presence of blowflies and yellow jackets was noted at the time of deposition. Blowflies began laying eggs near the cavities of the head, as well as near the bullet hole in the frontal bone, and folds in the skin near the head. The carcass remained in the fresh stage for one day.

On March 9th, TSD of one day, the carcass at O1 (APPENDIX B, Figure 57) transitioned from the fresh stage to the early decomposition stage (Table 12). This included pink-white appearance of the skin at the head and neck, marbling of the abdomen, and gray to green discoloration of the lower abdomen, and a pink-white appearance of the limbs. This period also contained the proliferation of blowfly larvae at the nasal and oral cavities, as well as the bullet hole on the frontal bone. This stage lasted for one day until bloat began to occur.

On March 10th, TSD of two days, the pig carcass transitioned into the early bloat stage (Table 12). The carcass remained in the bloat stage for an extended period of time (APPENDIX B, Figures 59, 60), during which the carcass accumulated VOCs in the abdomen and neck and ballooned in size. This period also saw the green and black discoloration of the lower abdomen, the marbling and black discoloration of the abdomen, the green and black discoloration of the face and neck, and receding of the lips and gingiva. Maggot masses had expanded to pack the oral and nasal cavity as well as the

ocular cavities, and were in high enough numbers to move the tongue around as they fed. Maggot mass temperature was recorded on March 12th, TSD of four days, at 9:20 AM. The current air temperature was 68.6° F and the first instar stage larval mass was 76° F which was 5° F warmer than the interface temperature of 71° F, and 7° F warmer than the ambient temperature. In response to the direct sunlight, the maggots were located deep within the orifices of the face, and were packed tightly in the through and under the lips to find shade. This stage lasted for a total of three days until decomposition was accelerated by a mass vulture scavenging event which will be discussed in the section titled "Carcass Consumption and Scavenging".

On March 13th, TSD of five days, the carcass was drastically reduced in soft-tissue mass (Table 12), and advanced well passed the advanced decomposition stage described as moist decomposition with limited bone exposure (APPENDIX B, Figure 62), a TBS of 19-24, to full skeletonization, a TBS of 27-35. The carcass was reduced to a pile of skin and skeletal elements, some with adhered soft tissue, by intensive vulture scavenging over the course of 8 h 28 m. Vulture scavenging will be discussed in the section titled "Carcass Consumption and Scavenging". At this point, the carcass was characterized by scattered, greasy skeletal elements with some skeletal elements with adhered soft tissue, and a pile of skin that was rather intact and turned inside out. Scattering of the elements will be discussed in the section titled "Avian Dispersal". The carcass was scored with a TBS of 29. From March 14th, TSD of six days, until June 1st the carcass progressed through the skeletonization stage. This included the gradual desiccation of the skin bag and the remaining soft-tissue, and the drying of skeletal

elements. The carcass was scored as TBS 35, the maximum TBS score representing complete skeletonization with dry bone, on April 27th, TSD of 50, after the remaining soft-tissue was completely desiccated, the skin bag was scavenged, and the remaining bones of the head, trunk, and limbs were completely dry.

Table 12: Pig O1 Decomposition Summary

Day	*Decomposition*	*TBS*	*Observations*	*KADD*
Day 0+2h	Fresh	3	Fly activity	0
Day 1	Early decomposition	5	Slight color change, no odor	294.5389
Day 2	Early decomposition	7	Slight bloat, color change, slight odor, slight maggot activity	590.4669
Day 3	Active decay	12	Moderate bloat, active decay, color change, strong odor, advanced maggot activity, purging	886.3391
Day 4	Active decay	12	Moderate bloat, active decay, color change, strong odor, advanced maggot activity, purging	1182.2113
Day 5	Active decay	12	Full bloat, active decay, purging, strong odor, advanced maggot activity,	1479.1946
Day 6	Skeletonization w/ some soft tissue	29	Slight odor, fly activity, greasy, wet remains	1777.6779
Day 7	Skeletonization w/ some soft tissue	29	Slight odor, fly activity, greasy, wet remains	2076.4946
Day 8	Skeletonization w/ some soft tissue	30	No odor, no fly activity, greasy remains	2374.7557
Day 9	Skeletonization w/ some soft tissue	30	Greasy remains, soft-tissue drying	2671.5168
Day 10	Skeletonization w/ some soft tissue	30	Greasy remains, soft-tissue drying	2968.1112

Day	*Decomposition*	*TBS*	*Observations*	*KADD*
Day 11	Skeletonization w/ some soft tissue	30	Greasy remains, fungus and mold growth	3263.039
Day 12	Skeletonization w/ some soft tissue	31	Greasy remains, some dried soft tissue fungus and mold growth	3558.5779
Day 13	Skeletonization w/ some soft tissue	31	Greasy remains, some dried soft tissue fungus and mold growth	3846.6723
Day 14	Skeletonization w/ some soft tissue	32	Greasy remains, some dried soft tissue fungus and mold growth	4135.7667
Day 16	Skeletonization w/ some soft tissue	32	Greasy remains, some dried soft tissue	4722.7888
Day 18	Skeletonization w/ some soft tissue	32	Greasy remains, some dried soft tissue	5313.7554
Day 20	Skeletonization w/ some soft tissue	32	Bones beginning to dry	5910.6665
Day 22	Skeletonization mostly dry bone	34	Bones beginning to dry, skin bag scavenged	6502.5778
Day 24	Skeletonization mostly dry bone	34	Bones drying	7100.8222
Day 27	Skeletonization mostly dry bone	34	Bones drying	7985.7166
Day 30	Skeletonization mostly dry bone	34	Bones drying	8870.5555
Day 36	Skeletonization mostly dry bone	34	Bones drying	10639.6773
Day 43	Skeletonization mostly dry bone	34	Bones drying	12705.9494
Day 50	Skeletonization dry bone	35	Dry bone	14784.7212
Day 57	Skeletonization dry bone	35	Dry bone	16875.2158
Day 64	Skeletonization dry bone	35	Dry bone	18948.7102
Day 71	Skeletonization dry bone	35	Dry bone	21044.038

Day	*Decomposition*	*TBS*	*Observations*	*KADD*
Day 78	Skeletonization dry bone	35	Dry bone	23138.8656
Day 85	Skeletonization dry bone	35	Dry bone	25235.0826

Pig Carcass O2

The pig carcass was deposited at O2 at the fresh stage of decomposition (Table 13) on March 8th, TSD of 0+2h, at approximately 2:15 PM (APPENDIX C, Figure 73). Algor mortis occurred naturally and was uninterrupted. At time of deposition, rigor mortis was beginning to occur, as the carcass presented stiff limbs when being handled. Also at the time of deposition, the pig carcass at O2 was scored with a TBS of 3, placing it in the freshest stage possible. The presence of blowflies and yellow jackets was noted at the time of deposition. Blowflies began laying eggs near the cavities of the head, as well as near the bullet hole in the frontal bone, and folds in the skin near the head. The carcass remained in the fresh stage for one day.

On March 9th, TSD of one day, the carcass at O2 transitioned from the fresh stage to the early decomposition stage (Table 13). This included pink-white appearance of the skin at the head and neck, marbling of the abdomen, and gray to green discoloration of the lower abdomen, and a pink-white appearance of the limbs (APPENDIX C, Figure 74). This period also contained the proliferation of blowfly larvae at the nasal and oral

cavities, as well as the bullet hole on the frontal bone. This stage lasted for one day until bloat began to occur.

On March 10th, TSD of two days, the pig carcass transitioned into the early bloat stage (Table 13). The carcass remained in the bloat stage for an extended period of time (APPENDIX C, Figures 76, 77), during which the carcass accumulated VOCs in the abdomen and neck and ballooned in size. This period also saw the green and black discoloration of the lower abdomen, the marbling and black discoloration of the abdomen, the green and black discoloration of the face and neck, and receding of the lips and gingiva. Maggot masses had expanded to pack the oral and nasal cavity as well as the ocular cavities. Maggots also spilled out of the mouth and accumulated in the shade beneath the head in a pool of decomposition fluid. Additionally, the upper chest and lower neck at the ground interface was red and raw-looking, possibly from ant activity. Maggot mass temperature was recorded on March 12th, TSD of four days, at 9:41 AM. The current air temperature was 69.7° F and the first instar stage larval mass was 82° F which was 12° F warmer than the interface temperature of 70° F, and 12° F warmer than the ambient temperature. In response to the direct sunlight, the maggots were located deep within the orifices of the face, and any other place where they could remain in shade. As mentioned previously, this included pooling beneath the head. This stage lasted for a total of three days until decomposition was accelerated by a mass vulture scavenging event which will be discussed in the section titled “Carcass Consumption and Scavenging”.

On March 13th, TSD of five days, the carcass was drastically reduced in soft-tissue mass (Table 13), and advanced well passed the advanced decomposition stage described as moist decomposition with limited bone exposure (APPENDIX C, Figure 79), a TBS of 19-24, to full skeletonization, a TBS of 27-35. The carcass was reduced to skeletal elements, some with adhered soft tissue, by intensive vulture scavenging over the course of 7 h 25 m. Vulture scavenging will be discussed in the section titled "Carcass Consumption and Scavenging". At this point, the carcass was characterized by scattered, greasy skeletal elements with some skeletal elements with adhered soft tissue. Scattering of the elements will be discussed in the section titled "Avian Dispersal". The carcass was scored with a TBS of 29. From March 14th, TSD of six days, until June 1st the carcass progressed through the skeletonization stage. This included the gradual desiccation of remaining soft-tissue, and the drying of skeletal elements. The carcass was scored as TBS 35, the maximum TBS score representing complete skeletonization with dry bone, on April 27th, TSD of 50, after the remaining soft-tissue was completely desiccated, and the remaining bones of the head, trunk, and limbs were completely dry

Table 13: Pig O2 Decomposition Summary

Day	*Decomposition*	*TBS*	*Observations*	*KADD*
Day 0+2h	Fresh	3	Fly activity	0
Day 1	Early decomposition	5	Slight color change, no odor	294.5389
Day 2	Early decomposition	7	Slight bloat, color change, slight odor, slight maggot activity	590.4669

Day	*Decomposition*	*TBS*	*Observations*	*KADD*
Day 3	Active decay	11	Moderate bloat, active decay, color change, strong odor, advanced maggot activity, purging	886.3391
Day 4	Active decay	12	Significant bloat, active decay, color change, strong odor, advanced maggot activity, purging	1182.2113
Day 5	Active decay	12	Full bloat, active decay, skin slippage, purging, strong odor, advanced maggot activity	1479.1946
Day 6	Skeletonization w/ some soft tissue	29	Slight odor, fly activity, greasy, wet remains	1777.6779
Day 7	Skeletonization w/ some soft tissue	29	Slight odor, fly activity, greasy, wet remains	2076.4946
Day 8	Skeletonization w/ some soft tissue	30	No odor, no fly activity, greasy remains	2374.7557
Day 9	Skeletonization w/ some soft tissue	30	Greasy remains, fungus and mold growth	2671.5168
Day 10	Skeletonization w/ some soft tissue	30	Greasy remains, fungus and mold growth	2968.1112
Day 11	Skeletonization w/ some soft tissue	31	Greasy remains, fungus and mold growth	3263.039
Day 12	Skeletonization w/ some soft tissue	31	Greasy remains, some dried soft tissue fungus and mold growth	3558.5779
Day 13	Skeletonization w/ some soft tissue	31	Greasy remains, some dried soft tissue fungus and mold growth	3846.6723
Day 14	Skeletonization w/ some soft tissue	32	Greasy remains, some dried soft tissue fungus and mold growth	4135.7667
Day 16	Skeletonization w/ some soft tissue	32	Greasy remains, some dried soft tissue fungus and mold growth	4722.7888
Day 18	Skeletonization w/ some soft tissue	33	Greasy remains, some dried soft tissue fungus and mold growth	5313.7554
Day 20	Skeletonization mostly dry bone	33	Bones beginning to dry fungus and mold growth	5910.6665
Day 22	Skeletonization mostly dry bone	34	Bones beginning to dry fungus and mold growth	6502.5778

Day	*Decomposition*	*TBS*	*Observations*	*KADD*
Day 24	Skeletonization mostly dry bone	34	Bones drying	7100.8222
Day 27	Skeletonization mostly dry bone	34	Bones drying	7985.7166
Day 30	Skeletonization mostly dry bone	34	Bones drying	8870.5555
Day 36	Skeletonization mostly dry bone	34	Bones drying	10639.6773
Day 43	Skeletonization mostly dry bone	34	Bones drying	12705.9494
Day 50	Skeletonization dry bone	35	Dry bone	14784.7212
Day 57	Skeletonization dry bone	35	Dry bone	16875.2158
Day 64	Skeletonization dry bone	35	Dry bone	18948.7102
Day 71	Skeletonization dry bone	35	Dry bone	21044.038
Day 78	Skeletonization dry bone	35	Dry bone	23138.8656
Day 85	Skeletonization dry bone	35	Dry bone	25235.0826

Carcass Consumption and Scavenging

All appropriate figures detailing carcass consumption and scavenging for pig carcass S1 will be included in the following chapter. Rather than include duplicate figures for pig carcasses S2, O1, and O2, representing the process of scavenging, redundant

figures will be included in specifically referenced appendices located at the conclusion of chapter 6.

Pig Carcass S1

The first and most intense scavenging event began on March, 13th, TSD of 5, and continued until the early morning of March 14th, TSD of 6. At approximately 10:50 AM at site S1 19 black vultures were recorded on camera approaching the carcass from all sides, some already beginning to feed at the site of the lower abdomen where the intestines breached the abdominal wall (Figure 12). The time lapse between deposition of the carcass and arrival of vultures to the carcass was approximately 116 hours and 25 minutes. Vultures were engaged in feeding on the carcass at 10:50 AM, and fed on the carcass starting with the lower abdomen, and the oral, rectal, and nasal cavities. These vultures at the cranial end of the carcass were feeding on the maggot masses that had accumulated in the eyes, nose, and mouth. This feeding interval occurred until approximately 6:55 PM that evening when the vultures, which are diurnal animals, roosted for the night. At this point in time, the carcass was out of camera view, but had appeared to have been reduced to bones, with some soft-tissue or musculature remaining in the limbs. The feeding resumed at approximately 7:28 AM when approximately 2 black vultures were recorded in frame scratching at the initial deposition site. This second feeding interval was much shorter, lasting until 8:32 AM when my advisor and I arrived at the Deep Foundations Geotechnical Research Area to record decomposition data. This

intense period of vulture scavenging occurred for 9 h 5 m, during which the 60lb (27kg) pig carcass deposited at site S1 was reduced to bones and skeletal elements with some soft-tissue still adhered.

Figure 12: Carcass S1 Day 5 - black vulture feeding on intestines that ruptured through lower abdominal wall due to extreme bloat.

An estimated maximum number of vultures at the site at one time based on what was recorded on camera was 42, and the required ADD in Kelvins (KADD) to achieve skeletonization was recorded as 1479.64. Pig deposition site S1 featured the removal and dispersal of boney elements, some with adhered soft-tissue and grease. Therefore, after the initial scavenging event, the TBS scoring criteria resulted in a TBS of 29 out of a maximum of 35, falling comfortably in the middle of the skeletonization category. The skeletal elements were dispersed throughout the site based on the foliage of the initial

deposition location. The dispersal information will be discussed in full in section “Avian Dispersal”.

During this mass feeding event, the carcass was reduced in a unique order (Figure 16). As mentioned previously, the vultures fed on the maggots at the cranial end and fed at the anus and lower abdomen of the caudal end where access to the viscera was easiest. Consequential to the maggot activity of the skull, the cranium and mandible were cleaned of most of the soft tissue and what remained was held to the bone by only skin. As a result, the cranium and mandible were the first elements to be disarticulated during feeding and came loose from the carcass at approximately 11:22 AM. Consumption of the viscera continued from the lower abdomen, and the opening in the neck created by the removal of the skull. After approximately two hours of feeding, the majority of the viscera and muscle tissue appeared to have been consumed, and feeding was largely focused on the remaining musculature at the base of the limbs through the original cranial and abdominal openings that had enlarged over the course of feeding. The skeletal elements of the ribcage were expelled as the carcass was consumed and dragged southward. The carcass was flattened as it was dragged and consumed, expelling the ribs, verts, scapulae, and os coxae. By approximately 1:17 PM, the carcass had been considerably reduced in size and deformed by feeding. It was then dragged out of view of the camera. The remaining duration of the feeding period exhibited vultures feeding on disarticulated elements that appeared to have been removed from the main carcass. These limbs were dragged, and dispersed around the site, and would occasionally be in view of the cameras. By nightfall no elements were visible on film. Feeding resumed in the

morning but was much less intense than the previous night. Vulture quantity was much less and equally distributed as the vultures appeared to be feeding on soft-tissue available and scattered throughout the site.

Unlike site S2, pig carcass S1 was also scavenged by bald eagles during the primary scavenging event. An adult bald eagle first appeared on camera at 12:36 PM (Figure 13), when the carcass had begun to be reduced in mass and was dragged southward. The bald eagle fed alongside both black and turkey vultures. The eagle was noted on camera at multiple times during the feeding period, and seemed to have taken part in dispersal of the remains as well (Figure 14). The eagle fed intermittently over the course of approximately four house. Additionally, a juvenile bald eagle was also recorded feeding on the carcass (Figure 15). This is significant because it means multiple eagles were feeding on the carcass at the same time, and they were willing to feed in conjunction and close proximity to vultures. In addition, the vultures did not appear to be cautious of the raptors' presence, possibly indicating this type of feeding arrangement occurs often, and vultures don't feel threatened by the large birds of prey.

Figure 13: Site S1 - bald eagle (red arrow) entering frame

Figure 14: Site S1 - adult bald eagle (red arrow) seen feeding and dispersing elements from initial deposition.

Figure 15: Site S1 - juvenile bald eagle (red arrow) scavenging dispersed remains

Figure 16: S1 Scavenging and Consumption Flowchart

The vultures directly altered the environment of pig deposition site S1 as a result of their feeding behavior. With so many vultures crowded around the carcass, competing to get access to feed (Figure 17), the repeated shuffling of their feet in addition to the movement of the carcass as it was manipulated resulted in a disturbed area at the initial

pig deposition site where the pine needles had been brushed away and the bare earth was exposed. This was further exacerbated by the scratching behavior administered after the carcass had been greatly reduced and vultures searched for leftover pieces of soft-tissue at the initial pig deposition site. Much like chickens scratch the ground with their beaks and feet to search for food, the vultures observed in this study did the same to glean any remaining pieces of food. This agitated the exposed ground surface and assisted in clearing the area of pine needles. Beak digging was also assumed to have occurred at the site since it was an observed behavior at site S2. It should be noted that the areas corresponding to the placement of the anal and oral cavities exhibited modifications of the soil as a result of digging activity, most-likely in response to the presence of decomposition fluid that purged from the cavities and accumulated near the openings. The foliage of the site was also greatly affected by the feeding period, as the brush and stems of nearby trees were broken and cleared as a result of crowded movement throughout the area (Figure 18). Lastly, the vultures also affected the site by scavenging the pitfall trap installed for collection of entomological data. The vultures removed the covering of the pitfall trap and fed on the collected insects within the plastic cup, preventing us from collected these data.

Figure 17: Vultures crowding around carcass from all sides

Figure 18: Site S1 immediately following departure of vultures, site is greatly disturbed

The vultures were not only destructive of the environment, but they also left traces of their presence at the site. This included feathers as well as fecal matter. Feathers were noted throughout the site, but were not accumulated in any recognizable distribution. Feathers were likely shed naturally, however, recorded images of intraspecies competition observed at other sites revealed that feathers were sometimes lost as a result of two vultures fighting and biting each other. Vulture feces was noted at the site, however it was not located easily due to the pine needle substrate making it difficult to detect.

Pig Carcass S2

The first and most intense scavenging event began on March, 13th, TSD of 5, and continued until the early morning of March 14th, TSD of 6. At approximately 11:15 AM at site S2 five black vultures were recorded on camera approaching the carcass from the direction of the caudal end (South of the carcass). The time lapse between deposition of the carcass and arrival of vultures to the carcass was approximately 117 hours. By 11:20 AM 12 black vultures and four turkey vultures were in frame with the carcass. Approximately seven black vultures were engaged in feeding on the carcass, specifically, one feeding at the anus and three feeding at the oral, nasal and ocular cavities. These three black vultures at the cranial end of the carcass were feeding on the maggot masses that had accumulated in the eyes, nose, mouth and beneath the skin of the face and chin. A solitary turkey vulture was standing to the southwest of the carcass in a small clearing

most likely waiting for an opportunity to feed. This feeding interval occurred until approximately 6:55 PM that evening when the vultures, which are diurnal animals, roosted for the night. At this point in time, the carcass had been reduced to skin and bones, with some soft-tissue or musculature remaining in the limbs. The feeding resumed at approximately 7:23 AM when approximately 31 black vultures were recorded in frame engaging in what is most accurately described as a feeding frenzy at the location of the initial deposition site in which the carcass was completely obscured from view by feeding vultures. This second feeding interval was much shorter, lasting until 8:32 AM when my advisor and I arrived at the Deep Foundations Geotechnical Research Area to record decomposition data. This intense period of vulture scavenging occurred for 8 h 45 m, during which the 65lb (29.5kg) pig carcass deposited at site S2 was reduced to skin and bones (APPENDIX A, Figures 47, 48).

An estimated maximum number of vultures at the site at one time based on what was recorded on camera was 43, and the required accumulated degree days in Kelvins (KADD) to achieve skeletonization was recorded as 1479.64. Pig deposition site S2 featured the removal and dispersal of boney elements, some with adhered soft-tissue and grease as well as a mound of skin representing the dermis of the posterior surface of the pig carcass (APPENDIX A, Figures 47, 48). Therefore, while soft-tissue from the pig carcass was still present, albeit just the skin of the carcass, after the initial scavenging event, the TBS scoring criteria resulted in a TBS of 29 out of a maximum of 35, falling comfortably in the middle of the skeletonization category. The skeletal elements and remaining skin was dispersed throughout the site based on the foliage at the initial

deposition location. The dispersal information will be discussed in full in section “Avian Dispersal”.

During this mass feeding event, the carcass was reduced in a unique disarticulation order (Figure 19). As mentioned previously, the vultures fed on the maggots at the cranial end and fed at the anus of the caudal end where access to the viscera was easiest. Consequential to the maggot activity of the skull, the cranium and mandible were cleaned of most of the soft tissue and what remained was held to the bone by only skin. As a result, the cranium and mandible were the first elements to be disarticulated during feeding and came loose from the carcass at approximately 11:35 AM. Consumption of the viscera continued from the anus, the opening in the neck created by the removal of the skull, and a new opening in the lower abdomen created by vulture activity. After approximately three hours of feeding, the majority of the viscera appeared to have been consumed, and feeding was largely focused on the musculature at the base of the limbs through the original cranial and caudal openings that had enlarged over the course of feeding. The skeletal elements of the upper torso were next to be removed. The cervical vertebrae, upper ribs, and scapulae were disarticulated from the cranial hole. As the scapulae were removed, the bones of the front limbs, still attached by ligaments, were pulled out of the cranial opening as well, resulting in the skin of the front limbs to be turned inside out. By approximately 5:23 PM, the carcass has been considerably reduced and is flattened by the removal of the bones of the abdomen. The front limbs have been disarticulated from the carcass and turned inside-out but are still adhered by skin. Ribs and verts expelled through the opening of the lower abdomen. At

approximately 6:30 PM, the carcass is pulled inside-out through the cranial hole. Throughout the course of feeding, the cranial hole becomes larger and becomes the primary feeding site. Once the opening is large enough, the carcass is turned inside-out. This appears to expel the majority of the ribs and verts not adhered to the skin. The carcass is greatly reduced and turned inside-out by the time the vultures depart the site for the evening. Feeding resumes in the morning but does not alter the appearance of the carcass further, nor does it reduce the carcass of mass.

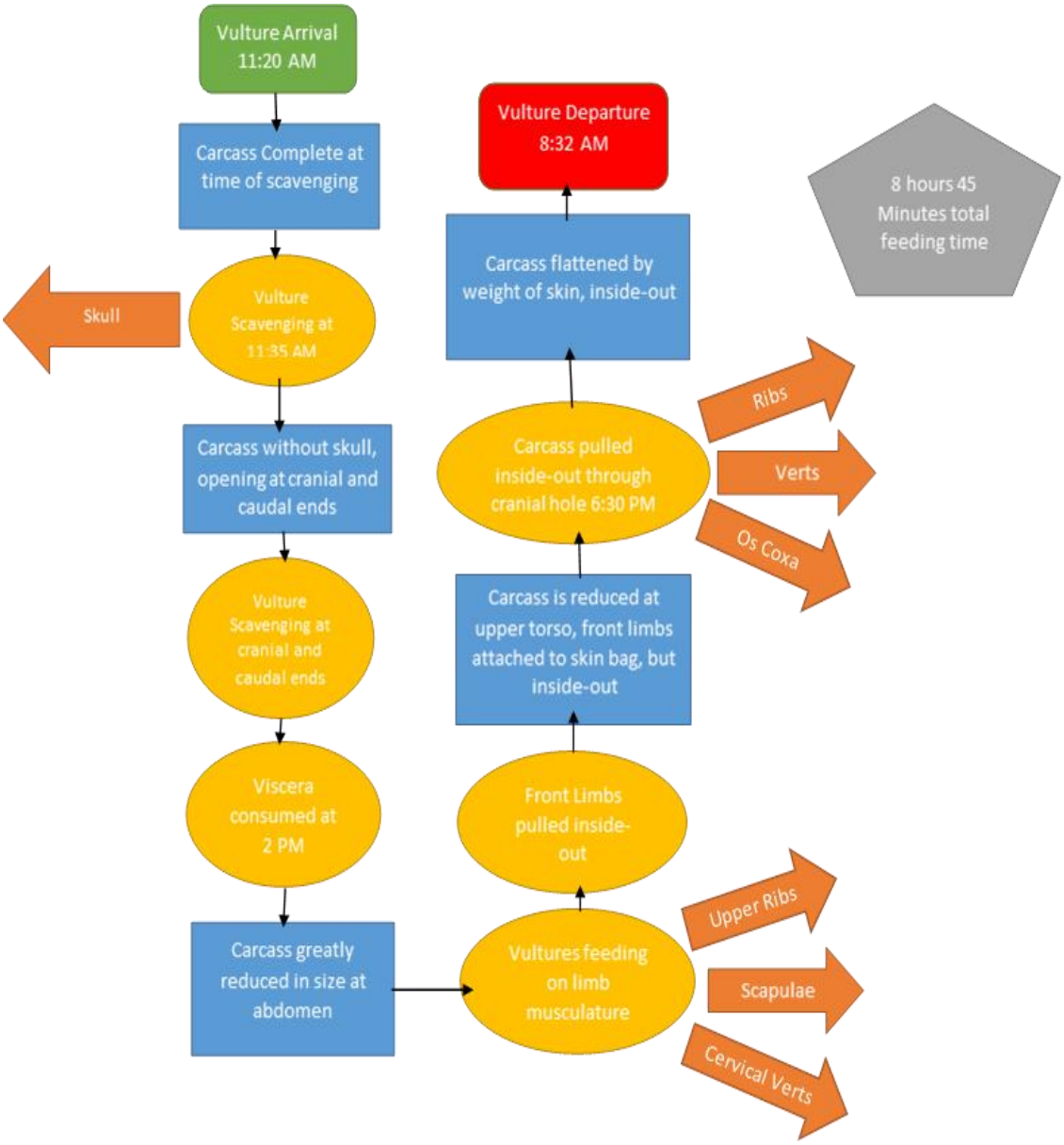


Figure 19: Day 5 S2 Scavenging and Consumption Flowchart

The vultures directly altered the environment of pig deposition site S2 as a result of their feeding behavior. With so many vultures crowded around the carcass, competing for access to feed (APPENDIX A, Figure 50), the repeated shuffling of their feet in

addition to the movement of the carcass as it is manipulated resulted in a disturbed area at the initial pig deposition site where the pine needles had been brushed away and the bare earth was exposed (APPENDIX A, Figure 47). This was further exacerbated by the scratching behavior administered after the carcass had been greatly reduced and vultures searched for leftover pieces of soft-tissue at the initial pig deposition site. Much like chickens scratch the ground with their beaks and feet to search for food, the vultures observed in this study did the same to glean any remaining pieces of food. This agitated the exposed ground surface and assisted in clearing the area of pine needles. Beak digging was also observed at the site, where a vulture will use the side of its beak as a shovel to remove dirt, most likely in an effort to locate food. It should be noted that the areas corresponding to the placement of the anal and oral cavities exhibited modifications of the soil as a result of digging activity, most-likely in response to the presence of decomposition fluid that purged from the cavities and accumulated near the openings. The foliage of the site was also greatly affected by the feeding period, as the brush and stems of nearby trees were broken and cleared as a result of crowded movement throughout the area (APPENDIX A, Figure 47). Lastly, the vultures also affected the site by scavenging the pitfall trap installed for collection of entomological data by feeding on the collected insects within the plastic cup, preventing us from collected these data.

The vultures were not only destructive of the environment, but they also left traces of their presence at the site. This included feathers as well as fecal matter. Feathers were noted throughout the site, but were not accumulated in any recognizable distribution. Feathers were likely shed naturally, however, recorded images of

intraspecies competition revealed that feathers were sometimes lost as a result of two vultures fighting and biting each other. Vulture scat was noted at the site, however it was not located easily due to the pine needle substrate making it difficult to detect.

Pig Carcass O1

The first and most intense scavenging event began on March, 13th, TSD of five, and continued until the early morning of March 14th, TSD of six. At approximately 11:19 AM at site O1 two black vultures were recorded on camera approaching the carcass from the west side. The time lapse between deposition of the carcass and arrival of vultures to the carcass was approximately 117 hours and 8 minutes. Vultures were engaged in feeding on the carcass at 11:23 AM, and fed on the carcass starting with the cranial and caudal ends, and attacking the skin of the lower abdomen. The vultures at the cranial end of the carcass were feeding on the maggot masses that had accumulated in the eyes, nose, mouth and beneath the skin of the face. The vultures fed on the carcass and dispersed elements over a confined area. This feeding interval occurred until approximately 6:43 PM that evening when the vultures, roosted for the night. At this point in time, the carcass was out of camera view, but had appeared to have been reduced to bones, some of which were still in frame. The feeding resumed at approximately 7:20 AM when a single black vulture was recorded in frame scratching at the initial deposition site. This second feeding interval was much shorter, lasting until 8:32 AM (APPENDIX B, Figure 62) when my advisor and I arrived at the Deep Foundations Geotechnical Research Area to

record decomposition data. This intense period of vulture scavenging occurred for 8 h 28 m, during which the 60lb (27kg) pig carcass deposited at site O1 was reduced to skin and bones, with some skeletal elements with soft-tissue still adhered and a mound of skin remaining from the carcass.

An estimated maximum number of vultures at the site at one time based on what was recorded on camera was 34, and the required KADD to achieve skeletonization was recorded as 1479.64. Pig deposition site O1 featured the removal and dispersal of boney elements, some with adhered soft-tissue and grease. Therefore, after the initial scavenging event, the TBS scoring criteria resulted in a TBS of 29 out of a maximum of 35, falling comfortably in the middle of the skeletonization category. The skeletal elements were dispersed throughout the site based on the foliage immediately in the vicinity of the initial deposition location. The dispersal information will be discussed in full in section “Avian Dispersal”.

During this mass feeding event, the carcass was reduced in a diverse order (Figure 20). As mentioned previously, the vultures began to feed on the cranial and caudal ends of the carcass, before breaching the intestinal wall and focusing feeding on the viscera. This occurred for approximately one hour until the carcass was apparently eviscerated. At this point the vultures continued to feed at the cranial end, expelling the mandible, but focused the majority of their feeding at the large opening in the abdomen as the carcass was in a position with the dorsal surface on the ground. Ribs and verts appeared to be dispersed as the vultures fed on the musculature of the lower body. The carcass was

reduced rather quickly, and by 1:41 PM the lower half of the body had been reduced to skin and bones. The verts and ribs appeared to be removed from the remaining carcass as it was dispersed southwest of the initial deposition. The carcass was stretched and scavenged over the course of the day, being dragged south of the initial deposition site near the fence line and deformed, before eventually being disarticulated at the midpoint of the spine. The long bones and os coxae of the lower body were dragged east back into camera view, while the mound of skin and bones of the upper body remained west of the camera viewing angle. By nightfall the carcass was mostly disarticulated and dispersed over the site. Over the course of the feeding interval, either the first day or the second morning, the skin bag was turned inside-out, like site S2, and the scapulae and the cranium were then expelled from the carcass. By the end of the feeding interval, the skin bag was largely intact and piled in a mound near the southern fence. The skin bag still contained some ribs, verts, and long bones of the forelimbs.

Figure 20: O1 Scavenging and Consumption Flowchart

The vultures directly altered the environment of pig deposition site O1 as a result of their feeding behavior. With so many vultures crowded around the carcass, competing to get access to feed, the repeated shuffling of their feet in addition to the movement of

the carcass as it was manipulated resulted in a disturbed area at the initial pig deposition site where the grass present was stamped and trampled, exposing the disturbed ground surface. This was further exacerbated by the scratching behavior administered after the carcass had been greatly reduced and dispersed from the initial deposition area and vultures searched for leftover pieces of soft-tissue. Much like chickens scratch the ground with their beaks and feet to search for food, the vultures observed in this study did the same to glean any remaining pieces of food. This agitated the exposed ground surface and assisted in clearing the area of vegetation. Beak digging also occurred at site O1. It should be noted that the areas corresponding to the placement of the anal and oral cavities exhibited modifications of the soil as a result of digging activity, most-likely in response to the presence of decomposition fluid that purged from the cavities and accumulated near the openings. The foliage of the site was also greatly affected by the feeding period, as the brush and stems of nearby trees were broken and cleared as a result of crowded movement throughout the area (APPENDIX B, Figure 62). Lastly, the vultures also affected the site by scavenging the pitfall trap installed for collection of entomological data. The vultures removed the covering of the pitfall trap and fed on the collected insects within the plastic cup, preventing us from collected these data (APPENDIX B, Figures 67, 72).

The vultures were not only destructive of the environment, but they also left traces of their presence at the site. This included feathers as well as fecal matter. Feathers were noted throughout the site, but were not accumulated in any recognizable distribution. Feathers were likely shed naturally, however, recorded images of

intraspecies competition revealed that feathers were sometimes lost as a result of two vultures fighting and biting each other. Vulture feces was noted at the site and was even on some of the mounted cameras.

Pig Carcass O2

The first and most intense scavenging event began on March, 13th, TSD of 5, and continued until the early morning of March 14th, TSD of 6. At approximately 11:50 AM at site O2 two black vultures were recorded on camera approaching the carcass from the caudal end. The time lapse between deposition of the carcass and arrival of vultures to the carcass was approximately 117 hours and 33 minutes. Vultures were engaged in feeding on the carcass at 11:50 AM, and fed on the carcass starting with the lower abdomen, and the rectal cavity. This did not last long, however, by 11:55 AM the carcass was completely obscured by feeding vultures, focusing on the abdomen. This voracious feeding interval occurred until approximately 6:28 PM that evening when the vultures, roosted for the night. At this point in time, the carcass was mainly out of camera view, but had appeared to have been reduced to bones, some of which were still in frame. The feeding resumed at approximately 7:40 AM when a multitude of black vultures were recorded in frame scratching at the initial deposition site. This second feeding interval was much shorter, lasting until 8:32 AM when my advisor and I arrived at the Deep Foundations Geotechnical Research Area to record decomposition data. This intense period of vulture scavenging occurred for 7 h 25 m, during which the 55lb (25.5kg) pig

carcass deposited at site O2 was reduced to bones and skeletal elements with some soft-tissue still adhere.

An estimated maximum number of vultures at the site at one time based on what was recorded on camera was 44, and the required KADD to achieve skeletonization was recorded as 1479.64. Pig deposition site O2 featured the removal and dispersal of boney elements, some with adhered soft-tissue and grease. Therefore, after the initial scavenging event, the TBS scoring criteria resulted in a TBS of 29 out of a maximum of 35, falling comfortably in the middle of the skeletonization category. The skeletal elements were dispersed throughout the site based on the foliage of the initial deposition location. The dispersal information will be discussed in full in section “Avian Dispersal”.

During this mass feeding event, the carcass was reduced in a unique order (Figure 21). As mentioned previously, the vultures began to feed on the caudal end of the carcass, before moving onto the abdomen in a feeding frenzy. This occurred for some time until the organs and viscera appeared to have been completely consumed. At this time the vultures fed from the anal cavity, and a whole created in the neck of the carcass. The majority of the feeding took place from this large opening in the abdomen as the carcass was in a position with the dorsal surface on the ground. Ribs and verts appeared to be dispersed as the vultures fed, and during dispersal and movement of the carcass westward, the skull was ejected from the carcass by approximately 12:53 PM. The carcass was reduced rather quickly, and by 1:24 PM it appeared like the carcass was skin and bones. The verts and ribs appeared to be disarticulated from the remaining carcass

which was largely skin which trapped the long bones of the forelimbs and hind limbs. The carcass was stretched and scavenged over the course of the day, being dragged south of the initial deposition site and stretched into a long thin form, before eventually being divided into limbs with adhered soft tissue. Much of the skin was consumed and by nightfall the carcass was completely disarticulated and dispersed over the site. Over the last two to three hours of the day, most of the vulture scavenging activity involved scratching the area for pieces of remaining soft tissue.

Similarly to site S1, pig carcass O2 was also scavenged by bald eagles during the primary scavenging event. Juvenile bald eagles were recorded scavenging in the remains with the vultures. The first juvenile bald eagle was recorded at 4:49 PM when the carcass was reduced to skin and disarticulated remains (APPENDIX C, Figure 80). An eagle was noted on camera at multiple times during the feeding period, and seemed to have taken part in dispersal of the remains as well (APPENDIX C, Figure 81). The juvenile eagle fed intermittently over the course of approximately one hour. Again, this is significant because it means multiple eagles were willing to feed in conjunction and close proximity to vultures. In addition, the vultures did not appear to be cautious of the raptors presence, possibly indicating this type of feeding arrangement occurs often, and vultures don't feel threatened by the large birds of prey.

Figure 21: O2 Scavenging and Consumption Flowchart

The vultures directly altered the environment of pig deposition site O2 as a result of their feeding behavior. With so many vultures crowded around the carcass, competing to get access to feed, the repeated shuffling of their feet in addition to the movement of

the carcass as it was manipulated resulted in a disturbed area at the initial pig deposition site where the grass present was stamped and trampled, exposing the disturbed ground surface. This was further exacerbated by the scratching behavior administered after the carcass had been greatly reduced and vultures searched for leftover pieces of soft-tissue at the initial pig deposition site. Much like chickens scratch the ground with their beaks and feet to search for food, the vultures observed in this study did the same to glean any remaining pieces of food. This agitated the exposed ground surface and assisted in clearing the area of vegetation. Beak digging also occurred at site O2. It should be noted that the areas corresponding to the placement of the anal and oral cavities exhibited modifications of the soil as a result of digging activity, most-likely in response to the presence of decomposition fluid that purged from the cavities and accumulated near the openings. The foliage of the site was also greatly affected by the feeding period, as the brush and stems of nearby trees were broken and cleared as a result of crowded movement throughout the area (APPENDIX C, Figure 79). Lastly, the vultures also affected the site by scavenging the pitfall trap installed for collection of entomological data. The vultures removed the covering of the pitfall trap and fed on the collected insects within the plastic cup, preventing us from collected these data.

The vultures were not only destructive of the environment, but they also left traces of their presence at the site. This included feathers as well as fecal matter. Feathers were noted throughout the site, but were not accumulated in any recognizable distribution. Feathers were likely shed naturally, however, recorded images of intraspecies competition observed at other sites revealed that feathers were sometimes

lost as a result of two vultures fighting and biting each other. Vulture feces was noted at the site, however it was not located easily due to the pine needle substrate making it difficult to detect.

Avian Dispersal

Pig Carcass S1

Site S1 was located in the southwest quadrant of the Deep Foundations Geotechnical Research Area and was placed in a small clearing tightly surround by long-leaf pines. The ground surface was covered in a thick layer of pine needles. The site was surrounded by pines and scattered patches of denser, taller grass. The pines were less dense south of the site, however the ground was not flat and had many areas of lower elevation.

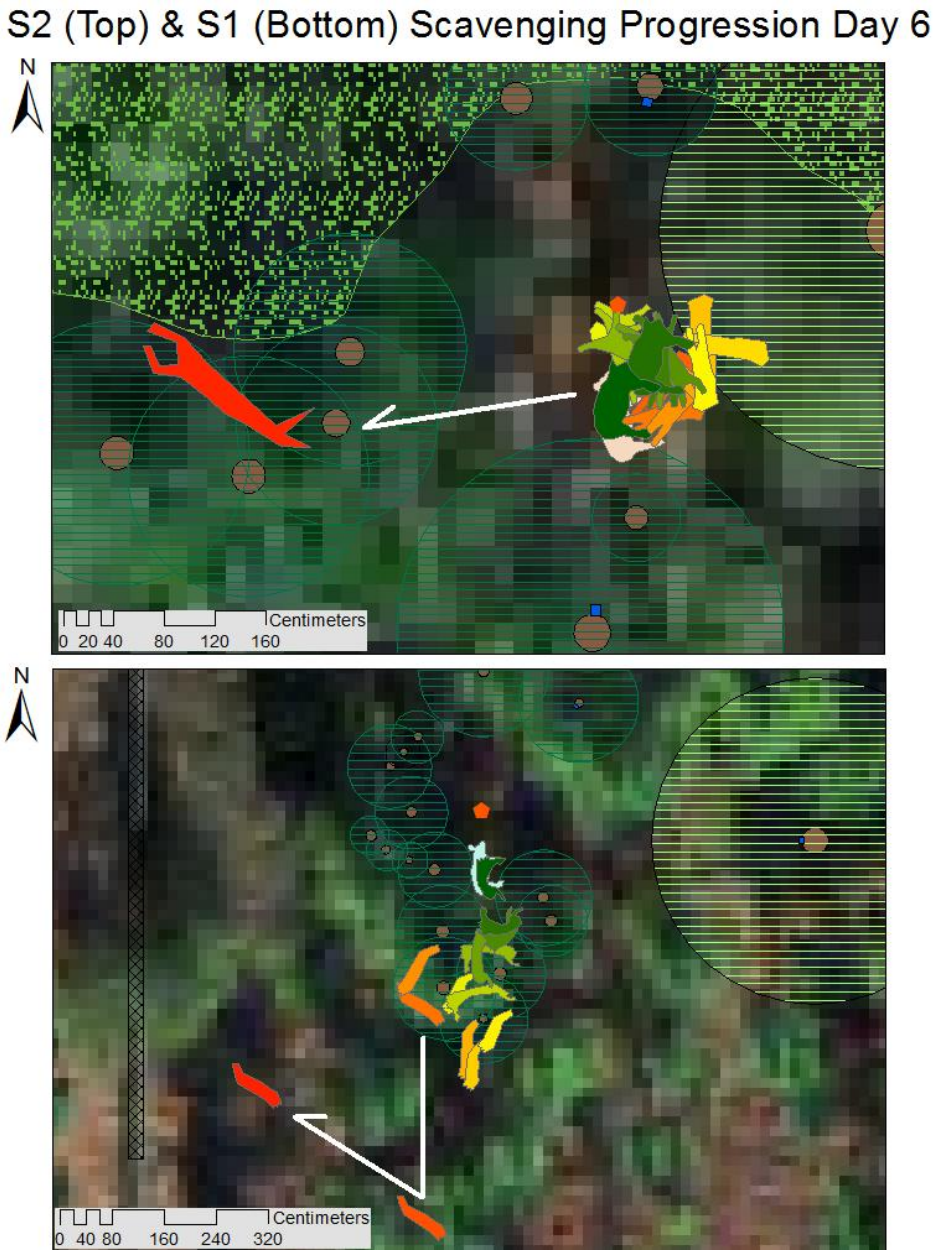


Figure 22: Map of Scavenging Progression (S2 & S1)

The carcass was reduced in mass and slowly dragged southward from the initial deposition site over the course of approximately 3 hours (Figure 22). The carcass was pivoted and deformed during the decomposition process, however the main directional

force was southward where the carcass was slowly dispersed further south as it was scavenged. The carcass spent a large amount of time off camera where it was consumed and disarticulated by vultures, however, the majority of the carcass appeared to be dragged southward, before finally being dragged northwest toward the western fence line. The carcass was eventually obscured from view again, and it was never located again intact. The location of the carcass was determined based on the site foliage, as the vultures were unable to maneuver through the tall grass and around the tightly packed trees on the western side of the site, which dictated their feeding behavior. The narrow area of the deposition allowed poor access of the carcass, which likely resulted in consumption at the cranial end and the lower abdomen. Since the lower abdomen was breached during bloat, greater access was available at this area, as well as easily scavenged tissues of the viscera. For this reason vultures accumulated at the caudal end and pulled and dragged the carcass southward during intraspecies competition and normal consumption behavior. Likely, as the carcass was dragged southward, more angles of the carcass were available for consumption which resulted in the carcass being disarticulated at the limbs and then dragged toward the fenceline. (Table 14).

Table 14: Vulture Scavenging Summary

Carcass	*Elements Interacted with*	*Time of Day*	*Stage of Decomposition*	*Skeletal Modifications*	*Observations*
S1	All skeletal elements and soft tissue	Daylight	Early Decomposition	Disarticulation of unfused elements, consumption of soft tissue	Ribs and Verts concentrated at deposition site, long bones on southern edge of deposition site, dispersed in open areas

Carcass	*Elements Interacted with*	*Time of Day*	*Stage of Decomposition*	*Skeletal Modifications*	*Observations*
S2	All skeletal elements and soft tissue	Daylight	Early Decomposition, Skeletonization	Disarticulation of unfused elements, consumption of remains	Ribs and Verts concentrated at deposition site, long bones on edge of deposition site, dispersed in open areas
O1	All skeletal elements and soft tissue	Daylight	Early Decomposition, Skeletonization	Disarticulation of unfused elements, consumption of remains	Ribs and Verts concentrated at deposition site, dispersed in open areas
O2	All skeletal elements and soft tissue	Daylight	Early Decomposition	Disarticulation of unfused elements, consumption of remains	Ribs and Verts concentrated at deposition site, long bones on edge of deposition site, dispersed in open areas

A total of 39 skeletal elements were located at the time of mapping on March 14th. Elements not recovered were either consumed by the vultures, lost amongst the foliage, or dispersed far enough away from the initial deposition site that they were unrecoverable. The skeletal elements were scattered throughout the site in areas with little dense foliage. Areas of tall grass harbored few skeletal elements, the majority of which were confined to the initial deposition site, and the cleared area south of the initial deposition where the carcass appeared to spend the majority of its time. Additionally, many elements were recovered directly west of the initial deposition site as the area was of a lower elevation and likely collected bones as they were dispersed and scavenged. The skeletal elements were scattered in the opposite direction of the position of the cranium. The majority of the skeletal elements (59%) were within three meters of the

initial deposition location (Figures 23, 24). The skeletal elements drastically decrease in frequency as the distance from the initial deposition site increases.

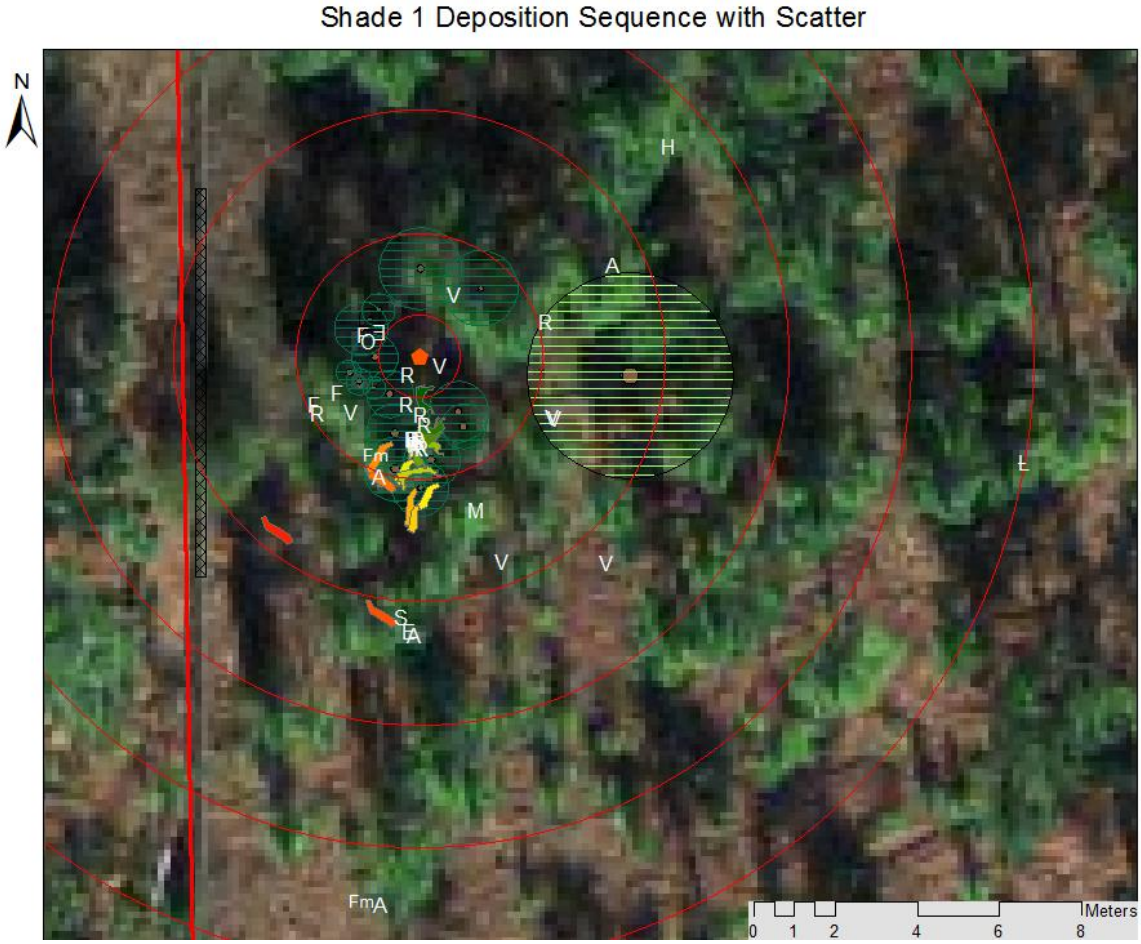


Figure 23: S1 Deposition Sequence and Scatter

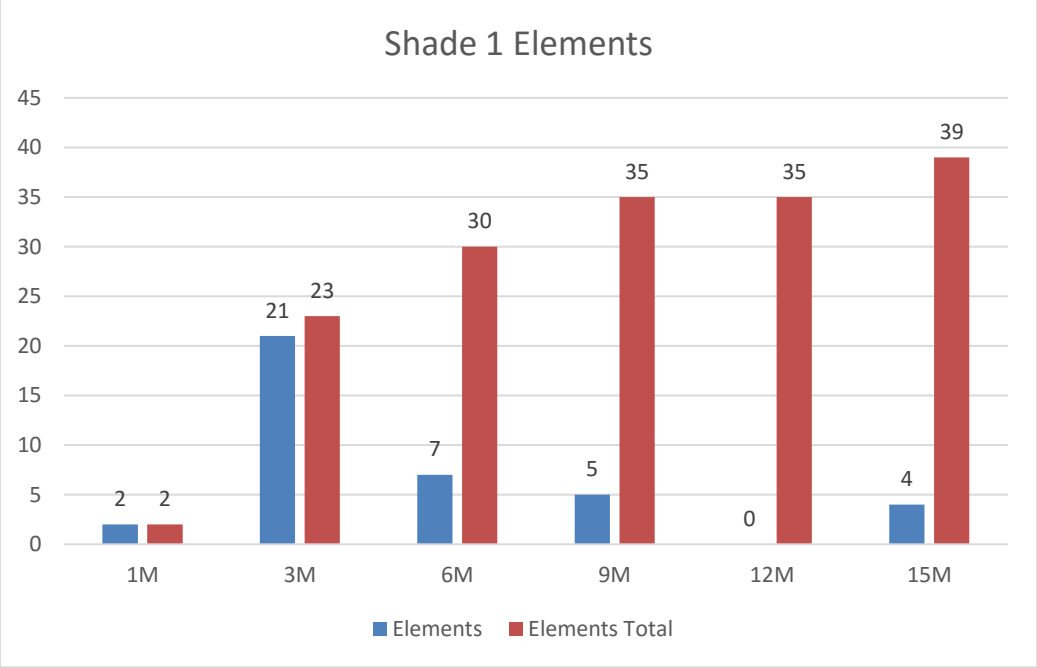


Figure 24: Scatter Bar Graph

Pig Carcass S2

Site S2 was located in the northwest quadrant of the Deep Foundations Geotechnical Research Area and was placed in a small clearing, about three meters in diameter, amongst the long-leaf pines. The ground surface was covered in a thick layer of pine needles. Directly to the north of the site there was dense tall grass which grew between the trees. The pines were less dense to the southwest and south.

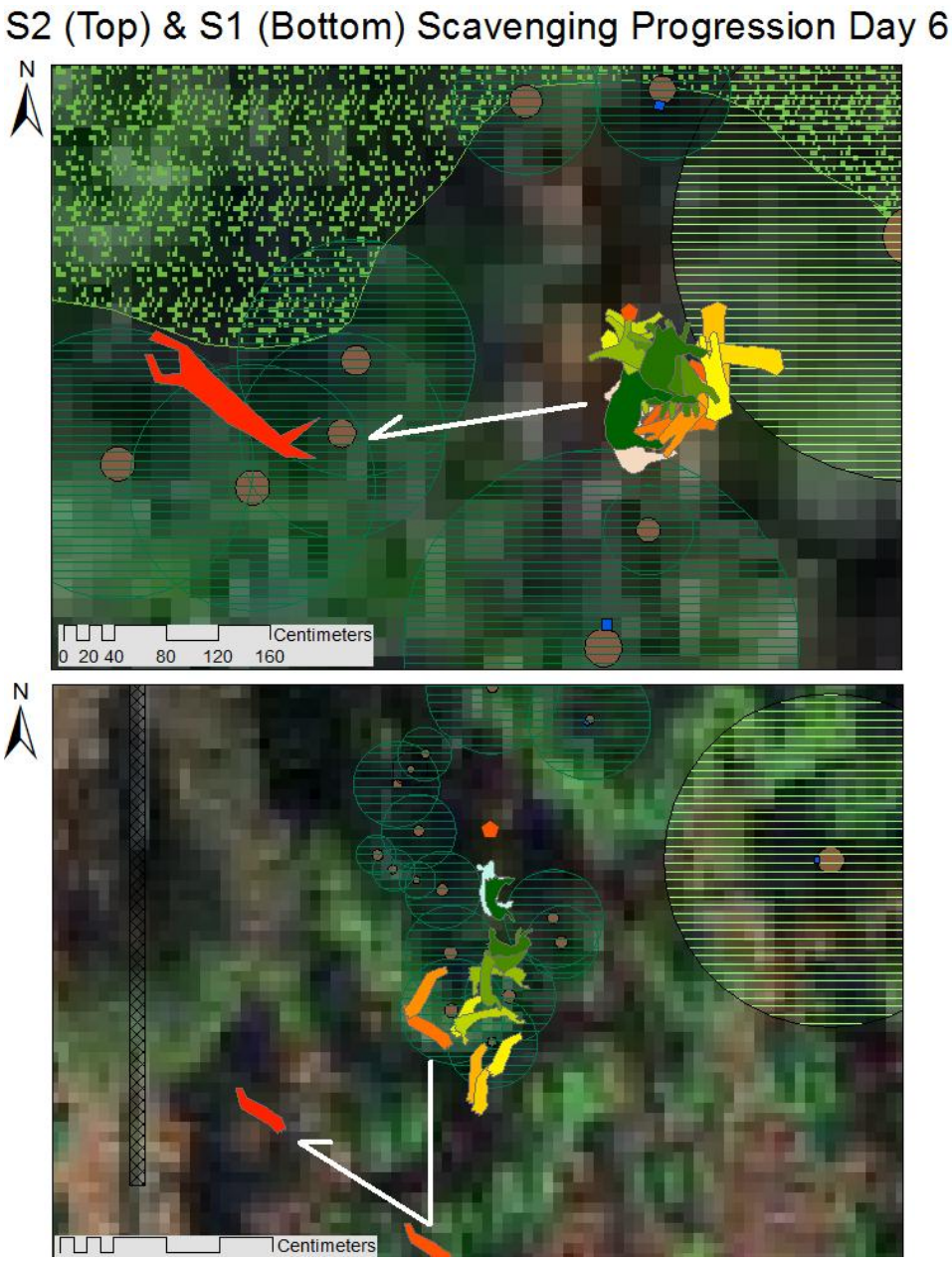


Figure 25: Map of Scavenging Progression (S2 & S1)

The carcass was reduced in mass and rotated within a meter of the initial deposition location (Figure 25). The reduced carcass was pivoted and deformed during

the decomposition process, however there was never a major directional force in any specific direction to move the carcass any distance until the early morning of March 14th, TSD of 6. With the carcass greatly reduced in mass and turned inside by the vulture scavenging activity, the carcass was then dragged by vulture agency approximately 3 meters to the west. The location of the carcass was determined based on the site foliage, as the vultures were unable to maneuver through the tall grass, which dictated their feeding behavior. The large, clear area of the deposition allowed generally equal access to all sides of the carcass, limiting intraspecies conflict, a driving force in carcass dispersal. Once edible soft tissue was at a minimum on the morning of March 14th, competition over remaining soft tissue resulted in the carcass being dragged west, however the carcass was never dragged out of an area of vulture access (Table 15).

Table 15: Vulture Scavenging Summary

Carcass	*Elements Interacted with*	*Time of Day*	*Stage of Decomposition*	*Skeletal Modifications*	*Observations*
S1	All skeletal elements and soft tissue	Daylight	Early Decomposition	Disarticulation of unfused elements, consumption of soft tissue	Ribs and Verts concentrated at deposition site, long bones on southern edge of deposition site, dispersed in open areas
S2	All skeletal elements and soft tissue	Daylight	Early Decomposition, Skeletonization	Disarticulation of unfused elements, consumption of remains	Ribs and Verts concentrated at deposition site, long bones on edge of deposition site, dispersed in open areas
O1	All skeletal elements and soft tissue	Daylight	Early Decomposition, Skeletonization	Disarticulation of unfused elements, consumption of remains	Ribs and Verts concentrated at deposition site, dispersed in open areas

Carcass	*Elements Interacted with*	*Time of Day*	*Stage of Decomposition*	*Skeletal Modifications*	*Observations*
O2	All skeletal elements and soft tissue	Daylight	Early Decomposition	Disarticulation of unfused elements, consumption of remains	Ribs and Verts concentrated at deposition site, long bones on edge of deposition site, dispersed in open areas

A total of 66 skeletal elements were located at the time of mapping on March 14th (Figure 26). Elements not recovered were either consumed by the vultures, lost amongst the foliage, or dispersed far enough away from the initial deposition site that they were unrecoverable. The skeletal elements were scattered throughout the site (APPENDIX A, Figure 47) in areas with little dense foliage. Areas of tall grass harbored few skeletal elements, the majority of which were confined to the initial deposition site, and the cleared area south of the initial deposition. The skeletal elements were scattered in the opposite direction of the position of the cranium. The majority of the skeletal elements (65%) were within three meters of the initial deposition location (Figures 26, 27). The skeletal elements drastically decrease in frequency as the distance from the initial deposition site increases.

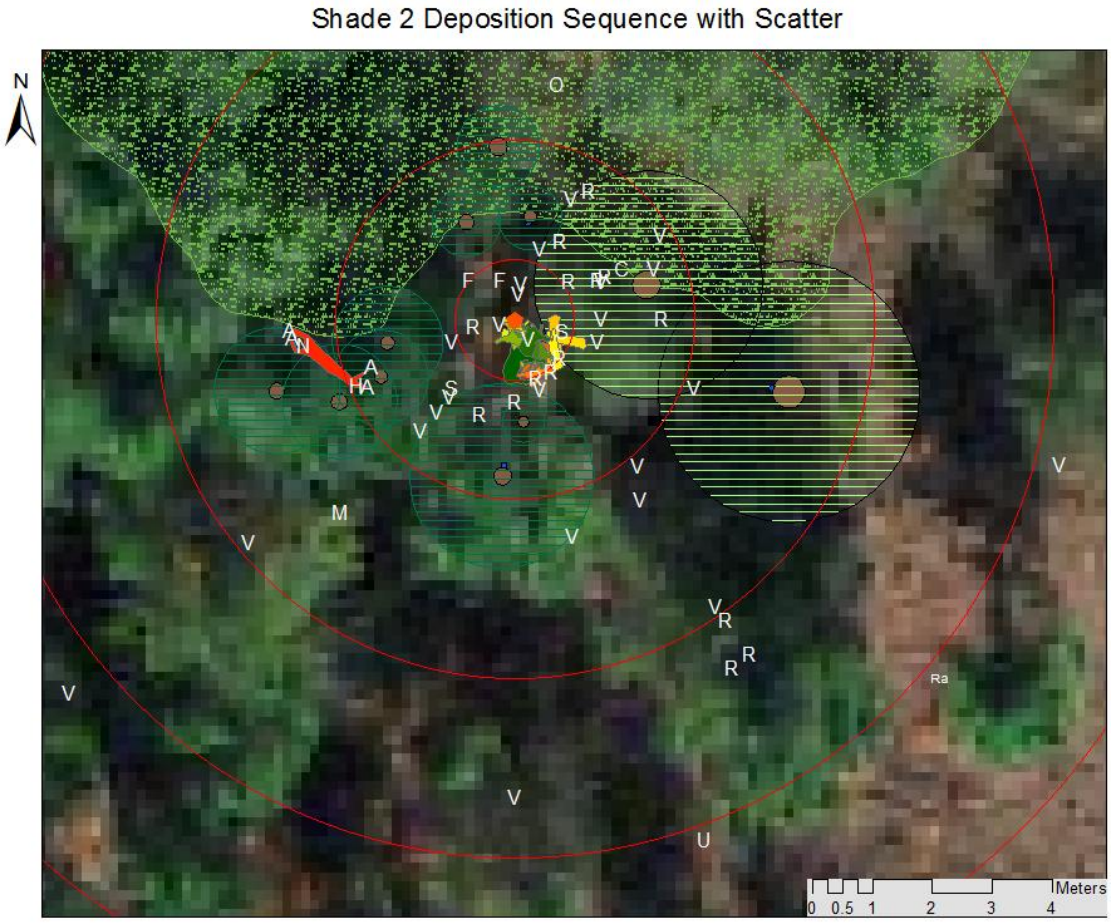


Figure 26: S2 Deposition Sequence and Scatter

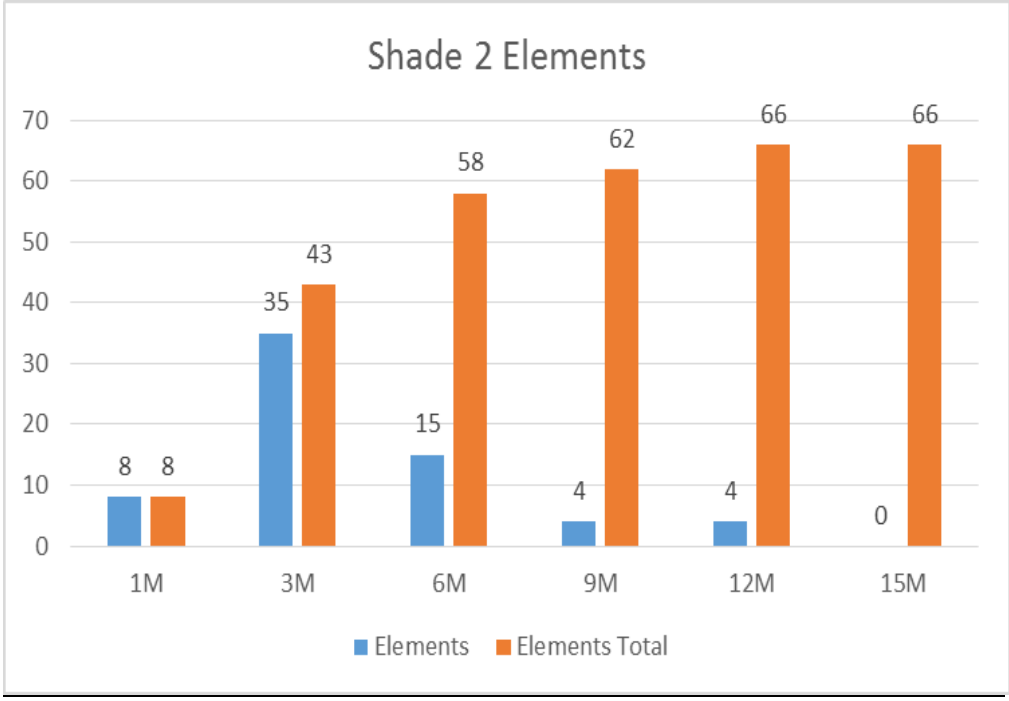


Figure 27: Scatter Bar Graph

Pig Carcass O1

Site O1 was located in the southeast quadrant of the Deep Foundations Geotechnical Research Area and was placed in wide-open field of tall grass. The tall grass was cleared prior to placement. The ground surface was covered in dirt, grass, and other random small shrubbery. The site was situated between a single deciduous tree and the southern fence line. A small cluster of pines was immediately west of the site. To the north of the site was the deciduous tree and a large field of tall, waist-high grass. To the

south of the site was the fence line. To the east and west of the site was scattered brush and trails cut through the grass by walking.

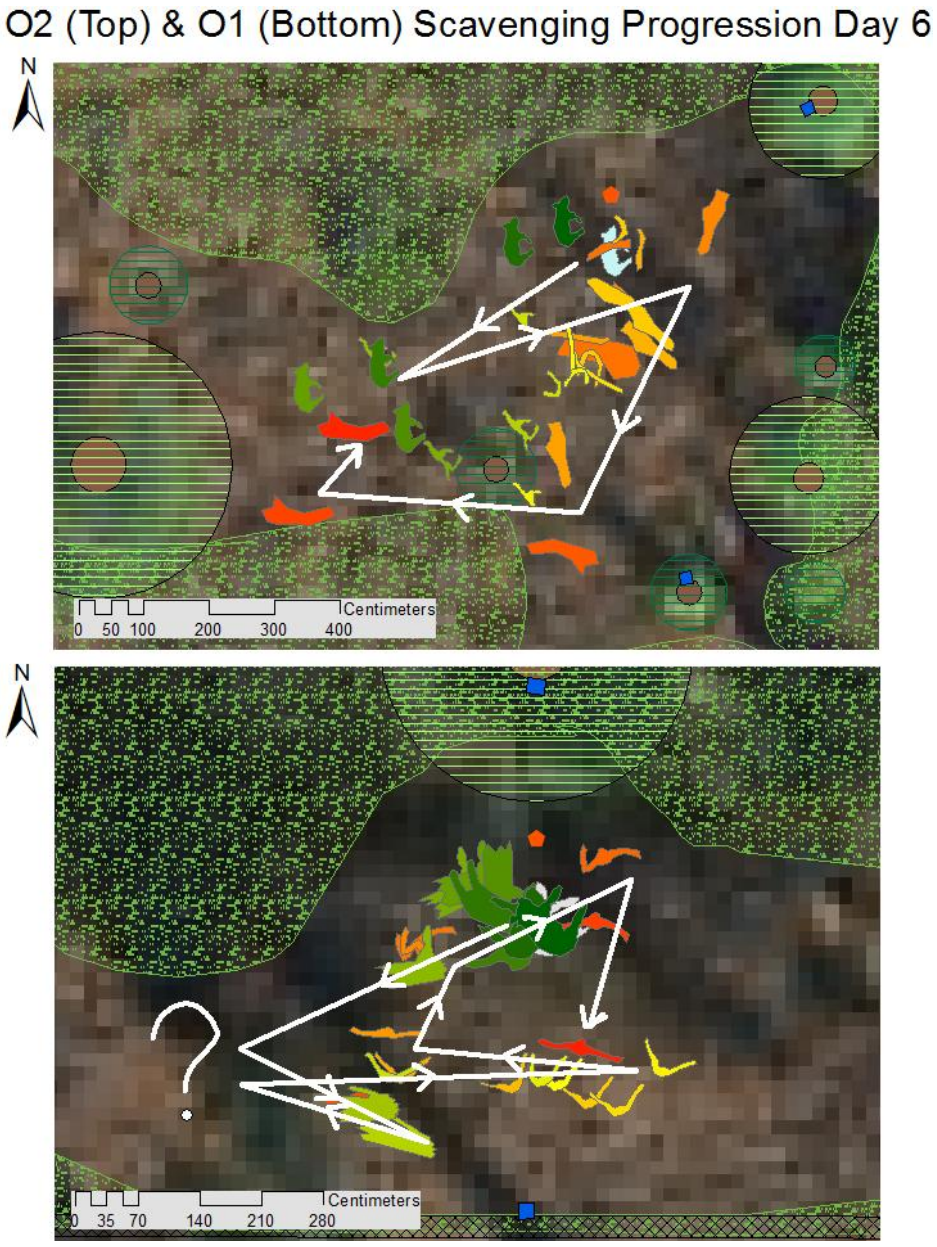


Figure 28: Map of Scavenging Progression (S2 & O1)

The carcass was quickly reduced in mass at the lower body and dragged westward from the initial deposition site (Figure 28). The carcass spent time off screen and when it

had returned it was deformed in shape. The deformed carcass was then dragged off screen again and was greatly stretched and reduced before being disarticulated. The skeletal elements of the lower body were still articulated and were dragged back into frame, eastward. These remains were scavenged and dispersed around the initial deposition site before finally resting equidistant between the initial deposition site and the south fence. The skin bag was out of view for the majority of the feeding period, however it ended up in a mound near the south fence.

The location of the carcass was determined based on the site foliage, as the vultures were unable to maneuver through the tall grass, and were somewhat contained by the fence line to the south. The large open area allowed for greater scavenging and movement of the carcass however dispersal was limited due to the features of the site containing the elements at both the northern and southern sides. The open area of the deposition allowed optimal access to the carcass, which likely resulted in mass consumption of soft tissue at the lower abdomen. For this reason vultures accumulated around the carcass, naturally moving in directions opposite of denser foliage. As the carcass was reduced and deformed, scavenging access differed and the carcass moved around the large open area. The large open area appeared to facilitate the quick succession of soft tissue consumption as well as the large area of dispersal. (Table 16).

Table 16: Vulture Scavenging Summary

Carcass	*Elements Interacted with*	*Time of Day*	*Stage of Decomposition*	*Skeletal Modifications*	*Observations*
S1	All skeletal elements and soft tissue	Daylight	Early Decomposition	Disarticulation of unfused elements, consumption of soft tissue	Ribs and Verts concentrated at deposition site, long bones on southern edge of deposition site, dispersed in open areas
S2	All skeletal elements and soft tissue	Daylight	Early Decomposition, Skeletonization	Disarticulation of unfused elements, consumption of remains	Ribs and Verts concentrated at deposition site, long bones on edge of deposition site, dispersed in open areas
O1	All skeletal elements and soft tissue	Daylight	Early Decomposition, Skeletonization	Disarticulation of unfused elements, consumption of remains	Ribs and Verts concentrated at deposition site, dispersed in open areas
O2	All skeletal elements and soft tissue	Daylight	Early Decomposition	Disarticulation of unfused elements, consumption of remains	Ribs and Verts concentrated at deposition site, long bones on edge of deposition site, dispersed in open areas

A total of 59 skeletal elements were located at the time of mapping on March 14th. Elements not recovered were either consumed by the vultures, lost amongst the foliage, or dispersed far enough away from the initial deposition site that they were unrecoverable. The skeletal elements were scattered throughout the site in areas with little dense foliage. Additionally, elements were recovered within a short distance of the initial deposition, with no elements dispersed passed 12 meters from the deposition site. This is likely due to relatively small confined nature of the site. The tall grass to the north and the fence to the south acted to distribute remains east and west. The skeletal elements were scattered in the opposite direction of the position of the cranium, which can be

partially attributed to the tall grass directly north of the cranial end. More than half of the remains (61%) were recovered within three meters of the initial deposition location (Figures 29 & 30). However, the vast majority (92%) of remains were located within six meters of the initial deposition site. This is due to the same confined nature of the site that was mentioned previously. The skeletal elements drastically decrease in frequency as the distance from the initial deposition site increases.

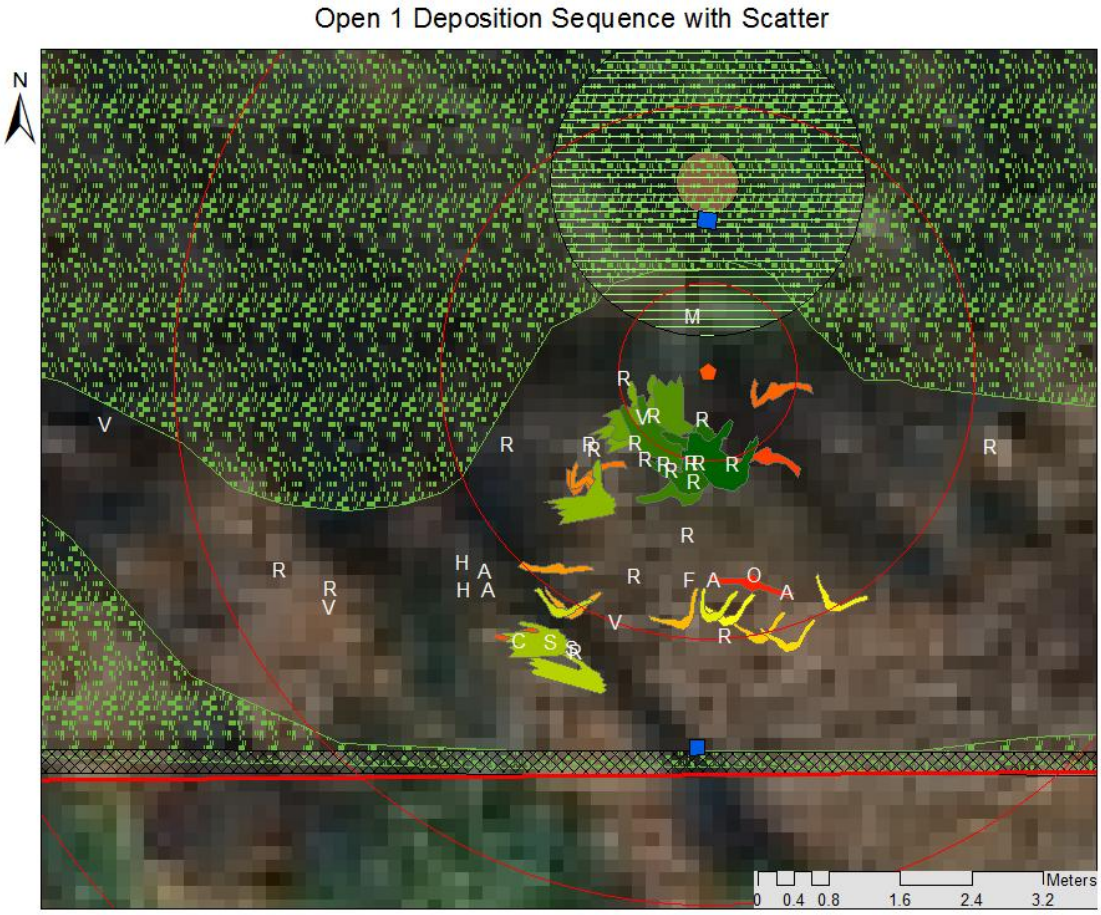


Figure 29: O1 Deposition Sequence and Scatter

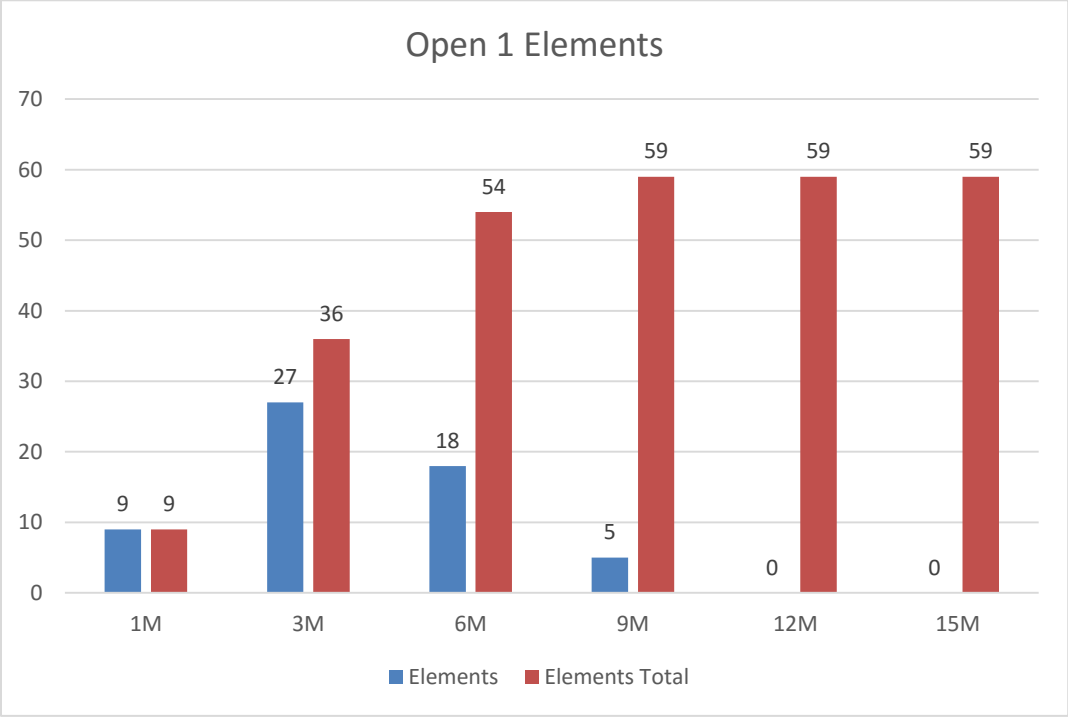


Figure 30: Scatter Bar Graph

Pig Carcass O2

Site O2 was located in the northeast quadrant of the Deep Foundations Geotechnical Research Area and was placed in an exposed field with very little tall grass. The ground surface was covered in dirt, grass, and other random small shrubbery. The site was surrounded by scattered pines and intermittent patches of denser, taller grass. The pines were less dense than the western half of the research area, and sparsely

populated site O2. South of the site opened up to a larger field of tall grass and more scattered trees.

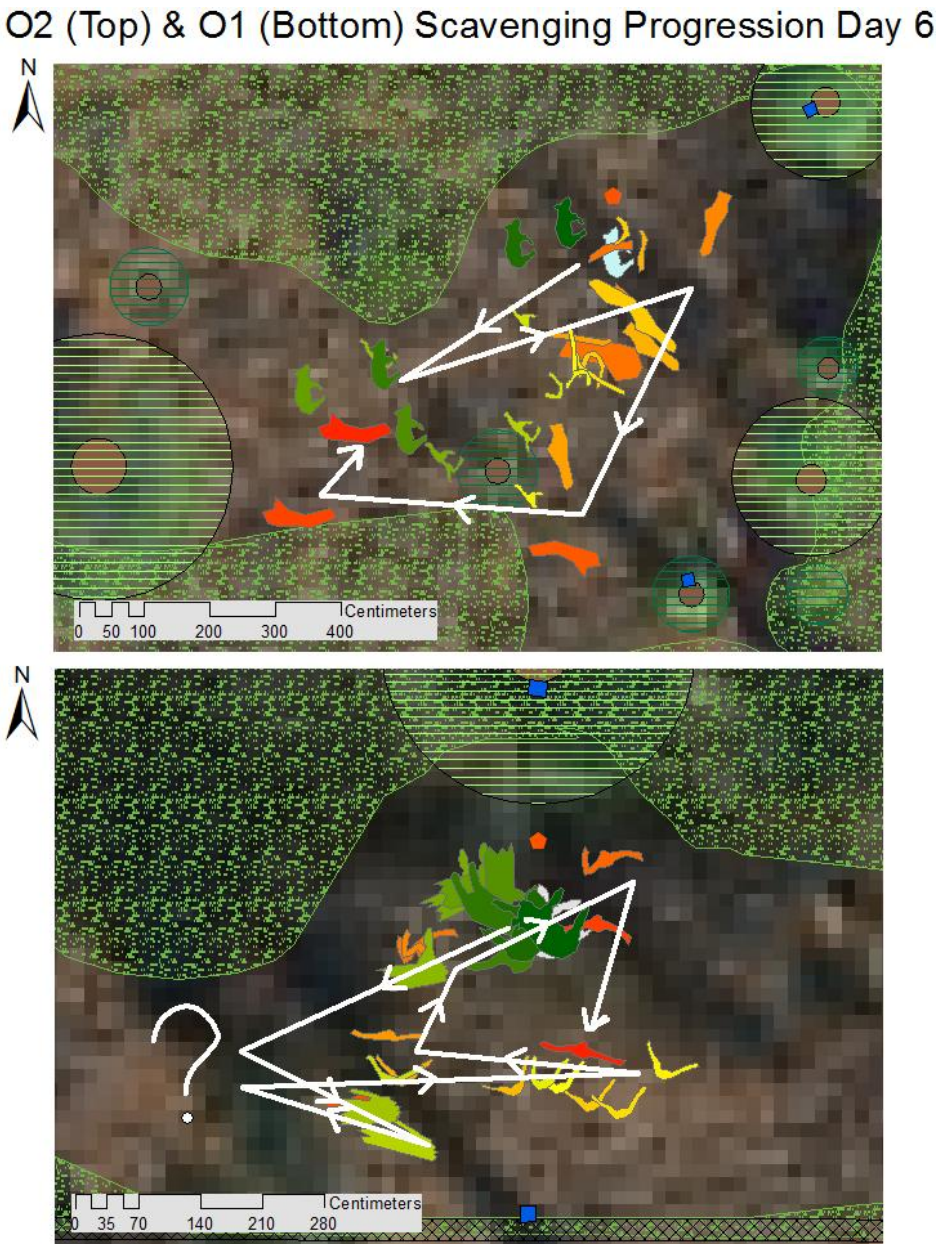


Figure 31: Map of Scavenging Progression (S2 & O2)

The carcass was quickly reduced in mass and dragged westward from the initial deposition site. Over the course of approximately 6 hours (Figure 31). The carcass was greatly stretched and deformed during the decomposition process, and dragged eastward before the limbs of the carcass were disarticulated. The carcass was then dragged southward, before finally being dragged westward into a clearing and completely disarticulated. The location of the carcass was determined based on the site foliage, as the vultures were unable to maneuver through the tall grass. The large open area allowed for greater scavenging of the carcass and dispersal over greater distances. The open area of the deposition allowed optimal access to the carcass, which likely resulted in mass consumption of soft tissue at the lower abdomen. For this reason vultures accumulated around the carcass, naturally moving in directions opposite of denser foliage. As the carcass was reduced and deformed, scavenging access differed and the carcass moved around the large open area. The large open area appeared to facilitate the quick succession of soft tissue consumption as well as the large area of dispersal due to the many carcass access angles provided to the vultures. (Table 17).

Table 17: Vulture Scavenging Summary

Carcass	*Elements Interacted with*	*Time of Day*	*Stage of Decomposition*	*Skeletal Modifications*	*Observations*
S1	All skeletal elements and soft tissue	Daylight	Early Decomposition	Disarticulation of unfused elements, consumption of soft tissue	Ribs and Verts concentrated at deposition site, long bones on southern edge of deposition site, dispersed in open areas

Carcass	*Elements Interacted with*	*Time of Day*	*Stage of Decomposition*	*Skeletal Modifications*	*Observations*
S2	All skeletal elements and soft tissue	Daylight	Early Decomposition, Skeletonization	Disarticulation of unfused elements, consumption of remains	Ribs and Verts concentrated at deposition site, long bones on edge of deposition site, dispersed in open areas
O1	All skeletal elements and soft tissue	Daylight	Early Decomposition, Skeletonization	Disarticulation of unfused elements, consumption of remains	Ribs and Verts concentrated at deposition site, dispersed in open areas
O2	All skeletal elements and soft tissue	Daylight	Early Decomposition	Disarticulation of unfused elements, consumption of remains	Ribs and Verts concentrated at deposition site, long bones on edge of deposition site, dispersed in open areas

A total of 54 skeletal elements were located at the time of mapping on March 14th. Elements not recovered were either consumed by the vultures, lost amongst the foliage, or dispersed far enough away from the initial deposition site that they were unrecoverable. The skeletal elements were scattered throughout the site in areas with little dense foliage. Additionally, elements were recovered quite a distance west of the initial deposition, this is likely due to disarticulation of remains and scatter the result of intraspecies conflict while the carcass was located in that area. The skeletal elements were scattered in the opposite direction of the position of the cranium. Exactly half of the remains (50%) were recovered within three meters of the initial deposition location (Figures 32, 33). However, the vast majority (85%) of remains were located within six meters of the initial deposition site. This is likely due to the amount of time the carcass spent being reduced west of the initial deposition site. Elements dispersed from the

carcass in that location were likely dispersed an even greater distance away from the primary deposition. This exemplifies the role site foliage play in dispersal. The larger area allowed for greater dispersal distances. The skeletal elements drastically decrease in frequency as the distance from the initial deposition site increases.

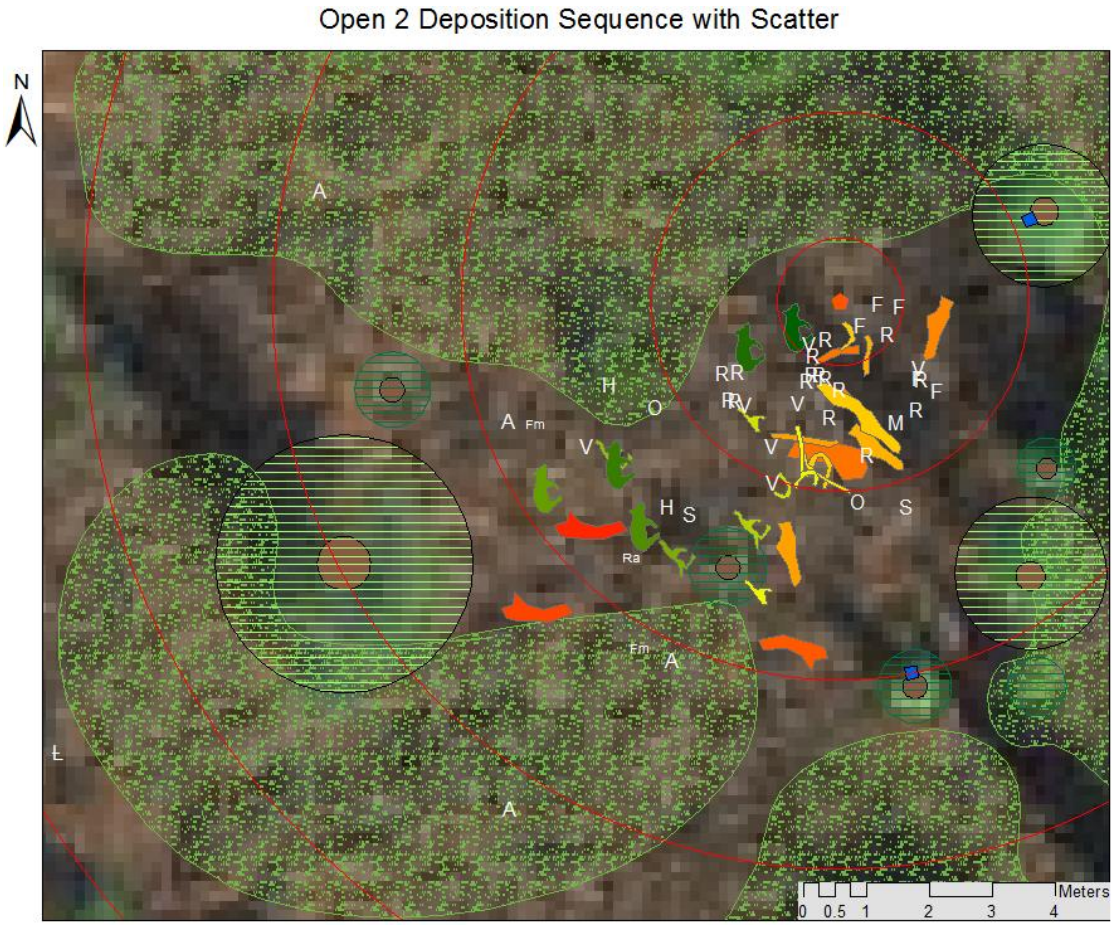


Figure 32: O2 Deposition Sequence and Scatter

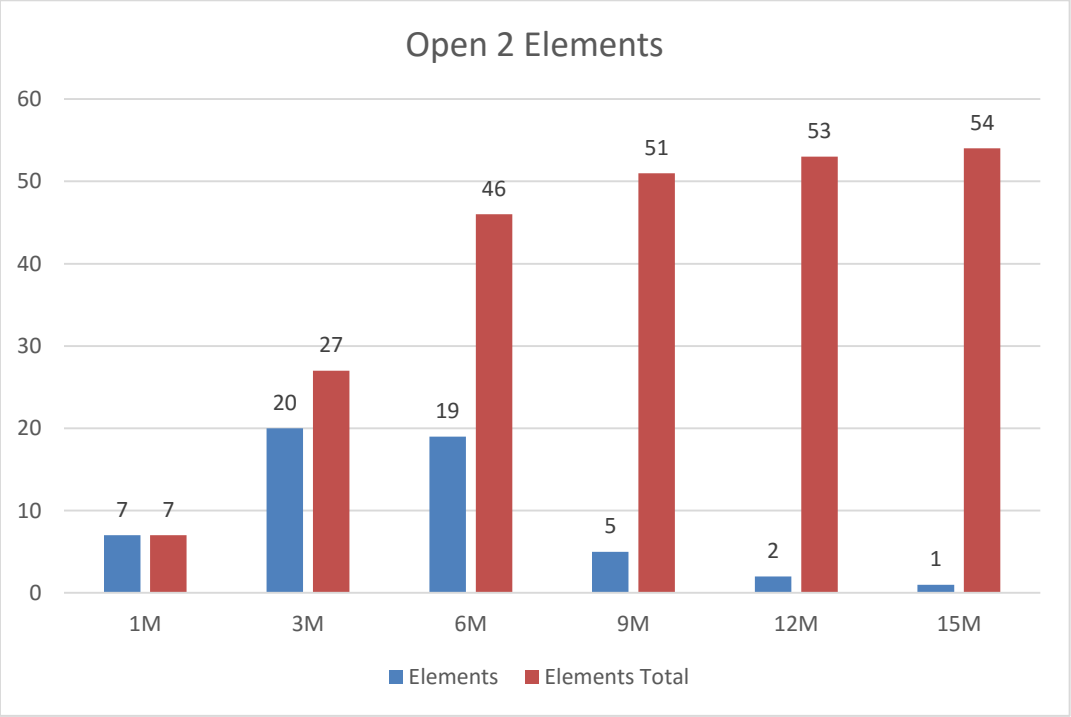


Figure 33: Scatter Bar Graph

Opossum Scavenging and Dispersal

All appropriate figures detailing opossum scavenging and dispersal of remains for pig carcass S1 will be included in the following chapter. Rather than include duplicate figures for pig carcasses S2, O1, and O2, representing opossum scavenging, redundant figures will be included in specifically referenced appendices located at the conclusion of chapter 6.

Pig Carcass S1

In addition to the initial period of intense scavenging by vultures on March 13th through March 14th, multiple subsequent scavenging episodes occurred at pig deposition site S1 (Figure 34). This includes scavenging by opossums (Figure 35) at 7 days TSD, 10 days TSD, 16 days TSD, 18 days TSD, 20 days TSD, 22 days TSD, 24 days TSD, 27 days TSD, and 30 days TSD. Armadillos were noted at the site upon deposition of carcasses, but were not recorded throughout the remaining duration of the study. Due to the large dispersal at this site, scavenging was often recorded via the removal or movement of skeletal elements as the cameras were not able to effectively cover the entirety of the site. The first opossum scavenging episode occurred on the night of March 15th. A flap of skin leftover from the initial scavenging event was removed from the site. Due to the nocturnal nature of opossums, it was concluded that removal of the skin flap had to have been a result of opossum scavenging. March 18th, a opossum scavenged and dragged a complete limb with adhered soft tissue approximately two meters southward from the initial deposition. On day 16, March 24th, a humerus and the complete limb located south of the deposition site were completely scavenged and removed from the site. Because these remains were scavenged in areas of thicker vegetation and completely removed, it was consistent with opossum scavenging (Table 18). No opossum was recorded on camera, however, the remains were a large distance from the cameras. On day 18, March 26th, a opossum was captured on camera at 8:20 PM. Due to the presence of soft tissue on the remains, scavenging was assumed. On day 20, March 28th, a opossum was recorded scavenging the site at 2:26 AM. No remains were dispersed. On

day 22, March 30th, the remains with soft tissue adhered were discovered missing and were remapped. Despite not being recorded on camera, it is assumed that a opossum scavenged the remains, as it was not located around the site the following day, and it is not consistent with other scavengers to completely remove elements from the site. Furthermore, no other scavengers had been recorded on camera at any of the sites, which narrowed the possible scavengers to the opossum. On day 24, April 1st, a opossum was seen at the site at 11:15 PM consuming soft-tissue. On day 27, April 4th, a opossum was again caught on camera at the site. No elements were moved, but scavenging was assumed. This also occurred on day 30, April 7th, when a opossum was recorded at the site. No elements were moved after day 30.

Table 18: Opossum Scavenging Summary Table

Carcass	*Elements Interacted with*	*Time of Day*	*Stage of Decomposition*	*Skeletal Modifications*	*Observations*
S1	Long bones, ankles, with adhered soft tissue	Night, early morning	Skeletonization	Removal of bones with adhered soft tissue	Sometimes multiple feeding periods a night, revisiting of site, removal of remains
S2	Skin bag, adhered elements of ankles	Night, early morning	Skeletonization	Removal of bones with adhered soft tissue, gnawing	Sometimes multiple feeding periods a night, revisiting of site, dispersing bone into heavy foliage and tall grass
O1	Skin bag, adhered elements of ankles	Night, early morning	Skeletonization	Removal of bones with adhered soft tissue	Sometimes multiple feeding periods a night, revisiting of site, dispersing bone into heavy foliage and tall grass
O2	Long bones, ankles, with adhered soft tissue	Night, early morning	Skeletonization	Removal of bones with adhered soft tissue	Sometimes multiple feeding periods a night, revisiting of site, removal of remains

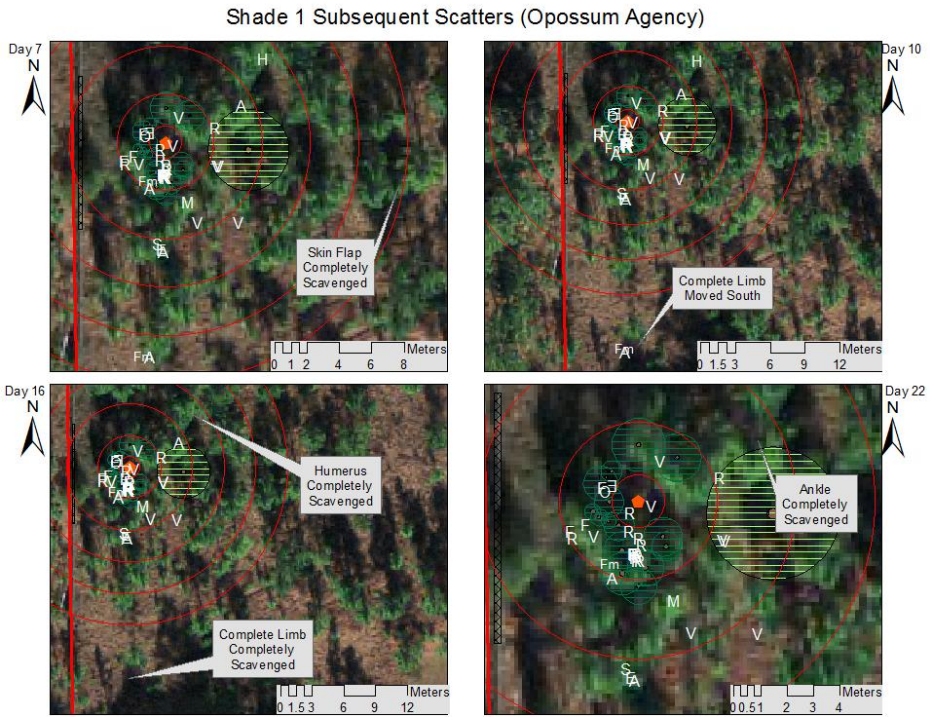


Figure 34: S1 Opossum Scatters

Figure 35: Site S1 - opossum scavenging, looking for remnants of soft tissue

Pig Carcass S2

In addition to the initial period of intense scavenging by vultures on March 13th through March 14th, multiple subsequent scavenging episodes occurred at pig deposition site S2 (Table 19). This includes scavenging by opossums (Figure 36) at 10 days TSD, 11 days TSD, 13 days TSD, 14 days TSD, 22 days TSD, 24 days TSD, and 26 days TSD. Armadillos were noted at the site upon deposition of carcasses, but were not recorded throughout the remaining duration of the study. The first opossum scavenging episode occurred on March 18th, TSD of 10, at 4:10 AM. The opossum is captured on camera feeding on the skin bag and dragging it approximately 10 feet west towards a cluster of trees before leaving prior to sunrise. The following day, March 19th, a opossum is captured on screen at 7:10 PM feeding on the carcass. It continued to feed off and on, until 9:32 PM when it was seen departing the area. On day 13, March 21st, the carcass was recorded in a different position. No opossum was recorded on camera, however, the carcass was a large distance from the game camera and did not trigger the IR beam. The carcass had been dragged north into a denser crop of trees among the tall grass. This behavior indicated scavenging by opossum over other avian species because vultures avoided the tall grass, likely because it was too dense for them to move through. On day 13, March 21st, a solitary turkey vulture was captured (APPENDIX A, Figure 49) feeding on adhered soft tissue on the elements near the initial skin bag location at 2:13 PM. The vulture did not alter the location of these elements. Later that evening, at 8:10 PM, a opossum was captured on camera feeding on the skin bag as well as the remains that the vulture was feeding on earlier that day (APPENDIX A, Figure 53). The feeding period

was short. Of note, on day 16, March 24th, a opossum was recorded scavenging the pitfall traps at the site. The opossum did not appear to scavenge the pig carcass remains, therefore it was not listed as a scavenging event. On day 22, the carcass was discovered missing and was remapped. Despite not being recorded on camera, it is assumed that a opossum scavenged the carcass, as it was located among dense foliage and would not have been easily fed upon by vultures. Furthermore, no other scavengers had been recorded on camera at any of the sites, which narrowed the possible scavengers to the opossum. All that remained was sparse hair, and small bone fragments which were collected (APPENDIX A, Figure 55). On day 22, March 30th, a opossum was seen at the site at 9:11 PM. No elements were moved, however, but scavenging by the opossum was assumed. On day 24, April 1st, a opossum was again caught on camera at the site. No elements were moved, but scavenging was assumed.

Table 19: Opossum Scavenging Summary Table

Carcass	*Elements Interacted with*	*Time of Day*	*Stage of Decomposition*	*Skeletal Modifications*	*Observations*
S1	Long bones, ankles, with adhered soft tissue	Night, early morning	Skeletonization	Removal of bones with adhered soft tissue	Sometimes multiple feeding periods a night, revisiting of site, removal of remains
S2	Skin bag, adhered elements of ankles	Night, early morning	Skeletonization	Removal of bones with adhered soft tissue, gnawing	Sometimes multiple feeding periods a night, revisiting of site, dispersing bone into heavy foliage and tall grass

Carcass	*Elements Interacted with*	*Time of Day*	*Stage of Decomposition*	*Skeletal Modifications*	*Observations*
O1	Skin bag, adhered elements of ankles	Night, early morning	Skeletonization	Removal of bones with adhered soft tissue	Sometimes multiple feeding periods a night, revisiting of site, dispersing bone into heavy foliage and tall grass
O2	Long bones, ankles, with adhered soft tissue	Night, early morning	Skeletonization	Removal of bones with adhered soft tissue	Sometimes multiple feeding periods a night, revisiting of site, removal of remains

After April 1st, opossum activity was recorded at the site on two other occasions, on day 34 and day 43, however, both times the skeletal elements were in a dry stage and no soft-tissue remained on the elements. The skeletal elements were not modified, therefore it was concluded that the opossums recorded on camera were likely traveling through the site and were incidentally captured on camera.

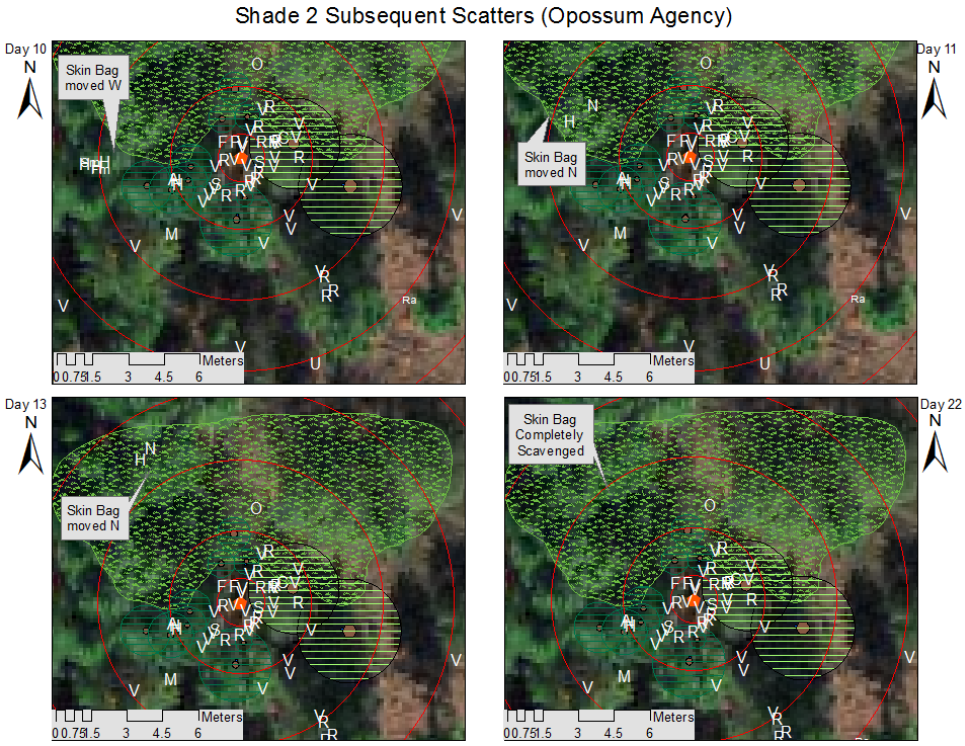


Figure 36: S2 Opossum Scatters

Pig Carcass O1

In addition to the initial period of intense scavenging by vultures on March 13th through March 14th, subsequent scavenging episodes occurred at pig deposition site O1 (Figure 37). This includes scavenging by opossums (Table 24) at 12 days TSD, 16 days TSD, 20 days TSD, 22 days TSD, and 25 days TSD, 26 days TSD, 27 days TSD and 32 days TSD. Armadillos were noted at the site upon deposition of carcasses, but were not recorded throughout the remaining duration of the study. The first scavenging episode was caused by vultures, rather than opossum, and occurred on the night of March 20th. A single Turkey vulture was recorded at the site at 12:48PM and fed on the articulated

lower limbs. Elements were rotated slightly. Later than night, a opossum was recorded feeding on the skin bag and dragged it west towards the tall grass and shrubs. On March 24th, another turkey vulture was also recorded around 11:15 AM scratching the initial deposition site and dragging the carcass eastward. Similar to March 20th, an opossum scavenged the skin bag, dragging it further west into the tall grass and bushes (TABLE 20) at approximately 11:50 PM. On day 22, March 30th, two opossums were recorded at the site at the same time at approximately 9:40 PM. The skin bag was completely scavenged and removed from the site and was not recoverable. From 25 days TSD till 27 days TSD, a opossum was seen at the site between 2 and 4 AM every morning. No elements were moved but scavenging was assumed. Finally, on April 5th, 32 days TSD, a opossum was recorded at the site. Again, no elements were removed or altered, but scavenging was assumed as the remains were not yet completely dry and would have been a source of food for the opossum.

Table 20: Opossum Scavenging Summary Table

Carcass	*Elements Interacted with*	*Time of Day*	*Stage of Decomposition*	*Skeletal Modifications*	*Observations*
S1	Long bones, ankles, with adhered soft tissue	Night, early morning	Skeletonization	Removal of bones with adhered soft tissue	Sometimes multiple feeding periods a night, revisiting of site, removal of remains
S2	Skin bag, adhered elements of ankles	Night, early morning	Skeletonization	Removal of bones with adhered soft tissue, gnawing	Sometimes multiple feeding periods a night, revisiting of site, dispersing bone into heavy foliage and tall grass

Carcass	*Elements Interacted with*	*Time of Day*	*Stage of Decomposition*	*Skeletal Modifications*	*Observations*
O1	Skin bag, adhered elements of ankles	Night, early morning	Skeletonization	Removal of bones with adhered soft tissue	Sometimes multiple feeding periods a night, revisiting of site, dispersing bone into heavy foliage and tall grass
O2	Long bones, ankles, with adhered soft tissue	Night, early morning	Skeletonization	Removal of bones with adhered soft tissue	Sometimes multiple feeding periods a night, revisiting of site, removal of remains

Figure 37: O1 Opossum Scatters

Pig Carcass O2

In addition to the initial period of intense scavenging by vultures on March 13th through March 14th, subsequent scavenging episodes occurred at pig deposition site O2 (Figure 38). This includes scavenging by opossums (Table 21) at 8 days TSD, 16 days TSD, 22 days TSD, and 27 days TSD. Armadillos were noted at the site upon deposition of carcasses, but were not recorded throughout the remaining duration of the study. The first opossum scavenging episode occurred on the night of March 16th. A single opossum was recorded at the site. Elements were not removed however scavenging was assumed. On March 24th, a opossum was also recorded around 12:15 AM sniffing the site before moving out of camera view. Again, no elements were removed, however scavenging was assumed. On day 22, March 30th, an articulated angle and a skin flap were both removed from the site. Both remains were on the edges of the site area and were located in longer grass. Due to their removal, opossum scavenging was assumed. Lastly, on day 27, April 4th, a opossum was captured on camera at 4:10 AM. Due to the presence of soft tissue on the remains, scavenging was assumed, however no elements were removed or dispersed.

Table 21: Opossum Scavenging Summary Table

Carcass	*Elements Interacted with*	*Time of Day*	*Stage of Decomposition*	*Skeletal Modifications*	*Observations*
S1	Long bones, ankles, with adhered soft tissue	Night, early morning	Skeletonization	Removal of bones with adhered soft tissue	Sometimes multiple feeding periods a night, revisiting of site, removal of remains

Carcass	*Elements Interacted with*	*Time of Day*	*Stage of Decomposition*	*Skeletal Modifications*	*Observations*
S2	Skin bag, adhered elements of ankles	Night, early morning	Skeletonization	Removal of bones with adhered soft tissue, gnawing	Sometimes multiple feeding periods a night, revisiting of site, dispersing bone into heavy foliage and tall grass
O1	Skin bag, adhered elements of ankles	Night, early morning	Skeletonization	Removal of bones with adhered soft tissue	Sometimes multiple feeding periods a night, revisiting of site, dispersing bone into heavy foliage and tall grass
O2	Long bones, ankles, with adhered soft tissue	Night, early morning	Skeletonization	Removal of bones with adhered soft tissue	Sometimes multiple feeding periods a night, revisiting of site, removal of remains

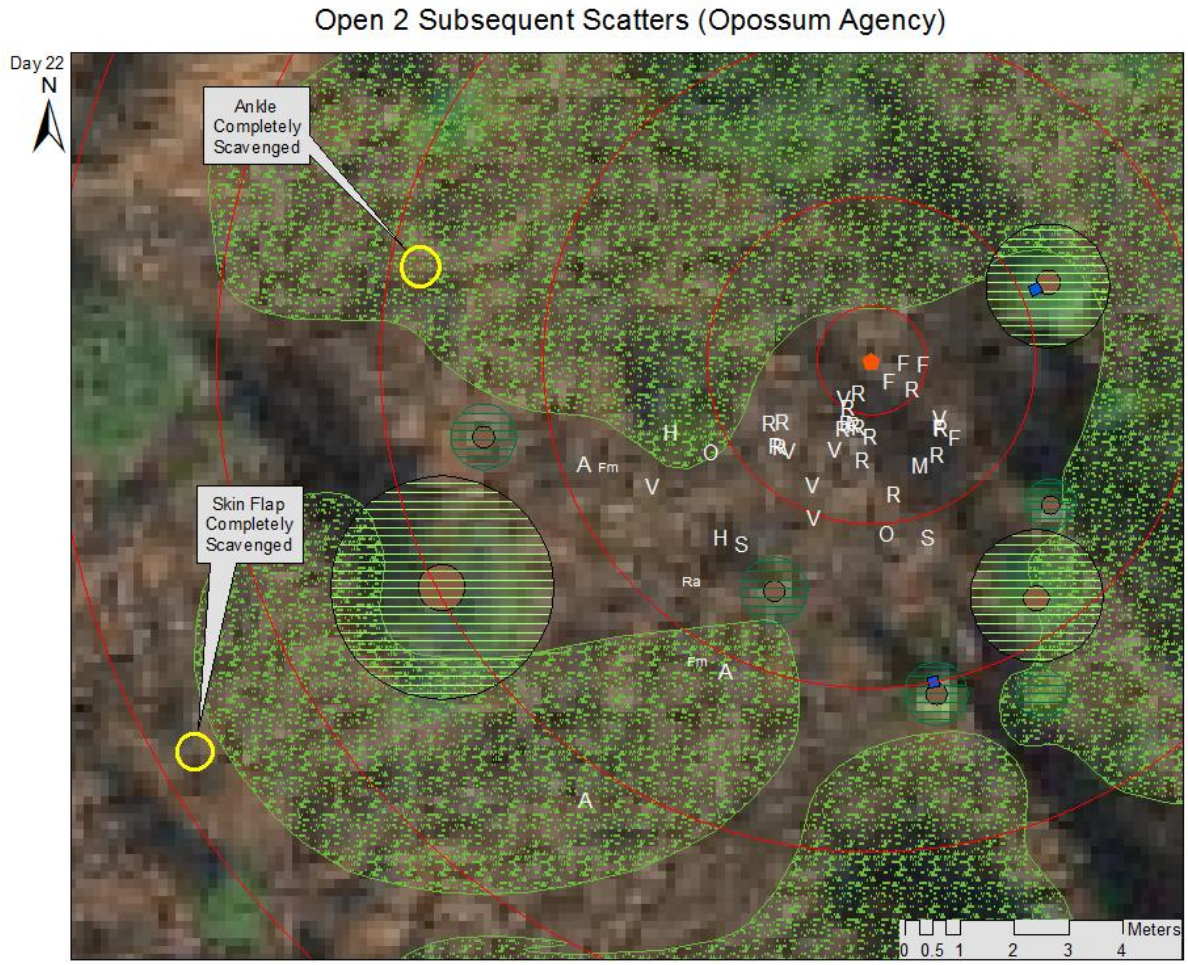


Figure 38: O2 Opossum Scatters

CHAPTER 5: DISCUSSION

The current study is significant because it is the first study to address vulture scavenging and dispersal in Central Florida. In addition, this research delves deeper into the following subjects: decomposition as it relates to body size, vulture scavenging and dispersal in different climates, effects of avian scavenging on tissue consumption and dispersal and the role site foliage plays in dispersal of skeletal elements, as well as sun-bleaching and soil-staining of skeletal elements. The data recorded in the current study will be compared with research from four similar studies (Spradley et al. 2012, Reeves 2009, Beck et al. 2015, Dabbs et al. 2013) in the following chapter (Table 22).

Table 22: Comparison of current study to four similar studies

Study	*Study Species*	*#*	*Duration*	*Location*	*Scavengers Recorded*	*Deposition*	*Dispersal Mapped*	*Carcass Size*	*Confined location*	*Game Cameras*
Current Study	Pig (*Sus scrofa*)	4	March 8th – June 1st	Orlando, FL	Black Vulture Turkey Vulture Opossom	Two in open grassland with no direct overhead canopy, two in pine flatwood forest with canopy	Yes	25-29.5kgs	Yes	Yes
Spradley et al. 2012	Human (*Homo sapiens*)	1	November 19th – June 10th	San Marcos, TX	Black Vulture Turkey Vulture	Grassland, No direct overhead canopy	Yes	N/A	Yes	Yes
Reeves 2009	Pig (*Sus scrofa*) Goat (*Capra aegagrus*)	5	26 days for first two pigs No duration for 3rd pig 10 days for the goat 12 days for the fourth pig	San Marcos, TX	Black Vulture Turkey Vulture	Open grassland, No direct overhead canopy	No	45kgs	Yes	Yes
Beck et al. 2015	Pig (*Sus scrofa*)	2	June 15th – July 17th	Arivaca, AZ	Black Vutlure Turkey Vulture Dog Cat Raven	Desert, one in shade, one in direct sunlight	Yes	27kgs	No	Yes
Dabbs et al. 2013	Pig (*Sus scrofa*)	6	October 2010 – October 2011	Carbondale, IL	Black Vulture Unidentified Large Scavenger	Open grassland, No direct overhead canopy	No	34-193kgs	Yes	Yes

Body Size

This research consists of small-sized pig carcasses around the size of a large child. The pig carcass size utilized in the present study was adapted from research conducted by Goff (1993), which states that a pig carcass approximately 23kg in size is the closest human analogue when evaluating the duration of the decomposition process based on the similar tissue depths, and trunk thickness. While studies evaluating avian scavengers tend to use larger carcasses, Reeves (2009) utilized pig carcasses that were also approximately 23kgs which can provide a direct comparison with this study. However, while Goff asserts that the 23kg pig carcass size may be ideal for comparable soft-tissue decomposition rates, problems arise when attempting to apply scavenging and dispersal data of pig carcasses to that of an adult human (Steadman 2016). There are certainly pros and cons to using pig carcasses as proxies for human cadavers. Obviously, pig carcasses are available in greater numbers, are easier to acquire, can be chosen at specific sizes, and there are fewer legal and ethical clearances to gain in order to work with them. The drawbacks to using pig carcasses, conversely, is their difference in anatomy, and the fact that data collected on pig carcasses cannot be directly applied to human cadavers. The purpose of this research is not to evaluate decomposition rates of carcasses to use as proxies for humans pig carcasses. Since the goal is to study the impact avian scavengers have on consumption, disarticulation, and dispersal of carcasses, these variables should apply across similarly sized mammals.

Table 23: Summary of results across similar studies

Study	*Carcass*	*TSD (Days) for initial vulture scavenging*	*Length of time for primary skeletonization (Days)*	*Site Characteristics*	*Maximum Dispersal*	*% of Dispersal within 3m*	*% of Dispersal within 6m*	*Scavenging Sequence*
Current Study	S1	5	6	Overhead canopy, tall grass, tree trunks	15m	59	77	Viscera, cavities of head & anus, musculature
	S2	5	6	Overhead canopy, tall grass, tree trunks	12m	65	88	Cavities of head & anus, viscera, musculature
	O1	5	6	Tall grass, Chainlink fence	9m	61	92	Cavities of head & anus, viscera, musculature
	O2	5	6	Tall grass	15m	50	85	Cavities of head & anus, viscera, musculature
Spradley et al. 2012	N/A	~7	38	Open area, brush	>15m	N/A	N/A	N/A
Reeves 2009	1st trial	1	3	Open area, brush	N/A	N/A	N/A	Cavities of head & anus, viscera, musculature
	2nd trial	1	4	Open area, brush	N/A	N/A	N/A	Cavities of head & anus, viscera, musculature
	3rd trial	1	3	Open area, brush	N/A	N/A	N/A	Cavities of head & anus, viscera, musculature
	4th trial	1	1	Open area, brush	N/A	N/A	N/A	Cavities of head & anus, viscera, musculature
	control	N/A	26	Open area, brush	N/A	N/A	N/A	Cavities of head & anus, viscera, musculature
Beck et al. 2015	Shade	22	25	Overhead canopy, desert	20m	26 (1m)	84 (5m)	N/A
	Sun	17	18	Brush, desert	27m	21 (1m)	72 (5m)	N/A
Dabbs et al. 2013	RS1	28	38	Open area, grass field	N/A	N/A	N/A	Cavities of head & anus, viscera, musculature
	RS2	1	7	Open area, grass	N/A	N/A	N/A	Cavities of head & anus,

Study	*Carcass*	*TSD (Days) for initial vulture scavenging*	*Length of time for primary skeletonization (Days)*	*Site Characteristics*	*Maximum Dispersal*	*% of Dispersal within 3m*	*% of Dispersal within 6m*	*Scavenging Sequence*
				field				viscera, musculature
	RS3	1	7	Open area, grass field	N/A	N/A	N/A	Cavities of head & anus, viscera, musculature
	RS4	0	27	Open area, grass field	N/A	N/A	N/A	Cavities of head & anus, viscera, musculature
	RS5	N/A	27	Open area, grass field	N/A	N/A	N/A	Cavities of head & anus, viscera, musculature
	RS6	2	4	Open area, grass field	N/A	N/A	N/A	Cavities of head & anus, viscera, musculature

The four pig carcasses used in this research were between 55 (25kgs) and 65lbs (29.5kgs) (Table 23). As a result of their smaller size compared to previous studies like Dabbs et al (2013), Spradley et al. (2012), Beck et al. (2015), and Reeves (2009), dispersal of the remains after the initial intensive scavenging episode occurred over a relatively small area. This was somewhat the result of site foliage and man-made fixtures, specifically the perimeter fence, which will be discussed in the section "Role of Site Foliage", however it was also likely the result of a shorter scavenging period due to a small carcass. The vast majority of elements at all sites, 88% at S2, 77% at S1, 85% at O2, and 92% at O1, were within 6m of the initial deposition site (Table 23). Furthermore, at least 50% of the elements were within 3m of the initial deposition site for all four sites as well.

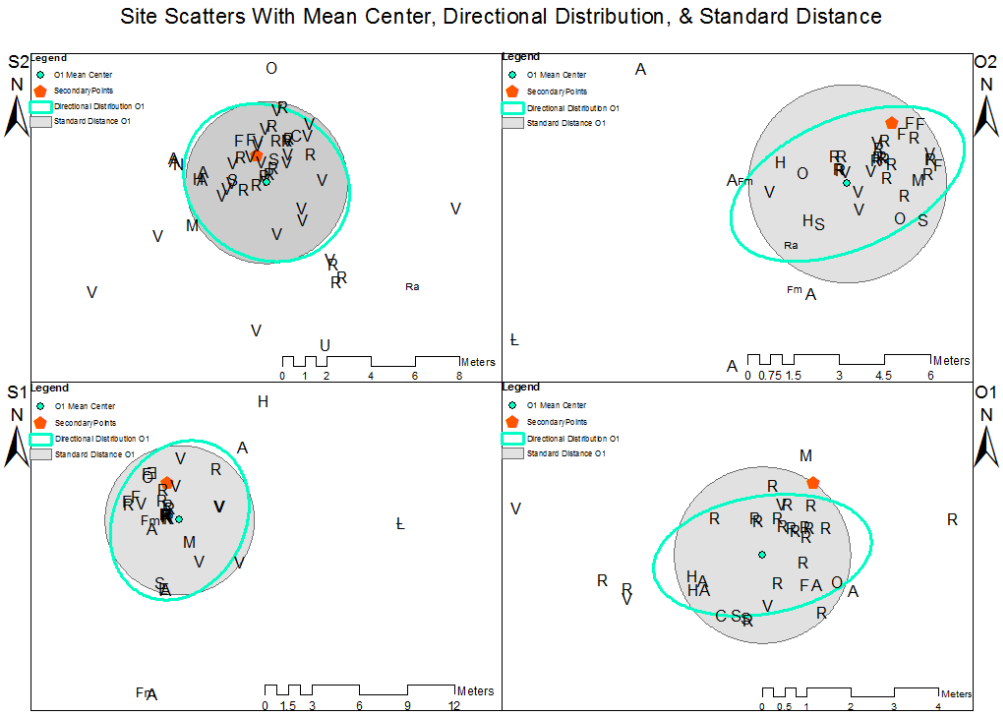


Figure 39: Spatial analysis of all four sites

This is very similar to the distribution and dispersal of elements recorded by Spradley et al. (2012). In their study, a female human cadaver was scavenged and dispersed over a similar area and distance, however this was accomplished over a far greater temporal period, and in fact, the intensive scavenging event in Spradley et al. (2012) resulted in very little dispersal (max distance of about 2m). Unfortunately, neither Reeves (2009) nor Dabbs et al. (2013) specifically evaluated dispersal of their carcasses, therefore comparisons cannot be drawn. Due to the similarity in carcass size, Beck et al. (2015) provided interesting dispersal results consistent with what was recorded in the

current study. The vast majority of elements were within 5m of the initial deposition, and had a similar distribution as sites O1 and O2.

The consistencies in dispersal of elements among small carcass sizes is important to note, because it can be argued via the data presented here that a concentrated dispersal within 5 or 6m of the initial deposition site can help locate the primary dispersal location, at least as it relates to a smaller body (Figure 39). Important evidence like shoe prints, tools, DNA evidence, and personal effects of the deceased (Gardner 2005, Haglund 1997) can be located at the primary dispersal location, meaning this method of using dispersal to locate initial location may yield new evidence. While the pig carcass is not an appropriate analogue for human skeletal dispersal (Steadman 2016), the current research highlights the probability that similar dispersal patterns of human remains may be an applicable method of locating primary deposition sites. Using the concentration of the skeletal remains as a "bullseye" to precisely locate the primary dispersal location (Figure 40) can also indicate the medicolegal relevance of the case, as a deposition site consistent with a transient camp may provide import information surrounding cause of death, where a deposition site more consistent with a clandestine grave may be indicative of a forensically significant death (Dupras et al. 2012).

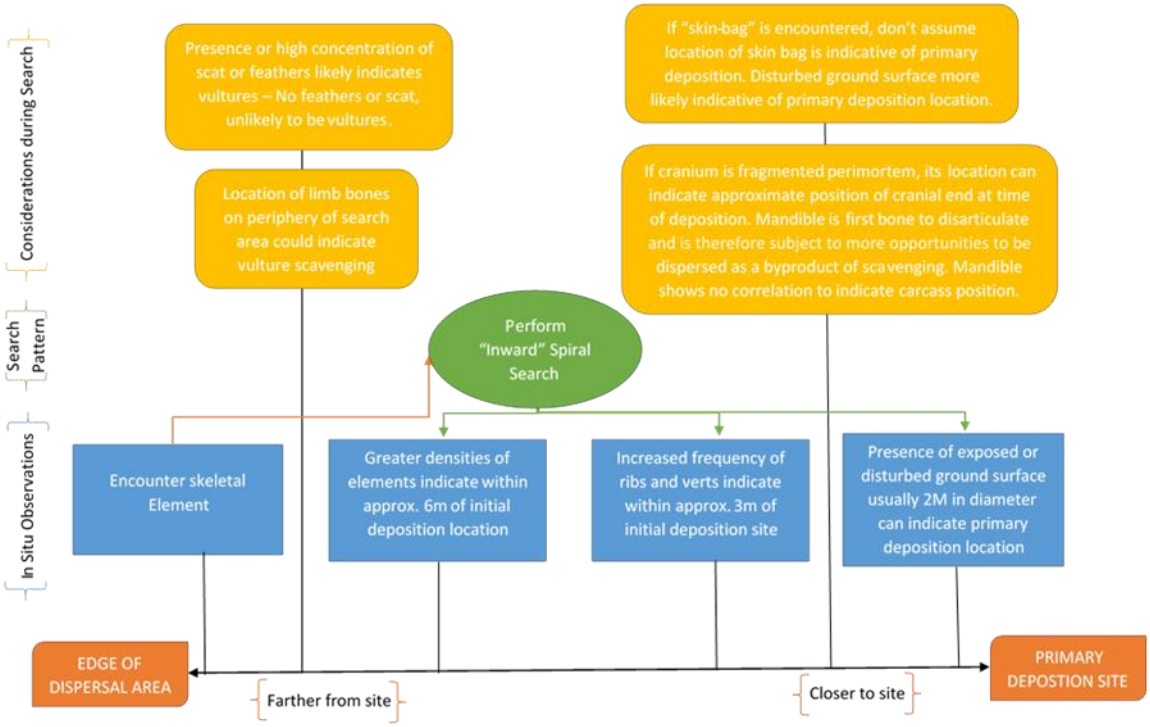


Figure 40: Vulture scavenging site search flowchart

In the current study carcasses were skeletonized between 7 h 25 m and 9 h 5 m of active vulture feeding time (Table 24). The lightest carcass, O2, was skeletonized in the least amount of time, approximately 7 h 25 m, and the heaviest carcass, S2 was skeletonized in the second most amount of time, 8 h 45 m. This indicates that carcass size in the current study may have had an impact on feeding time as there was a general increase in time needed to skeletonize a carcass as the carcass increased in weight.

However, it should be noted that the number of vultures at the site may have affected feeding time, as sites S1 and O1, both with 27kg carcasses, were skeletonized in 9 h 5 m and 8 h 28 m respectively, but S1 had a maximum number of

vultures at one time of 42, while O1 had a maximum number of vultures at one time of 34. This difference in feeding time, despite equal weight, may be attributed to the sites, as both open sites, O1 and O2, were skeletonized in less time than the shaded sites, S1 and S2, with carcasses of comparable size.

Due to the periodic nature of the scavenging presented in Dabbs et al. (2013), it is difficult to draw a conclusion, however it should be noted that their study did not draw the same number of vultures and therefore did not seem to be a correlation between carcass size and amount of time it took to reach skeletonization.

Table 24: Summary table of scavenging of pig carcasses

Specimen	*Weight*	*Date and Time of Deposition*	*Date and Time of Vulture Arrival*	*Lapse Between deposition and arrival*	*Max Vultures*	*Feeding Time*	*KADD Required to Reach Bloat Stage*	*KADD Required to Reach Skeletonization*
S1	60lbs	3/8/16 14:15	3/13/16 10:50	116 h 25 m	42 11:15 AM	9 h 5 m	590.745	1479.64
S2	65lbs	3/8/16 14:15	3/13/16 11:15	117 h	43 11:43 AM	8 h 45 m	590.745	1479.64
O1	60lbs	3/8/16 14:15	3/13/16 11:23	117 h 8 m	34 6:03 PM	8 h 28 m	886.673	1479.64
O2	55lbs	3/8/16 14:15	3/13/16 11:48	117 h 33 m	44 12:38 PM	7 h 25 m	886.673	1479.64

The research conducted by Spradley et al. (2012) indicated a slightly different relationship between body size and consumption rate. They used a human female carcass, which can be reasonably assumed to weigh between 110lbs and 160lbs, which was skeletonized in "less than 5 h" with a vulture maximum of "over 30" (Spradley et al. 2012). This is significantly faster skeletonization time than the results of the current study. Furthermore, the study site in Spradley et al (2012) was an open area with little foliage, as determined via inspection of photography. While an open environment facilitating scavenging is consistent with the current study, the consumption rate is not comparable across studies. By dividing approximate minutes of consumption time by approximate weight of the cadaver in Spradley et al. (2012)(280min/135lbs=2.07min/lb) we can conclude that one pound of soft-tissue was consumed approximately every two minutes during Spradley et al.'s (2012) study, while using the same equation, the current study resulted in 8.09min/lb for O2, and 8.47min/lb for O1 which is considerably longer. This does not even account for the vulture maximum recorded for all three carcasses, which were higher for O2 and O1, 44 and 34 respectively, than the human carcass which was "over 30". A reasonable assumption would be that the larger long bones of the human cadaver unequally skewed the overall weight of the cadaver compared to the pig carcasses which have relatively small long bones and limbs.

The research conducted by Reeves (2009), is more consistent with the current study. In Reeves (2009), a 60lb (27kg) pig was skeletonized in an open environment in approximately 2 h 39 m, with a vulture maximum of approximately 35. This is very similar to the current study in carcass size, vulture maximum, and deposition site,

however Reeves (2009) experienced skeletonization in 159 minutes. Using the same equation as used in the previous paragraph, this results in 2.65 minutes to consume one pound of soft-tissue. This is more than three times faster than scavenging in the current study, however it is somewhat more consistent with the estimation from Spradley et al. (2012). It is important to note that Reeves (2009) included other carcasses in her study, however these did not experience a single intensive scavenging event similar to the ones recorded in the current study, and therefore are difficult to compare.

The carcasses in the current study were scavenged in a somewhat consistent manner, albeit with some slight differences and distinctions that will be discussed in the following section and section "Avian Scavenging". Consistent among all carcasses, was that the vulture scavenging sequence began by scavenging at the cavities of the head and the anus. The only difference was with carcass S1. The intestines breached the lower abdominal wall during the bloat stage, therefore the vultures directed scavenging to the lower abdomen and the exposed viscera instead of the anal cavity. The vultures focused on the cranial end due to the presence of fly larva occupying the oral, nasal, and ocular cavities. The vultures fed on the larva until they were no longer availably, and then the vultures focused on the soft-tissue of the throat and neck. Usually, the entire skull would be ejected from the carcass during the beginning of the scavenging episode due to the previous consumption of soft-tissue by fly larva.

After the skull is ejected from the carcass, typically the carcass is scavenged through the hole created in the neck as well as the hole created in the lower abdomen.

The viscera is the first tissue to be consumed by the vultures, but after the carcass has been eviscerated the abdominal hole will be used to feed on the musculature of the lower body. During this stage the ribs and vertebrae will be removed while the carcass is rotated, rolled, dragged, and deformed throughout the site.

Scavenging of the musculature and remaining soft tissue continues until the carcass is reduced to the point of mainly skin and bones. The carcass is usually greatly deformed at this point. At this stage, the skeletal elements begin to disarticulate and limbs can be removed, oftentimes with the skin pulled inside-out still attached. The two skin bags recovered were pulled inside-out during this stage as the elements are scavenged and pulled but still articulated. Once the skin rips the long bones, scapulae, and os coxae are dispersed. These elements are generally picked at by vultures for a long period of time, but it was consistent across all sites for the limbs to be almost completely articulated still after departure of vultures.

This general sequence of carcass scavenging was recorded at all four sites in the current study, which is consistent with the scavenging sequence recorded by Dabbs et al. (2013) however, the scavenging sequence in that particular study took place over multiple days. Scavenging sequence was also similar compared to Reeves (2009) which recorded the same sequence of anal cavity first, with tissues of the head, and abdomen following. Similarly, the mandible was the first element to be disarticulated in all pig trials conducted by Reeves (2009). Spradley et al (2012) does not go into detail regarding

scavenging sequence of the human cadaver, and Beck et al. (2015) only mentions the vultures focused on the caudal end first.

The consistent scavenging sequence attributed to vultures is significant because it creates an expectation for which trauma can be compared to. Understanding the sequence that vultures will scavenge a carcass provides a new line of evidence that can positively affect TSD estimations. Scavenging of the anal region, lower abdomen, and facial orifices could be indicative of early vulture scavenging sequence as opposed to canid scavenging tendencies of scavenging the face first and working caudally (Haglund 1997), or scavenging the viscera via the paunch then proceeding to eat the musculature of the quarters (Haynes 1980).

Climate

The climate of Central Florida differs from the climates in which similar studies have occurred. Dabbs et al.'s (2013) study was conducted in southern Illinois, and while climate was not a main focus of the research, they mention that the cold temperatures experienced during the winter months resulted in only 3.3 ADD over the course of 28 days, however decomposition was continuing despite the temperature not rising above 0°C. This is an issue not experienced in Central Florida as the temperature rarely dips below 40°F on the coldest days of the year. Furthermore, the study conducted in southern Illinois recorded carcass deposition dates in December, October, September, and late August, which affected the decomposition stage of the carcass at first arrival of vultures

(Dabbs et al. 2013). There is no mention of average temperature, or rainfall over the course of the research.

Spradley et al.'s (2012) study took place in San Marcos, Texas where the mean annual temperature is 60°F with summer highs of over 90°F and lows of 40°F during the winter months, with every month with the exception of December and January posting recorded highs of over 90°F (Dixon 2000). Spradley et al. (2012) state that the cold weather in late November delayed bloat for over a month which resulted in a long interval between deposition and skeletonization. The average daily high from day after deposition to skeletonization was 11.39°C and the average daily low was 2°C (Spradley et al. 2012) which greatly hindered decomposition. Extended periods of temperatures this low are unrecorded in Florida. Since decomposition rate is so dependent on temperature this is a tremendous difference between Florida and any other region on the continental US. Reeves' (2009) study also took place in San Marcos, Texas at Freeman Ranch, however the deposition periods encompassed the summer months which are more similar to the summer months in Central Florida. Reeves did not explicitly state information pertaining to the weather over the course of her research, however it can be gleaned that the weather did not hinder the progression of decomposition in anyway, and the carcass decomposed uninterrupted.

Beck et al (2015) conducted their study in southern Arizona. Over the course of the study period the average high was 33.61°C and the average low was 2.78°C. Rainfall was mentioned as having occurred during the first few weeks of the experiment and

acting as a deterrent for vulture scavenging of the remains. This massive swing in average temperature and amount of rainfall are incomparable with the current study. This is significant due to the fact that southern Arizona and Central Florida may appear to be have similar climates, however the relatively arid desert with huge swings in temperature are in vast contrast to the consistently warm and humid weather of Central Florida as a region.

The difference in climate data among similar studies strengthens the argument that similar research is necessary in multiple regions across the US in order to better comprehend the role climate plays in decomposition rate, with particular focus given to regional scavenging. This difference in environments, even those that on the surface would appear to be similar (IE: Southern Arizona, Central Texas, Central Florida), highlights the relevance of this type of research and its potential use and application in research and the legal system. Not only is research into regional climates and their effect on decomposition necessary as it pertains to scavenging, but the rate of weathering varies across regions and is based on a multitude of variables that are major factors when attempting to estimate PMI from weathering stage (Ubelaker 1997).

Avian Scavenging

Avian scavengers behave differently, and are capable of different interactions with forensic remains compared to the most common terrestrial scavengers, dogs and coyotes. Primarily, their collective ability to fly and access otherwise secluded remains

sets avian scavengers apart from terrestrial scavengers, therefore access needs to be considered when evaluating evidence of scavenging and decomposition. Additionally, it may be possible to determine the difference between avian scavenging and scavenging as a result of canids.

The avian scavengers present in the current study were limited to three specific species of bird: the black vulture (*Corygyps atratus*), the turkey vulture (*Cathartes aura*) and the bald eagle (*Haliaeetus leucocephalus*) (Table 25). Neither of these species are specific to the central Florida region, however the turkey vulture and the bald eagle are not common scavengers reported in currently available forensic research on scavenging. Furthermore, all three species were documented as being involved in the primary mass scavenging event that occurred at five days TSD, however in different capacities.

The black vultures were responsible for the majority of the soft tissue scavenging that was recorded during the mass scavenging event. Black vultures were the first avian scavenger to contact the remains in all four sites, however it is unclear if the detection by black vultures wasn't facilitated by the behavior of the turkey vultures. Furthermore, black vultures scavenged the remains in far greater numbers than any other species and for a longer period of team, being the first to arrive and the last to leave. The behavior exhibited by black vultures was also far more aggressive than the other scavengers (APPENDIX A, Figure 51). The majority of the conflict-induced dispersal was a result of black vultures fighting over pieces of tissue, sometimes setting off the entire wake into a feeding frenzy.

Table 25: Avian scavenger recorded in the current study

Species	*Sites*	*Approx. #*	*Dispersal rate**	*Time of arrival*	*Behavior*
Bald Eagle (Haliaeetus Leucocephalus)	S1, O2	1-2	Low	After majority of tissue loss and dispersal	Passive, predatory
Black Vultures (Corygyps atratus)	All	30+	High	Initiated scavenging and dispersal	Aggressive, rapacious
Turkey Vulture (Cathartes aura)	All	3-7	Low - Med	Shortly after beginning of scavenging and dispersal	Passive, cautious

*Based on video evidence of impact on dispersal in the current study

The turkey vultures were the second most active avian scavenger at all four sites. They scavenged in far fewer numbers than the black vultures and fed for much shorter intervals, which can possibly be attributed to their less aggressive behavior. Like the black vultures, however, they fed for almost the entire duration, off and on, of the mass scavenging event. While they were involved for a long duration of time, it did not appear that they had a large impact on amount of tissue consumption or disarticulation and dispersal. It is clear after reviewing the footage of each deposition site that the black vultures were most responsible for the rapid consumption of soft-tissue, and their presence in a region should greatly impact TSD estimates (APPENDIX A, Figure 52).

The bald eagle was also recorded during the mass scavenging event. The relationship of the bald eagle to the scavenging event was vastly different compared to the vultures recorded in this research. The bald eagle was only recorded at two sites, S1 and O2, and did not show up until well after the majority of the soft-tissue was consumed and the skeletal elements were already being dispersed. Furthermore, the bald eagles

recorded fed for very short intervals of time, and were not nearly as aggressive as the black vultures while scavenging. The turkey vultures and black vultures did not seem to mind scavenging alongside the raptors, however, when a juvenile bald eagle at site O2 made a swift movement towards a disarticulated limb, the vultures feeding around it jumped out of the way. This is consistent with the small number of reports of bald eagles preying on vultures (Coleman & Fraser 1986). While they have been reported to feed on vultures, it is unlikely this behavior occurs often as the large communal roosting behavior of vultures is a likely deterrent of predation (Coleman & Fraser 1986). Bald eagles were observed one at a time, however, both a juvenile and an adult were recorded at site S2, they were never captured in the same frame, so it is unknown if they fed together or fed separately. Furthermore, it can be assumed that carrion represent an opportunity for an easy meal that bald eagles will not pass up in Central Florida.

The behavior such as inter and intraspecies conflict acting as a catalyst for dispersal and the subsequent impact that scavenging black and turkey vultures had on the carcasses recorded in the current study is consistent with what was recorded in similar studies. However, no other similar studies reported scavenging by bald eagles, or discussed the drastic impact that vulture scavenging had on the deposition sites. While bald eagles are documented in every state of the contiguous US (Bull & Farrand 1987), the seasonality of their residence is not always consistent. They are sea eagles and are more commonly found in coastal areas (Bull & Farrand 1987), which explains their appearance in the current study and not those studies conducted in southern Illinois (Dabbs et al. 2013), Central Texas (Spradley et al. 2012; Reeves 2009), and southern

Arizona (Beck et al. 2015). Vulture scavenging and behavior had a large impact on each site. Specifically the vultures modified the site by destroying the original forensic context of the site. This included digging with the beak, scratching of the ground surface with the talons, defecating on the site, destroying and removing both groundcover in the form of leaf litter and twigs and branches of trees near the ground surface. These modifications can severely impact the original forensic context at the time the carcass was deposited and therefore must be considered when evidence of vulture scavenging is encountered in the field. In addition, this study recorded the highest number of vultures at a single site at one time which was 43. In comparison, Spradley et al. (2012) only recorded a vague maximum of "over 30".

Canids are the most regularly reported scavengers of human remains and are capable of modification of tissue, consumption of remains, dispersal of skeletal elements and alteration of the scene, much like avian scavengers are capable of (Haglund 1997). It was determined that canid scavenging occurs in a consistent order which is particularly true for bodies scavenged prior to other forms of decompositional modification (Haglund 2006). This sequence typically involves consumption of the face and neck of the individual first, followed by disarticulation of the upper extremities from the body and consumption of the viscera. Further disarticulation of the lower body ensues, followed by extensive gnawing and dispersal of long bones and elements of the axial skeleton (Haglund 2006). This is in some ways similar to the scavenging sequence of avian scavengers recorded in the current research, however gross consumption of soft-tissue is drastically different. Vultures used preexisting openings to consume soft-tissue, and

would not consume the skin of the carcass, whereas canids removed and shredded through the skin of the individuals used by Haglund (2006) as case studies. Even greater differences exist in the skeletal modifications between avian and canid scavengers. The current research did not specifically note any skeletal modifications as a result of vulture scavenging, however canid scavenging is always associated with excessive gnawing and destruction of bone (Haglund 2006). Clearly the difference in dentition between canid and avian scavengers has a large impact on skeletal modifications, considering vultures do not possess the dentition needed to gnaw or destroy bone in a matter similar to canids. Further differences are evident in the comparison between canid dispersal and avian dispersal tendencies. Canid scavengers possess the ability to disperse bones great distances (Haglund 2006) however the majority of the remains are recovered within 100m of the initial deposition site. This is a much larger area than what was seen in the current research, where avian scavengers dispersed remains within a 15m radius. This may indicate that terrestrial scavengers are more apt to remove tissue for consumption at a later location, where avian scavengers appear to consume tissue at the site, meaning dispersal by avian scavengers occurs as it is consumed. Furthermore, Haglund (2006) states that upper extremities are recovered infrequently due to the scavenging sequence of canids. No remains were noted specifically as missing after vulture scavenging in the current study which indicates that presence of the upper extremities may be a good indicator of scavenger type.

The unique avian scavengers and their behaviors recorded in the current research should help others adjust forensic TSD estimates based on quantity of birds, and the

specific species residing the in area. Black vultures are common to the southern half of the contiguous US, and therefore are not found in abundance in the north, or at all in southern Canada (Avery 2004). Since black vultures were the greatest consumers during the scavenging event it can be extrapolated that scavenging by all vultures will be greatly accelerated in the regions where black vultures are present. Turkey vultures are common throughout the US, and have summer ranges that spread into southern Canada, however they do not consume soft-tissue at the same rate as the black vulture as a result of their smaller feeding numbers, less rapacious appetite and passive behavior. It could be assumed that the further south, and deeper into black vulture territory carrion is deposited in, the quicker skeletonization will be achieved. By applying this to medicolegal contexts in both the northern and southern US, you can temper expectations on the time interval skeletonization should be achieved in due to avian scavenging. Obviously the entire biome needs to be considered when establishing accurate TSD predictions, since the northern US may lack black vultures but is abundant in terrestrial scavengers not seen in the southern US, like wolverines and badgers, etc, however, in instances when a carcass is unreachable by terrestrial scavengers the current study could serve as an aid in TSD estimation.

Site Foliage and Dispersal

In the current study the dispersal of the carcass was not only the result of scavenging behaviors of vultures, eagles, and opossums, but it was heavily influenced by

the foliage and structures adjacent to the deposition site. While the deposition sites were categorized as either heavy shade, or direct sunlight, each of the four sites displayed unique site characteristics that were found to impact dispersal patterns.

As previously mentioned, two pig carcasses were deposited in heavily shaded environments (S1, S2), and two pig carcass were deposited in environments with direct sunlight for nearly the entirety of the day (O1, O2). This was included to determine whether site canopy influenced scavenging, and also to determine how site canopy influenced bone staining in the form of sun-bleaching and soil-staining. Sun-bleaching and soil-staining will be discussed in the section titled “Sun-bleaching and Soil-staining”.

Contradictory to the assumption that a denser canopy would increase time to discovery, canopy density did not appear to influence scavenging. While site S1 and S2 were the first to be scavenged during the mass scattering event, they preceded scavenging of O1 by only approximately eight minutes. Furthermore, scavenging of S1 25 m prior to S2 is more likely attributed to the fact that the small intestines had ruptured through the abdominal wall during the bloat stage. Undoubtedly this released VOCs that attracted turkey vultures which in turn attracted black vultures. It can be assumed that due to the rupturing of the lower abdomen, this acted as a signal to the committee of vultures that the carcass was in fact a deceased animal, rather than a sick, or sleeping one. This idea is reinforced by the fact that vultures were seen in the area but did not scavenge the carcasses for five days and show little hesitation when scavenging roadkill, which almost always exhibits external trauma. Black vultures showed no hesitation in scavenging the

intestines of the S1 carcass, which is contrary to the initial hesitation shown at S2, O1, and O2, where black vultures cautiously approached complete, intact carcasses. Furthermore, it can be argued that the close proximity to S1 may have facilitated discovery and scavenging of sites S2 and O1. Sites S2 and O1 were both closer to S1 than to O2, and perhaps the naturally progression of discovery occurred from southwest corner to northeast corner as feeding vultures on the periphery of site S1 located O1 or S2. This could also explain the nearly identical discovery times of site S2 and O1, separated by only eight minutes.

The amount of time it took to achieve bloat should be taken into consideration, however, when determining the cause of longer discovery periods for O1 and O2. These sites took between 30 minutes and 1 hour longer to be discovered than S1 and S2, but unlike S1 and S2, did not achieve bloat until a day later, a KADD of 886.673 as opposed to a KADD of 590.745. Since the bloat stage is an important period of active decomposition where putrefaction and release of VOCs is greatest, the accumulation and dissemination of VOCs into the lower atmosphere and thus the attention of the turkey vultures may have been negatively affected by the retardation of the bloat stage. Direct sunlight retarding the process of decomposition has previously be documented (Galloway 1997; Bass 1997; Mann et al. 1990), however it is not entirely known why. Some assumptions relate to the dehydration rate of soft-tissue exposed to direct sunlight, however this has yet to be confirmed (Galloway 1997). Considering this, it may be assumed that sites O1 and O2 were less detectible to vultures which may explain why

they were last to be discovered, despite not having any overhead canopy. However, more research in this area needs to be completed in order to confirm this assumption.

The research conducted by Beck et al (2015) further confirmed there appears to be no relation between canopy densities and scavenging, however, unlike the current research, they noted the "sun pig" as being scavenged first, and skeletonized quicker. It should be noted that the southern Arizona desert is home to more terrestrial scavengers than Central Florida and their interactions with the carcasses played a role in decomposition rate as well by altering soft-tissue mass, and access to the carcass, thus making comparisons between studies difficult.

The pig carcasses studied in Dabbs et al. (2013) were all placed in what would be defined as direct sunlight for the purposes of the current research. They recorded a wide range of "lapse before arrival" of vultures of 2 h and 45 m to 28 days. This illustrates the unpredictability of scavenging, and places the temporal periods of the current study in perspective. It's more than likely that the differences recorded in scavenger discovery and onset of bloat are well within the natural ranges of variation and are simply more noticeable due to a small sample size. Furthermore, Dabbs et al. (2013) confirm that any carcasses deposited at the same time were skeletonized at the same time, regardless of season. While there study did see the placement of pig carcasses in close proximity to one another, it is unclear if that has any correlation to scavenging, or for that matter, what constitutes "close proximity" when dealing with vultures that rely on olfactory sense rather than sight to locate carrion.

The ability of site foliage to influence dispersal of remains and skeletal elements is unique to outdoor surface scatters. The current research noted consistent influence on dispersal by the same types of foliage across all four deposition sites. Common across all sites (Figures 23, 26, 29, 32) was the tendency for skeletal elements and remains to be confined to areas of no grass, or very short grass. This is likely caused by the behavior of the scavenging animals responsible for the dispersal. In the current study, the majority of the dispersal was perpetrated by vultures, which are lightly built animals. They weigh approximately 3 to 4kgs, therefore, waist-high tall grass is unmanageable to move through. Furthermore, their feeding behavior consisting of intraspecies competition and rapacious feeding, means multiple birds are consuming soft-tissue and moving the carcass at the same time. Coupled together, this results in the carcass and elements being shifted and moved around open areas accessible to vultures.

It is hard to confirm these findings in currently published research due to the lack of information provided pertaining to site foliage and other helpful characteristics. Generally, it was ascertained that the elements tended to disperse from higher elevations to lower elevations during scavenging (Spradley et al. 2012), however direct influence of foliage on dispersal was not explicitly discussed. The research conducted by Spradley et al. (2012) appeared to take place in a large, wide-open with no grass and sparse shrubbery. Consequently, the scatter and dispersal appeared to be fluid and followed a random progression. Furthermore, Beck et al. (2015) also appeared to conduct their experiment in a somewhat open environment. Unfortunately, they provide no pictures or maps detailing foliage from which a conclusion can be drawn.

With the knowledge that vulture dispersals are likely scattered in short grass or on exposed ground, the location of elements can provide an approximate idea of the site characteristics at the time of the dispersal. Skeletal elements scattered in short grass can indicate vulture scattering that occurred recently, however scattered elements in taller grasses, and denser foliage can indicate vulture dispersal that occurred sometime prior to regrowth of the foliage. Further supplementation of element staining and drying can help make these assumptions easier, however more research needs to be done on the subject in order to accurately predict site characteristics at the time of scavenging and dispersal.

In contrast, the opossum scavenging and dispersal recorded in the current study demonstrated a tendency of dispersal, usually of complete limbs or large articulated remains, into thicker and denser foliage. This is very different from the tendencies of vulture scavenging (Pokines & Baker 2014, Spradley et al. 2012, Dabbs et al. 2013, Reeves 2009), and when encountered at a freshly altered scene, one can conclude that opossum agency is the cause of the specific dispersal. The ability to make this assumption drastically decreases as site foliage grows and thicker and denser as opportunistic weeds take root in the newly disturbed open area of the primary deposition site. For this reason a scatter that took place a long period of time before analysis will not be able to be identified as specifically opossum or vulture dispersal without in situ evidence like feathers, or scat, and even then it is not a certainty.

CHAPTER 6: FUTURE CONSIDERATIONS AND CONCLUSIONS

Future Avenues of Research

Throughout the duration of the current study it became clear that multiple avenues of research were necessary in order to better understand vulture scattering and dispersal as well as taphonomic staining of skeletal elements. Since the current research is the first known attempt to study vulture scavenging and dispersal in Central Florida, the foundation for future research has been established, however limitations have been discovered that must be addressed if possible in future research.

Firstly, the current study could be reproduced in several different ways. This includes depositing and recording decomposition of a single pig carcass for a three month period coinciding with a season. This could help elucidate the role, if any, seasonality has in vulture numbers or behavior and the resulting impact this may have on dispersal and subsequent staining of skeletal elements. Additionally, by reducing the number of pigs at the site to only a single carcass, this will better represent type of depositions that vultures would naturally encounter and may be more indicative of consumption and dispersal patterns that would be encountered in a medicolegal context.

Furthermore, research could be conducted using different sizes of carcasses. It's commonly known that the number and size of bones differ between juvenile and adult pigs, which will drastically alter how carcasses are scavenged and dispersed by vultures. Understanding the extent of time it takes for vultures to skeletonize a 25kg pig compared to a 50kg or 75kg pig could help determine how body size impacts scavenging times and

dispersal if at all. This information is vital to understand how vulture scavenging behavior may be altered depending on body size as it applies to medicolegal contexts. The pig carcasses utilized in the current study represent the smallest justifiable size to research because anything smaller would likely consumed in its entirety (bones and all), but applications of the research are limited by the smaller carcass size.

In regards to dispersal of elements by vultures, more research is necessary to comprehend the role if any that ground elevation plays during the dispersal process. Spradley et al. (2012) noted in their research that elements dispersed from higher to lower ground, however that was not a focus of the current study and would be important information to attain in the context of Central Florida which is mostly flat. While gravity indicates that bones will accumulate downslope of the original deposition, it should be determined if vultures are capable of dispersing elements uphill, or if there are specific elements more prone to uphill or downhill dispersal as a result of vulture activity. This information would further assist in shaping search techniques designed for use in the event of vulture dispersal.

To better understand the scavenging behavior of vultures, it would also be important to understand the role that trauma may have on vulture detection rate of carcasses. It was posed by the author of the current research that the scavenging of the carcasses after five days in situ despite numerous vultures spotted circling above and perching in the trees may have been the result of a lack of an outward sign of trauma or indicator of death. While the pigs were euthanized via gunshot wound to the frontal bone,

which is inherently a trauma, euthanasia was done off site and therefore no outward indicator of trauma was visible at the research site and the bullet hole was nearly invisible due to placement of the carcass. Vultures facilitate much of the scavenging that occurs on roadkill, and first scavenging of fresh roadkill rarely takes five days after death in Central Florida. The main difference is that most animals killed by collision with a vehicle exhibit outward trauma in the form of exposed viscera, blood loss, and disarticulation. The truly understand this mechanism and its effect on vulture scavenging. The study should be reproduced using either multiple carcasses that have been split, or bisected in different ways, or a mixture of both intact carcasses, and ones that have been altered by trauma in order to record vulture scavenging times, and any effect on dispersal that may not be predicted. Understanding the role that trauma plays in vulture discovery and subsequent scavenging is integral to understanding vulture scavenging in a forensic context, as any carcass deposited in a secondary location as a result of criminal acts has a relatively high probability of external signs of trauma.

In addition to shortcomings of research on vulture scavenging, very little information is available on the forensic impact opossums have on consumption of soft-tissue, bone modification, and dispersal. Clearly this is a direction forensic research needs to explore due to the prevalence of opossums throughout the US. The current research has exposed a greater need for information regarding opossum behavior and diet as well.

Not only could the current study be reproduced and altered to test different variables, but the current study in its current form provides a standard format that can and

should be implemented across different geographical regions in order to standardize research efforts. This would result in consistently recorded data that would allow for better comparisons. One of the greatest challenges of the current study was the comparison across presently published research. By providing a template for data collection and tested variables, consistent conclusions and better comparisons could be drawn between future research. The currently published research on the topic of vultures scavenging, consumption, and dispersal has been ambitious, but there is no consistency across studies. The relatively low-cost design of the current research and the broad range of measurables allow for collection of numerous data that is easily compared to studies utilizing the same standard format.

Conclusions

Despite the recent increase in research related to vultures as a taphonomic agent in decomposition and dispersal there is still much that needs to be studied before all the variables that affect how and why vultures scavenge and disperse skeletal elements when and where they do. While the current study did not find any correlation between canopy and vulture scavenging, it was learned that vultures in the Central Florida region are highly destructive of the environment during scavenging, and are directly manipulated by the foliage at the depositional site. Furthermore, the amount and variety of scavenging as a result of opossums and bald eagles in Central Florida is valuable information regarding known scavengers in the region.

The most important information learned as a result of the current study is the large impact vultures have on consumption of remains and dispersal of skeletal elements in the Central Florida region that must be considered by investigators when attempting to evaluate a forensic scene. The rate of soft-tissue consumption capable by a large wake can accelerate early decomposition to the point of skeletonization in less than a week. Combining that with the large area of elemental dispersal vultures are capable of results in an impressive ability to completely obliterate a surface deposit. Vulture activity of this magnitude does leave signs that can assist the anthropologist in locating the primary deposition location. These include feathers and scat, the disturbance of the ground surface at the location of the primary deposition, the concentration of specific skeletal elements like ribs, vertebrae, and bones of the skull indicating primary deposition location, and the modification of foliage in the vicinity of the primary deposition in the form of broken branches, trampled foliage, and small pits dug with beaks. However, this very same modification of initial deposition site can change and destroy forensic context and therefore vulture impact on the site must be noted and accounted for. With the application of this knowledge in a forensic context in Central Florida, it can be reasonably assumed that this knowledge would aid in the location and retrieval of remains in the field, and the reconstruction of the context surrounding the primary deposition location.

Further research into avian scavenging and dispersal as they pertain to regional variation is needed in order to fully understand their effects on TSD estimates. With more regional variability recorded, further comparisons can be made, and only then will the current study reach its full potential as valuable data on scavenging, and dispersal in

Central Florida. An attempt was made in this study to establish a protocol for interpreting dispersal as a result of vulture scavenging in Central Florida. This information, if compiled by geographic region over the course of future studies, can be used to train individuals in search techniques, and identification of vulture scavenging according to the region in which they are employed.

APPENDIX A: PIG CARCASS S2

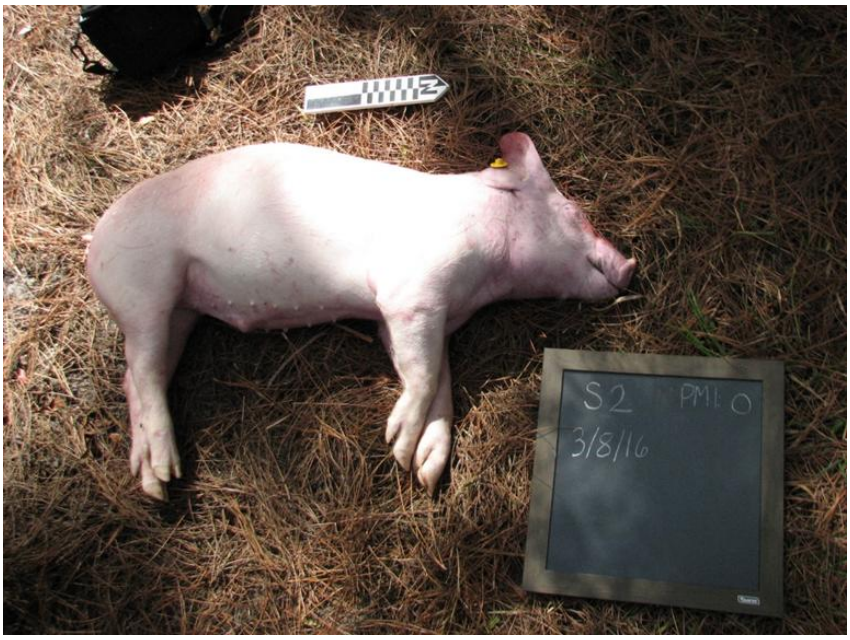


Figure 41: Carcass S2 Fresh Stage Day 0+2h

Figure 42: Carcass S2 Early Decomposition Stage Day 1

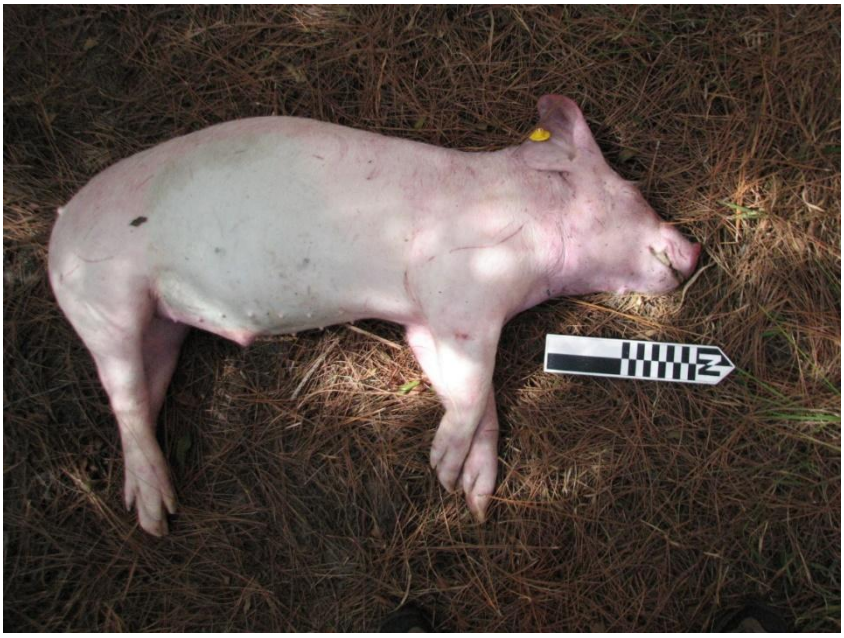


Figure 43: Carcass S2 Early Bloat Stage Day 2

Figure 44: Carcass S2 Bloat Stage Day 3

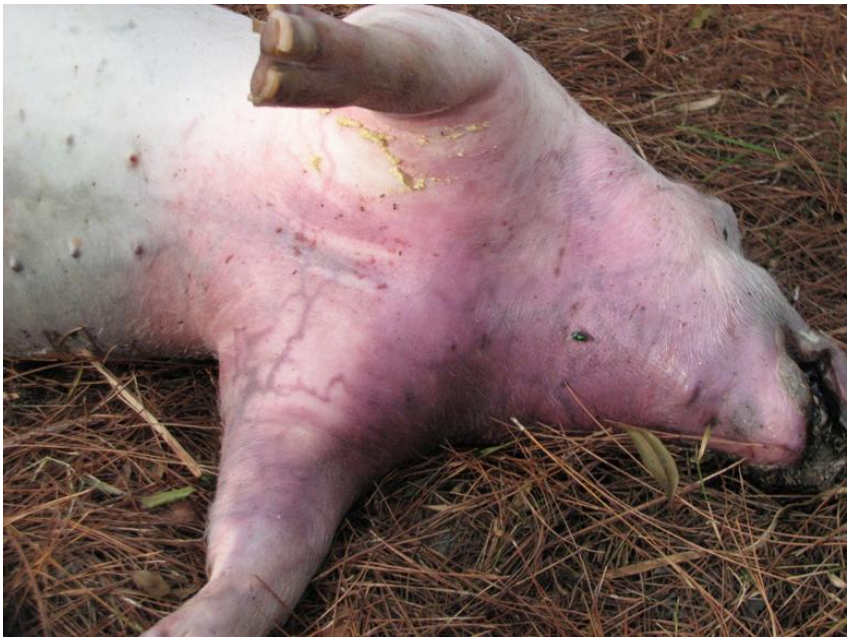


Figure 45: Carcass S2 Bloat Stage Day 4 with marbling of the chest and neck

Figure 46: Carcass S2 Active Decay Stage Day 5 with maggot masses under the lips and the skin of the chin and skin slippage of the chin.

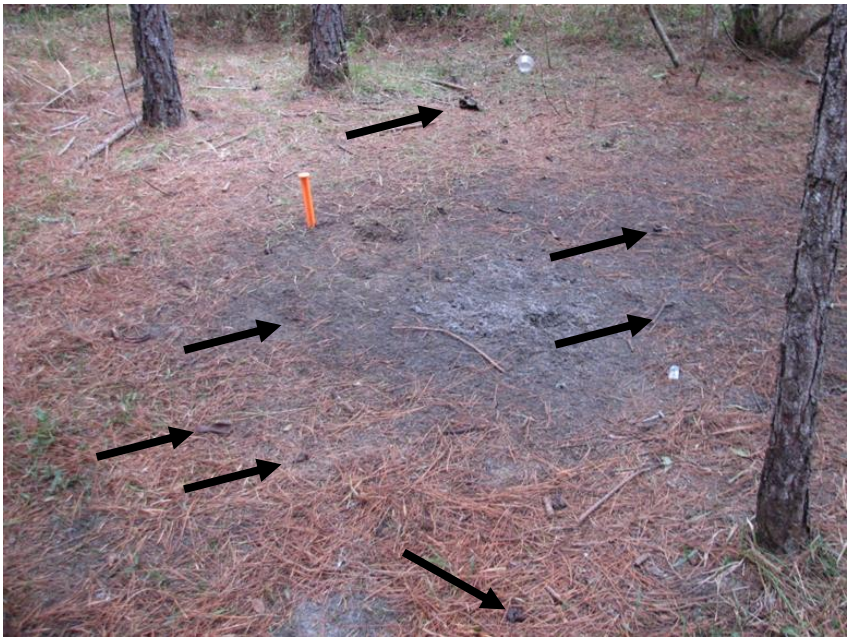


Figure 47: S2 Site Day 6 - Image of the site after intensive vulture scavenging; note the disturbed ground surface cleaned of pine needles with elements scattered throughout (arrows).

Figure 48: Carcass S2 Day 6; Note the adhered long bone elements still attached to the skin bag. The skin was turned inside-out and is greasy, and wet in the picture.

Figure 49: Turkey vulture feeding on remains. No black vultures scavenged this carcass with the exception of the mass scavenging event

Figure 50: Carcass S2 obscured from view; note the amount of vultures, the position of the carcass, and the fact that vultures have almost completely obscured the carcass from view.

Figure 51: Black vultures chasing another with a piece of carcass, example of intraspecies conflict; note the birds are fighting and altering the site as they fight, resulting in loss of feathers

Figure 52: Carcass S2 with black vultures feeding and turkey vultures standing aside as an example of interspecies behavior; note the vultures feeding at the caudal end, the hole formed behind the head, and the vulture attacking the lower abdomen where the intestinal wall is thin.

Figure 53: Opossum feeding on soft tissue remains.

Figure 54: Bone fragments (possible phalanx and calcaneus) that have been modified an gnawed by opossum, recovered from site S2

APPENDIX B: PIG CARCASS O1

Figure 55: Carcass O1 Fresh Stage Day 0

Figure 56: Carcass O1 Early Decomposition Stage Day 1

Figure 57: Carcass O1 Early Decomposition Stage Day 2

Figure 58: Carcass O1 Early Bloat Stage Day 3

Figure 59: Carcass O1 Bloat Stage Day 4

Figure 60: Carcass O1 Active Decomposition and Bloat Stage Day 5

Figure 61: Carcass O1 immediately after departure of vultures; note the site after the departure of the vultures (condition of the foliage and the ground surface)

Figure 62: Carcass O1 dispersal of remains and scavenging at site; note the bisection of the carcass, the behavior of the vultures at the initial deposition site, and the scavenging of the skin bag near the south fence.

Figure 63: Carcass O1 turkey vulture scavenging soft tissue with solitary turkey vulture scavenging the remaining soft-tissue on the elements of the lower body. Note, the new angle of the camera.

Figure 64: Black vulture digging with beak; note the behavior of the vultures and the modification this action has on the site.

Figure 65: Site O1 vulture feeding frenzy; note the behavior of the turkey vultures avoiding the frenzy, and the carcass completely obscured from view.

Figure 66: Turkey vulture scavenging pitfall trap; notice the turkey vulture dispersing the lid of the pitfall trap.

Figure 67: Black vulture swallowing skeletal element

Figure 68: Opossum dispersal drag; note the distance and direction of the drag is consistent with the opossums' behavior of dragging remains into denser foliage.

Figure 69: Opossum dispersal drag end; note the distance and direction of the drag and the ability of the opossum to drag remains larger than itself.

Figure 70: Two opossums scavenging; note the number of opossums at the site at one time which is significant because it means that these scavenging events could possibly be the work of multiple opossums over multiple days.

Figure 71: Opossum scavenging pitfall trap; note the opossum scavenging the pitfall trap of bugs beneath the lid, while the lower limbs are visible at the site which could signify the minimum amount of soft-tissue required to appeal to opossum scavenging.

APPENDIX C: PIG CARCASS O2

Figure 72: Carcass O2 Fresh Stage Day 0+2h

Figure 73: Carcass O2 Early Decomposition Stage Day 1

Figure 74: Carcass O2 Early Decomposition Stage Day 2

Figure 75: Carcass O2 Bloat Stage Day 3; note the red throat.

Figure 76: Carcass O2 Bloat Stage Day 4; note the color of the carcass and the skin slippage of the chin.

Figure 77: Carcass O2 Active Decomposition Stage Day 5; note the skin slippage of the chin and the red, raw color the throat likely caused by ant activity.

Figure 78: Carcass O2 immediately after departure of vultures; note the disturbed ground surface, and the altered foliage around the site.

Figure 79: Carcass O2, juvenile eagle scavenging carcass with black vultures; note the eagle is feeding in conjunction with the black vultures.

Figure 80: Carcass O2, juvenile eagle scavenging and dispersing carcass with black vultures; note eagles were recorded at multiple sites.

APPENDIX D: DATA COLLECTION SHEET

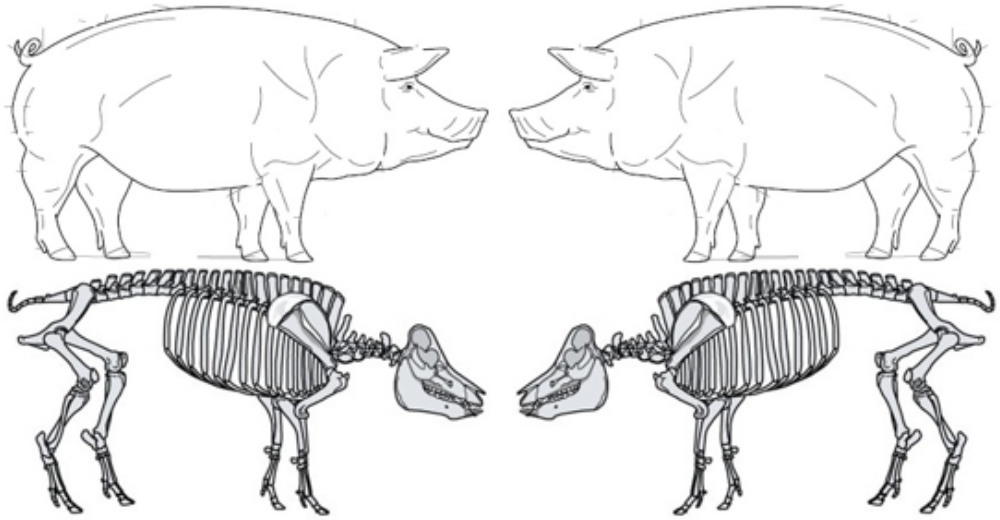
DATE:_____ DAY #:_____ SPECIMEN:_____

TIME ARVL:_____ DPTR:_____

TEMP CRNT_____AVG:_____ HUMIDITY_____ RAINFALL 24H_____ PRESSURE:_____

ANIMALS ENCOUNTERED AT SITE	ON CAMERA

RIGHT LEFT



Using Sketches, Record the following:

Traces of scavenging (SC) Visible wounds (W) Larval Masses (LM1, LM2, etc) Sample locations (1,2,etc)

TBS HEAD:_____	TBS TORSO:_____	TBS LIMBS:_____
□Fresh	□Fresh	□Fresh
□Pink-White with slippage	□Pink-White with slippage	□Pink-White with slippage
□Gray to green w/ Fresh skin	□Gray to green w/ Fresh skin	□Gray to green w/ Fresh skin
□Discoloration and brown shades, dry	□Purging, Bloating, Green color	□Discoloration and brown shades, dry
□Purging at orifices, neck/face bloat	□Post-bloating, green to black color	□Brown to black, leathery skin
□Brown to black discoloration	□Sagging flesh, abdomen caving in	□Moist decomp w/ bone exposure <.5
□Caving in of flesh on head/neck	□Moist decomp w/ bone exposure <.5	□Mummification w/ bone exposure
□Moist decomp w/ bone exposure <.5	□Mummification w/ bone exposure	□Bone exposure >.5 of area w/ fluids
□Mummification w/ bone exposure	□Bone exposure >.5 of area w/ fluids	□Bones Largely dry, some grease
□Bone exposure >.5 of area w/ fluids	□Bones with dry tissue cover >.5	□Dry Bones
□Bones with dry tissue cover >.5	□Bones Largely dry, some grease	
□Bones Largely dry, some grease	□Dry Bones	
□Dry Bones		

Use TBS Score Tables on Last Page to determine TBS

TBS HEAD:_____ LIMBS:_____ TORSO:_____ TOTAL:_____

Was Site Remapped?:_____

DISARTICULATION/DECOMP NOTES

General Observations

CAMERA LOG

BEGINNING HANDHELD CAMERA IMG #:_____ ENDING #:_____
BEGINNING GAME CAMERA____ IMG#:_____ ENDING #:_____
BEGINNING GAME CAMERA____ IMG#:_____ ENDING #:_____

NOTES:_____

OF ATTACHMENTS:_____

ENTOMOLOGY DATA

SAMPLE #	TIME	P/L	DESCRIPTION	LM TEmp	INT TEMP

NOTES:_____

MUNSELL COLOR OF BONES

LOCATION/BONE:_____	_COLOR:_____

BEHRENSMEYER SCORING

BONE:_____	_SCORE:_____	_DESCRIPTION:_____

BEHRENSMEYER SCORING

Stage 1.—Bone shows cracking, normally parallel to the fiber structure (e.g., longitudinal in long bones). Articular surfaces may show mosaic cracking of covering tissue as well as in the bone itself. Fat, skin and other tissue may or may not be present. (Fig. 2a)

Stage 2.—Outermost concentric thin layers of bone show flaking, usually associated with cracks, in that the bone edges along the cracks tend to separate and flake first. Long thin flakes, with one or more sides still attached to the bone, are common in the initial part of Stage 2. Deeper and more extensive flaking follows, until most of the outermost bone is gone. Crack edges are usually angular in cross-section. Remnants of ligaments, cartilage, and skin may be present. (Fig. 2b)

Stage 3.—Bone surface is characterized by patches of rough, homogeneously weathered compact bone, resulting in a fibrous texture. In these patches, all the external, concentrically layered bone has been removed. Gradually the patches extend to cover the entire bone surface. Weathering does not penetrate deeper than 1.0–1.5 mm at this stage, and bone fibers are still firmly attached to each other. Crack edges usually are rounded in cross-section. Tissue rarely present at this stage. (Fig. 2c)

Stage 4.—The bone surface is coarsely fibrous and rough in texture; large and small splinters occur and may be loose enough to fall away from the bone when it is moved. Weathering penetrates into inner cavities. Cracks are open and have splintered or rounded edges. (Fig. 2d)

Stage 5.—Bone is falling apart in situ, with large splinters lying around what remains of the whole, which is fragile and easily broken by moving. Original bone shape may be difficult to determine. Cancellous bone usually exposed, when present, and may outlast all traces of the former more compact, outer parts of the bones. (Fig. 2e)

TOTAL BODY SCORING

A. Fresh	
(1pt)	1. Fresh, no discoloration
B. Early decomposition	
(2pts)	1. Pink-white appearance with skin slippage and some hair loss.
(3pts)	2. Gray to green discoloration: some flesh still relatively fresh.
(4pts)	3. Discoloration and/or brownish shades particularly at edges, drying of nose, ears and lips.
(5pts)	4. Purging of decompositional fluids out of eyes, ears, nose, mouth, some bloating of neck and face may be present.
(6pts)	5. Brown to black discoloration of flesh.
C. Advanced decomposition	
(7pts)	1. Caving in of the flesh and tissues of eyes and throat.
(8pts)	2. Moist decomposition with bone exposure less than one half that of the area being scored.
(9pts)	3. Mummification with bone exposure less than one half that of the area being scored.
D. Skeletonization	
(10pts)	1. Bone exposure of more than half of the area being scored with greasy substances and decomposed tissue.
(11pts)	2. Bone exposure of more than half the area being scored with desiccated or mummified tissue.
(12pts)	3. Bones largely dry, but retaining some grease.
(13pts)	4. Dry bone.

A. Fresh	
(1pt)	1. Fresh, no discoloration.
B. Early decomposition	
(2pts)	1. Pink-white appearance with skin slippage and marbling present.
(3pts)	2. Gray to green discoloration: some flesh relatively fresh.
(4pts)	3. Bloating with green discoloration and purging of decompositional fluids.
(5pts)	4. Postbloating following release of the abdominal gases, with discoloration changing from green to black.
C. Advanced decomposition	
(6pts)	1. Decomposition of tissue producing sagging of flesh; caving in of the abdominal cavity.
(7pts)	2. Moist decomposition with bone exposure less than one half that of the area being scored.
(8pts)	3. Mummification with bone exposure of less than one half that of the area being scored.
D. Skeletonization	
(9pts)	1. Bones with decomposed tissue, sometimes with body fluids and grease still present.
(10pts)	2. Bones with desiccated or mummified tissue covering less than one half of the area being scored.
(11pts)	3. Bones largely dry, but retaining some grease.
(12pts)	4. Dry bone.

A. Fresh	
(1pt)	1. Fresh, no discoloration
B. Early decomposition	
(2pts)	1. Pink-white appearance with skin slippage of hands and/or feet.
(3pts)	2. Gray to green discoloration; marbling; some flesh still relatively fresh.
(4pts)	3. Discoloration and/or brownish shades particularly at edges, drying of fingers, toes, and other projecting extremities.
(5pts)	4. Brown to black discoloration, skin having a leathery appearance.
C. Advanced decomposition	
(6pts)	1. Moist decomposition with bone exposure less than one half that of the area being scored.
(7pts)	2. Mummification with bone exposure of less than one half that of the area being scored.
D. Skeletonization	
(8pts)	1. Bone exposure over one half the area being scored, some decomposed tissue and body fluids remaining.
(9pts)	2. Bones largely dry, but retaining some grease.
(10pts)	3. Dry bone.

REFERENCES

Allen ML, Elbroch LM, Wilmers CC, Wittmer HU. 2015. The comparative effects of large carnivores on the acquisition of carrion by scavengers. Am Nat 185(6): 822-833.

Avery ML. 2004. Trends in North American vulture populations. USDA national wildlife research center 116-121.

Baker SE. 2012. Accumulation Behaviours and Taphonomic Signatures of Extant Verreaux's Eagles, Aquila Verreauxii, in Southern Africa. Unpublished M.A. dissertation, University of the Witwatersrand, Johannesburg, South Africa.

Bass WM. 1997. Outdoor Decomposition Rates in Tennessee. In *Forensic Taphonomy: Postmortem Fate of Human Remains*, Haglund WD, Sorg MH (eds). CRC Press, New York, NY.

Beck J, Ostericher I, Sollish G, De Leon J. 2015. Animal scavenging and scattering and the implications for documenting the deaths of undocumented border crossers in the Sonoran desert. J Forensic Sci 60: 11-20.

Behrensmeyer AK. 1978. Taphonomic and ecological information from bone weathering. Paleobiol 4(2):150-162.

Bochenski ZM, Tornberg, R. 2003. Fragmentation and preservation of bird bones in uneaten food remains of the Gyrfalcon *Falco rusticolus*. J Arch Sci 30:1665-1671.

Brothwell DR. 1976. Further evidence of bone chewing by ungulates: The sheep of North Ronaldsay, Orkney. J Arch Sci 3:179-182.

Bull J, Farrand J. 1987. Audubon society field guide to North American birds: Eastern region. 4648-469. Knopf, New York, NY.

Byers SN. 2008. Introduction to forensic anthropology. Pearson Education, Boston, MA.

Carlson AJ. 1940. Eating of bone by the pregnant and lactating gray squirrel. Sci 91:573.

Carter DO, D Yellowlees, M Tibbett. 2007. Cadaver decomposition in terrestrial ecosystems. Naturwissenschaften 94: 12-24.

Chen C, Gilbert CL, Yang G, Guo Y, Segonds-Pichon A, Ma J, Evans G, Brenig B, Sargent C, Affara N, Lusheng H. 2008. Maternal infanticide in sows: Incidence and behavioural comparison between savaging and non-savaging sows at parturition. Appl Anim Behav Sci 109(2-4):238-248.

Christensen AM, Passalacqua NV, Bartelink EJ. 2014. Forensic anthropology current methods and practice. AP press New York.

Clark MA, Worrell MB, Pless JE. 1997. Postmortem changes in soft tissues. In *Forensic Taphonomy: The Postmortem Fate of Human Remains* WD Haglund and MH Sorg (eds.) 151-164. CRC Press, Boca Raton, FL.

Coleman JS, Fraser JD. 1986. Predation on black and turkey vultures. Wilson Bulletin 98(4): 600-601.

Coventry AF. 1940. The eating of bone by squirrels. Sci 92: 128.

Dabbs GR, Martin DC. 2013. Geographic variation in the taphonomic effect of vulture scavenging: the case for Southern Illinois. J Forensic Sci 58(1):20-25.

Damann FE, Carter DO. 2014. Human decomposition ecology and postmortem microbiology in *Manual of forensic taphonomy*. CRC Press, Boca Raton, FL.

Delany MF, Abercrombie CL. 1986. American alligator food habits in north central Florida. J Wildl manage 50:348-353.

Di Maio DJ, Di Maio VJM. 2001. Forensic Pathology (2nd. Ed.). CRC Press, Boca Raton, FL.

Dix J, Graham M. 2000. Time of death, decomposition and identification: An atlas. CRC Press, Boca Raton, FL.

Dixon R. 2000. Climatology of the freeman ranch. Freeman Ranch Publication Series 1:1-9.

Dupras TL, Schultz JJ, Wheeler SM, Williams LJ. 2011. Forensic recovery of human remains: Archaeological approaches. CRC Press, Boca Raton, FL.

Efremov IA. 1940. Taphonomy: A new branch of paleontology. Pan-Amer Geol 74:81-93.

Einarsen AS. 1956. Determination of some predator species by field signs. Oregon State Monographs Studies in Zoology 10:1-34.

Evans, WED. 1963. The chemistry of death. Charles C Thomas, Springfield, IL.

Folk MJ, Woodward AR, Spalding MG. 2014. Predation and scavenging by american alligators on whooping cranes and sandhill cranes in Florida. Southeast Nat 13(1):64-79.

Galloway A. 1997. The process of decomposition: A model from the Arizona-Sonoran desert. In *Forensic taphonomy: Postmortem fate of human remains* Haglund WD, Sorg MH (eds.). CRC Press, New York, NY.

Galloway A, Birkby WH, Jones AM, Henry TH, Parks BO. 1989. Decay rates of human remains in an arid environment. J Forensic Sci 34:607-616.

Gardner RM. 2005. Practical crime scene processing and investigation. CRC Press, New York, NY.

Gennard D. 2012. Forensic entomology an introduction. Wiley Blackwell, New York.

Gilmour R, Skinner M. 2012. Forensic scatology: Preliminary experimental study of the preparation and potential for identification of captive carnivore scat. J Forensic Sci 57:160-165.

Goff ML. 1993. Estimation of the postmortem interval using arthropod development and successional patterns. Forensic Sci Rev 81:81-94.

Haglund WD. 1997. Dogs and coyotes: Postermortem involvement with human remains. In *Forensic taphonomy: The postmortem fate of human remains*, Haglund WD, Sorg MH (eds.). CRC Press, New York, NY.

Haglund WD, Sorg MH. 2006. Forensic taphonomy: The postmortem fate of human remains. CRC Press, New York, NY.

Hamilton MD, Spradley MK. 2011. Purported drug cartel use of vultures as a method of body disposal. J Forensic Id 6:425-429.

Haynes G. 1980. Evidence of carnivore gnawing on Pleistocene and recent mammalian bones. Paleobiol 6:341-351.

Haynes G. 1982. Utilization and skeletal disturbances of North American prey carcasses. Arctic 35:266-281.

Haynes G. 1983. A guide to differentiating mammalian carnivore taxa responsible for gnaw damage to herbivore limb bones. Paleobiol 9:164-172.

Houston DC. 1986. Scavenging efficiency of turkey vultures in tropical forest. Condor 88:318-323.

Hudson J. 1993. The impacts of domestic dogs on bone in forager camps; Or, the dog-gone bones. In *From bones to behavior: Ethno archaeological and experimental contributions to the interpretation of faunal remains*, J Hudson (ed.), PP. 301-323. Center for Archaeological Investigations, Occasional Paper no. 21, Southern Illinois University, Carbondale, IL.

Kelly NE, Sparks DW, DeVault TL, Rhodes Jr OE. 2007. Diet of black and turkey vultures in a forested landscape. Wilson J Ornithol 119:267-270.

Kent S. 1981. The dog: An archaeologist's best friend or worst enemy- the spatial distribution of faunal remains. J Field Arch 8:367-372.

Klepinger L. 2006. Fundamentals of forensic anthropology. New Jersey: Wiley.

Klippel WE, Synstelien JA. 2007. Rodents as taphonomic agents: Bone gnawing by brown rats and gray squirrels. J Forensic Sci 52(4): 765-773.

Komar D, Beattie O. 1998. Identifying bird scavenging in fleshed and dry remains. Can Soc Forensic Sci J 31:177-188.

Krause WJ, Krause WA. 2006. The opossum: Its amazing story. Department of Pathology and Anatomical Sciences. Columbia, Missouri.

Kruuk H. 1972. The spotted hyena: a study of predation and social behavior. Chicago, IL: University of Chicago Press.

Kruuk H. 2002. Hunter and hunted: Relationships between carnivores and people. New York: Cambridge University Press.

Lariviere S. 2001. Ursus americanus. Mamm Species 647:1-11.

Layne JN. 1996. Audubon's crested caracara. Pages. In *Rare and endangered biota of Florida*, JA Rodgers, HW Kale, HT Smith (eds.). Vol. 5: Birds. University Press of Florida, Gainesville, FL.

Love JC, Marks M. 2003. Taphonomy and time: Estimating the postmortem interval. In *Hard evidence: Case studies in forensic anthropology*, DW Steadman (ed.), 160-175. Prentice Hall, Upper Saddle River, NJ.

Madea B, Dettmeyer R, Schmidt P. 2007. Leichenschau. In *Praxis Rechtsmedizinn,* Madea B (ed.) Berlin: Springer.

Maehr DS, Belden RC, Land ED, Wilkins L. 1990. Food habits of panthers in Southwest Florida. J Wildl Manage 54(3):420-423.

Mann RW, Bass WM, Meadows L. 1990. Time since death and decomposition of the human body: variables and observations in case and experimental field studies. J Forensic Sci 35(1): 103-111.

McGowan, K. J. 2001. Fish Crow (*Corvus ossifragus*). In *The Birds of North America*, Poole A, Gills F (eds.). The Birds of North America Online, Ithaca, New York.

McGraw WS, Cooke C, Shultz S. 2006. Primate remains from African crowned eagle (*Stephanoaetus coronatus*) nests in Ivory Coast's Tai Forest: Implications for primate

predation and early hominid taphonomy in South Africa. Am J Phys Anth 131:151-165.

Megyesi MS, Nawrocki SP, Haskell NH. 2005. Using accumulated degree-days to estimate the postmortem interval from decomposed human remains. J Forensic Sci 50(3):1-9.

Morrison J. 1996. Crested caracara (Caracara plancus). In *The birds of North America, No. 249,* A Poole, F Gill (eds.) The Academy of Natural Sciences, Philadelphia PA, and The American Ornithologists' Union, Washington DC.

Mouton E. 2009. Testimony before the United States Senate, Committee on Environment and Public Works, Subcommittee on Water and Wildlife. 3 December 2009. 9 pp.

Murad TA. 1997. The utilization of faunal evidence in the recovery of human remains. In *Forensic taphonomy: The postmortem fate of human remains,* WD Haglund, MH Sorg (eds.). CRC Press, Boca Raton, FL.

Murphy KM, Felzien GS, Hornocker MG, Ruth TK. 1998. Encounter competition between bears and cougars: some ecological implications. Ursus 10:55-60.

Murphy KM, Ruth TK. 2010. Diet and prey selection of a perfect predator. In *Cougar: ecology and conservation,* Hornocker M, Negri S (eds.). University of Chicago Press, Chicago, IL.

Perper J. 1993. Time of death and changes after death: Part 1: Anatomical considerations. In *Medicolegal investigation of death: Guidelines for the application of pathology to crime investigation* (3rd edn.) WU Spitz (ed.), 14-49. Charles C Thomas. Springfield, IL.

Pobiner BL. 2007. Hominin-carnivore interactions: Evidence from modern carnivore bone modification and early pleistocene archaeofaunas (Koobi Fora, Kenya: Olduvai Gorge, Tanzania). Unpublished PhD Dissertation, Department of Anthropology, Rutgers University, Newark, NJ.

Pokines JT. 2014. Introduction: Collection of macroscopic osseous taphonomic data and the recognition of taphonomic suites of characteristics. In *Manual of forensic taphonomy*. Pokines JT Symes SA (eds.) Boca Raton: CRC Press.

Pokines JT, Baker SE. 2014. Avian taphonomy. In *Manual of forensic taphonomy,* Pokines JT, Symes SA (eds.) Boca Raton. CRC Press.

Reeves NM. 2009. Taphonomic effects of vulture scavenging. J Forensic Sci 54:523-528.

Rice AN, Ross JP, Woodward AR, Carbonneau DA, Percival HF. 2007. Alligator diet in relation to alligator mortality on Lake Griffin, Florida. Southeast Nat 6:97-110.

Ricketts DR. 2012. Scavenging effects and scattering patterns on porcine carcasses in Eastern Massachusetts. Unpublished MS Thesis, Boston University School of Medicine, Boston MA.

Rippley A, Larison NC, Moss KE, Kelly JD, Bytheway, JA. 2012. Scavenging behavior of Lynx Rufus on human remains during the Winter months of Southeast Texas. J Forensic Sci 57(3): 699-705.

Roen KT, Yahner RH. 2005. Behavioral responses of avian scavengers in different habitats. Northeast Nat 12:103-112.

Roze U. 2009. The North American porcupine. Ithaca, NY: Cornell University Press.

Sibley CG, Monroe BL. 1990. Distribution and taxonomy of birds of the world. Yale University Press, New Haven, CT.

Smith MD, Dunn AC. 2011. The coyote: Facts and myths about living with this wild canid. Alabama Cooperative Extension System 1-6.

Sorg MH, Haglund WD, Wren JA, Collar A. 2012. Taphonomic impacts of small and medium-sized scavengers in northern New England. Proceedings of the American Academy of Forensic Sciences 18:400.

Spradley MK, Hamilton MD, Giordano A. 2012. Spatial patterning of vulture scavenged human remains. Forensic Sci Int 219:57-63.

Steadman DW. 2016. Differential raccoon scavenging among pig, rabbit, and human subjects. Presented at the AAFS 2016.

Stager KE. 1964. The role of the olfaction in food location by the turkey vulture (Cathartes aura). Los Angeles County Museum Contributions to Science, No 18.

Stewart PA. 1978. Behavioral interactions and niche separation in the black and turkey vultures. Living Bird 17:79-84.

Stewart TD. 1979. Essentials of forensic anthropology: Especially as developed in the United States. Charles C Thomas, Springfield, IL.

Stolen ED. 2000. Foraging behavior of vultures in central Florida. Fla Field Nat 28:173-181.

Sutcliffe AJ. 1973. Similarity of bones and antlers gnawed by deer to human artefacts. Nature 246:428-430.

Sutcliffe AJ. 1977. Further notes on bones and antlers chewed by deer and other ungulates. Deer 4:73-82.

Swift MJ, OW Heal, JM Anderson. 1979. Decomposition in terrestrial ecosystems. Blackwell Scientific, Oxford, UK.

Thomaides C, Valdex R, Reid WH, Raitt RJ. 1989. Food habits of turkey vultures in west Texas. J Raptor Res 23:42-44.

Ubelaker DH. 1997. Taphonomic applications in forensic anthropology. In *Taphonomy: The Postmortem Fate of Human Remains*, WD Haglund, MH Sorg, (eds.) Boca Raton: CRC Press, 139-150.

US Department of Agriculture Food Safety and Inspection Service. 2003. FSIS Directive 6900.2, Rev 1: Humane handling and slaughter of livestock. Washington: Government Printing Office.

Vass AA, Bass WM, Wolt JD, Foss JE, Ammons JT. 1992. Time since death determinations of human cadavers using soil solution. J Forensic Sci 37:1236-1253.

Wallace MP, Temple SA. 1987. Competitive interactions within and between species in a guild of avian scavengers. The Auk 104:190-295.

Zevelof SI. 2002. Raccoons: A natural history. Smithsonian Institution Press, Washington.