PRELIMINARY DECOMPOSITION STUDY IN THE WILLAMETTE VALLEY OF OREGON: A MULTI-METHOD COMPARISON AND SHARP FORCE TRAUMA EFFECTS

by

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A THESIS

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Determining time since death (post-mortem interval or PMI) is an essential part of medico-legal death investigations. PMI can give investigators important information about time of death and may help answer questions about the events leading up to death. The purpose of this study was to collect decompositional data from an understudied region (Oregon), and compare multiple scoring methods that are current standards developed in regions such as Tennessee, in order to characterize the effects of regional variation on decomposition and taphonomy. Six pig heads were placed on the ground surface in a fenced enclosure and exposed to the natural winter environment of the Willamette Valley (WV) of Oregon for sixty days. Three of these pig heads underwent sharp force trauma infliction (SFT) in order to compare rate of decay with remains that have a singular SFT wound. Stage of decomposition, temperature, precipitation, and preliminary entomological data were collected throughout the sixty-day observation period. These data were used to compare Anderson and VanLaerhoven's (1996) stages of decomposition model to Megyesi et al.'s (2005) total body scoring (TBS) system in the WV; compare and contrast similar studies from different seasons within the WV;

and analyze the effects of increase in number of open wounds (SFT) on decomposition rates and insect activity.

This study found that decomposition in the WV during the cold/wet season (winter) did not closely align with either Anderson and VanLaerhoven (1996) or Megyesi et al. (2005). Analyses of statistical, qualitative, and interobserver error suggests that neither scoring method is a perfect fit for the WV. Winter decay was found to occur at a slower pace when compared to summer decay and was overall more variable. Partial mummification and rehydration of the remains was observed multiple times during this study. Increase in number of SFT wounds did not influence rate of decay. Sub-environmental differences were found to have an effect on decomposition rate and a considerable amount of small animal and avian scavenging of the remains occurred throughout the study. Scavenging influenced rate of decay through loss of mass that propelled decomposition forward.

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Introduction

Taphonomy can be defined as the study of processes that affect an organism after death (Haglund and Sorg, 1997b). The term was originally coined by Efremov (1940) as the transition of animal remains from the biosphere to the lithosphere and stems from the Greek words, taphos meaning burial or death and nomos meaning law, to translate as the laws of burial (Christensen et al., 2014; Haglund and Sorg, 1997a; McLaughlin, 2003). Forensic taphonomy is a sub-discipline of forensic anthropology that uses taphonomic models, approaches, and analyses in medico-legal contexts to estimate time since death, reconstruct the events surrounding death, and distinguish human behaviors and actions from those of earth's natural forces (Christensen et al., 2014; Haglund and Sorg, 1997b). Furthermore, forensic taphonomy aims to reconstruct the events that are ante- (before), peri- (at or around), and postmortem (after death) through collection and analysis of data pertaining to depositional context, discriminating peri and postmortem alteration of remains, and estimating time since death (Haglund and Sorg, 1997b).

Estimating time since death (postmortem interval) is an essential part of medico-legal death investigations. Post-mortem interval (PMI) can provide investigators with important information about time of death and may help answer questions about the events leading up to death (Christensen et al., 2014; Cockle and Bell, 2015). This, in addition to other information a body can provide, helps investigators determine cause and manner of death, corroborate or disprove alibis, narrow the possible suspect pool in homicide investigations, and assist in identification (Christensen et al., 2014, Megyesi et al., 2005; Wescott, 2018). PMI, however, is not easy to estimate. Length of exposure and environmental conditions such as temperature, rainfall, and humidity greatly affect PMI estimation in an outdoor crime scene (Christensen et al., 2014). As a result, decomposition research has become extremely important in determining appropriate, accurate protocols for estimating PMI (Christensen et al., 2014; Wescott, 2018). Current research typically relies on decomposition rates to estimate PMI and has yielded methods involving physical markers and insect activity (entomology) (Christensen et al., 2014, Megyesi et al., 2005).

Forensic science has recently been criticized for the scientific basis of their methods and methodologies (National Research Council, 2009; Wescott, 2018). The Daubert standards state that the validation and standardization of methods are essential for subsequent use and legal admissibility (Daubert v. Merrel Dow Pharmaceuticals, Inc., 509 U.S. 579 (1993)). Daubert requires forensic scientists, including forensic anthropologists, to substantiate their assertions with scientifically tested methods that are testable, reliable, and repeatable. Forensic anthropologists have responded to these requirements by conducting and publishing validation studies of previously accepted methods and assertions (Dirkmaat et al., 2008). A study conducted by the National Research Council found that significant improvement is needed within the various forensic science disciplines in regard to their methodologies and practices. These findings led to recommendations from the council that advised these disciplines on how they could improve through creation of new methods and approaches within their respective fields (National Research Council, 2009). A current goal within the field of forensic taphonomy is to test current practices and develop new methods that are accurate and precise in estimating PMI (Wescott, 2018).

The primary objective of this study was to collect decompositional data from an understudied region (Oregon), and compare multiple scoring methods that are current standards developed in such regions as Arizona, British Columbia, South Carolina, and Tennessee in order to characterize the effects of regional variation on decomposition and taphonomy (Anderson and VanLaerhoven, 1996; Bass, 1997; Galloway et al., 1989; Megyesi et al., 2005; Payne, 1965). The following was collected for comparative purposes: stages of decomposition, temperature, precipitation, and preliminary entomological data. These data were used to compare Anderson and VanLaerhoven's (1996) stages of decomposition model to Megyesi et al.'s (2005) total body scoring (TBS) system in the Willamette Valley (WV); compare and contrast similar studies from different seasons within the WV; and analyze the effects of sharp force trauma (SFT) on decomposition rate and insect activity.

Background

Taphonomic Research Facilities

A great deal of what is known about forensic taphonomy has been gained through observational studies on decomposition and postmortem modification of humans and non-human animals. These studies generally are conducted at outdoor field laboratories also known as taphonomic research facilities (Christensen et al., 2014). In 1980, Dr. William Bass established the first human decomposition research facility at the University of Tennessee, Knoxville (UTK) (Shirley et al., 2011; Wescott, 2018). This facility, the Anthropological Research Facility (ARF), is the outdoor taphonomic facility associated with the Forensic Anthropology Center (FAC) at UTK (Shirley et al., 2011). ARF has allowed researchers to study taphonomy and decomposition in a semi-controlled, scientific manner while maintaining a natural outdoor setting (Shirley et al., 2011; Wescott, 2018). The pioneering work at ARF concentrates on the physical changes in the hard and soft tissues of the body during decomposition and abiotic variables (e.g. temperature, rainfall, humidity) that influence rate of decomposition (Wescott, 2018). Early studies provided the initial foundation for developing methods that estimate time since death or PMI (Wescott, 2018).

Employing UTK's methods and statistical outcomes in forensic investigations has become standard practice in the 39 years since the establishment of ARF (Bass, 2003). Although these studies have yielded excellent data on postmortem changes in Tennessee, it is widely recognized that these changes are highly influenced by regional environment and climatic factors, especially temperature (Christensen et al., 2014;

Cockle and Bell, 2015; Galloway et al., 1989; Mann et al., 1990; McLaughlin, 2003; Suckling et al., 2015). Changes in temperature, precipitation, and regional insect populations can all affect the rate at which a body decomposes. These highly influential variables pose a problem for the forensic community outside of Tennessee, as extrapolating UTK's methods might not provide the most accurate results when applied to a region with a differing climate (Bass, 1997; Christensen et al., 2014; Cockle and Bell, 2015; Galloway et al., 1989; Mann et al., 1990; McLaughlin, 2003; Suckling et al., 2015). In recent years, more institutions have developed similar taphonomic research facilities in order to conduct their own research and analyze decomposition within varying environments (Christensen et al., 2014). These facilities include the: Forensic Anthropology Center at Texas State (FACTS); Southeast Texas Applied Forensic Science Facility (STAFS); Forensic Investigation Research Station (FIRS) in Colorado; and Forensic Osteology Research Station (FOREST) in North Carolina (Christensen et al., 2014).

Multidisciplinary Oregon Taphonomy Investigative Studies (MORTIS)

In order to establish standards for PMI estimation in regions with different environmental conditions, studies comparable to those done in Tennessee must be conducted (Dirkmaat et al., 2008; Galloway et al., 1989). In January 2019, a 50 ft x 50 ft chain link fenced enclosure was built on an upland disturbed meadow environment owned by Lane Community College (LCC). This enclosure is the initial structure that will become a larger taphonomic facility encompassing multiple sub-environments and potentially multiple locations within the WV of Oregon. The new facility, Multidisciplinary Oregon Taphonomy Investigative Studies, (MORTIS), will be used in a multitude of ways, including but not limited to: processing of animal/faunal remains for building skeletal collections at colleges, universities, and museums; conducting specific research projects across an array of academic fields; and forensic research and training. Currently, MORTIS is using pigs (Sus scrofa) as proxies for human decomposition. The use of pigs as proxies for human decomposition is well documented in decomposition literature. Pigs have become the preferred surrogate for humans due to their similar internal anatomy, fat distribution, chest cavity size, omnivorous diet, and lack of heavy fur (Anderson and VanLaerhoven, 1996; Calce and Rogers, 2007; France et al., 1997; McLaughlin, 2003; Notter et al., 2009; Payne, 1965; Schoenly et al., 2007). Additionally, usage of pigs has other advantages including ease of procurement and reasonably low cost which elicits studies with higher sample sizes (Schoenly et al., 2007). However, a future goal of the facility is to conduct decompositional studies using human remains.

Site Ecology

The climate of the WV is relatively mild throughout the year, characterized by wet, cool winters, and dry, warm summers. The climate most closely resembles that of a Mediterranean climate, however, Oregon's winters are somewhat wetter and cooler than a typical Mediterranean climate. Similar to most of Western Oregon, the WV has a predominant winter rainfall climate, with approximately 50% of the annual total from December to February, lesser amounts in the spring and fall, and barely any during the summer. There is substantial variation in precipitation in the WV, ranging from annual totals below 40 inches in the Portland area to upwards of 80 inches in the Cascade and Coast range foothills. Elevation is the most important variable when determining annual precipitation totals. Average precipitation for the Eugene area is approximately 46 inches per year (Taylor and Hannan, 1999). During the observation period (January 14th- March 15th), the total precipitation recorded was 10.86 inches (275.84 mm) (Ruscher, 2019). Mean high temperatures range from the low 80s in the summer to about 40° F in the coldest months, while average lows are generally in the low 50s in summer and low 30s in winter (Taylor and Hannan, 1999). During the observation period, the average high temperatures ranged from 34.16° to 63.14° F (1.2°-17.3° C) and the average low temperatures ranged from 21.92° to 46.76° F (-5.6° - 8.2° C) (Ruscher, 2019). Snowfall occurs almost every year, however, amounts are generally quite low with an average of 5-10 inches per year and occur during the months of December through February (Taylor and Hannan, 1999). Multiple snowstorms accumulated snow at a higher than average rate during the observation period between February 25th, 2019 and March 3rd, 2019. The total snow accumulated was approximately 19.1 inches (485.14 mm) (Ruscher, 2019). Relative humidity is highest during early morning hours and is generally 80-100% throughout the year. During the afternoon, humidity is lowest, ranging from 70 to 80% during January to 30-50% in the summer. Winters are likely to be cloudy with average cloud cover during the coldest months exceeding 80%. Sunshine is much more common in the summer, with average cloud cover less than 40% (Taylor and Hannan, 1999).

The facility is located in an upland disturbed meadow environment. The enclosure includes perennial and annual grasses, shrubs, and herbs (Appendix 1). Although tree cover is lacking, thick shrub and herbaceous layers provide protection from sunlight similar to many environments that include trees. The shrub layer includes:

Scott's broom (*Cytisus scoparius*); Armenian blackberry (*Rubus Armeniacus*); and teasel (*Dipsacus fallonum*) (a perennial herb/shrub). The herbaceous layer includes: teasel (*Dipsacus fallonum*); European corn salad (*Valerianella corniculate*); dovefoot geranium (*Geranium mole*); willow dock (*Rumex salicifolia*); narrow-leaf plantain (*Plantago lanceolate*); oxeye daisy (*Chrysanthemun leucanthemum*); Queen Anne's lace (*Daucus carrota*); and hairy cat's ear (*Hypochaeris radicata*). The grass layer includes: tall red fescue (*Schedonorus arundinaceus*); ripgut brome (*Bromus rigidus* (or *diandrus*)); and velvet grass (*Holchus lanatus*) (Holmes, 2019).

Wildlife observed within and in the vicinity of the facility during the time of this study included: gray fox (*Urocyon cinereoargenteus*); striped skunk (*Mephitis mephitis*); western spotted skunk (*Spilogale gracilis*); bobcat (*Lynx rufus*); Virginia Opossum (*Didelphis virginiana*); common racoon (*Procyon lotor*); white-tailed deer (*Odocoileus virginianus*); California ground squirrel (*Otospermophilus beecheyi*); and as yet unidentified rodents. There was also a large variety of bird life in the area. Tukey vultures (*Cathartes aura*) were most directly impactful to this research. Additionally, a variety of small birds (yet unidentified to species) were directly observed and photographed on the remains. During observations, bald eagles (*Haliaeetus leucocephalus*), wild turkeys (*Meleagris gallopavo*), and a sharp-shinned hawk (*Accipiter striatus*) were also observed.

Research in Pacific Northwest (PNW)

Forensic taphonomic research within the Pacific Northwest (PNW; WA, OR, ID, BC) has been extremely limited. In total, there have been four studies conducted within the region that produced data on decomposition (Anderson and VanLaerhoven, 1996; England, 2006; McLaughlin, 2003; Shean et al., 1993). Shean et al. (1993) placed two pigs (22.7 kg (50 lbs) and 20.3 kg (45 lbs) (*Sus scrofa*) in a shaded and unshaded environment approximately 300 meters apart in the woods of The Evergreen State College campus near Olympia, Washington on June 27, 1986. Each pig was placed in a wooden-framed chicken wire casket in order to aid in the collection of insects and inhibit animal and avian scavenging of the remains. Observations concluded on August 15, 1986. The purpose of this project was to observe and record rate of decay (measured through loss of weight and girth) and record data on insect colonization of the remains. A 10 cm long incised wound was made on the neck of each carcass to examine the effect, if any, that an unnatural opening would have on fly ovipositional site preference. This study concluded that the decomposition rate of both pigs was primarily influenced by insect colonization and growth, which in turn was influenced by ambient air temperatures. Although the sites were only 300 meters apart, different ambient air temperatures were recorded throughout the observation period between the two sites. This difference was associated with access to sunlight and higher daily maximum temperatures occurring at the open site. Although insect colonization was observed in the inflicted wound sites, the authors state that overall differences in decay rate between the two carcasses were primarily associated with differences in ambient temperature (Shean et al., 1993).

Anderson and VanLaerhoven (1996) placed seven 22 kg (50 lbs) pigs (*sus scrofa*) in an open and sunlit rural farming area in B.C. on June 9, 1992. Each set of remains were protected from large animal scavenging by a cage. Observations were recorded for a period of approximately nine months or 271 days postmortem. The purpose of this project was to collect data on insect colonization of carrion in order to shed light on decompositional processes within the region. This study also categorized remains into stages of decomposition that were modified from Payne (1965)'s decompositional stages (Anderson and VanLaerhoven, 1996). Results showed that the remains progressed through the fresh stage of decomposition according to previous research but remained in each subsequent stage longer than previous studies recorded. This disparity was attributed to the different environmental conditions that B.C. presents when compared to other regions (Anderson and VanLaerhoven, 1996).

Research in Oregon

At this time, there have only been two decompositional related studies conducted within Oregon. McLaughlin (2003) placed four hogs (*Sus scrofa*) weighing between 104 and 136 kg (230 to 300 lbs) in the forests of Lane County, Oregon during June 2002. Data collection ceased on Day #100 of the study (September 20, 2002). The four different locations chosen for each of the hogs ranged from heavily forested areas to clearcuts. The goal of this study was to address questions concerning predator tissue ingestion and dispersal (scavenging), in order to aid in death investigations in rural Lane County and Western Oregon. Although not the primary objective of the project, decomposition stages were recorded throughout the observation period using a modified version of Anderson and VanLaerhoven's (1996) stages of decomposition (Figure 1). Results showed that turkey vultures (*Cathartes aura*) were a major factor in scavenging of carcasses in both forested and clearcut environments. Additionally, there was a noted difference in the rate of decay between the clearcut and the forested sites. The clearcut sites had warmer temperatures than the forested sites which resulted in faster rates of decay for the remains placed in these locations. Patterns in decomposition seemed to be mostly dependent on average temperatures throughout the observation period. It is also notable that during the two days of rain during the observation period, very little maggot activity was visible externally, as the maggots had receded into the carcass entirely (McLaughlin, 2003).

England (2006) placed two 36.3 kg (80 lbs) clothed pig carcasses (*Sus scrofa*) in a grassy wooded area north of Corvallis, Oregon on July 15, 2005. The study was conducted over a five-month period and concluded on November 30, 2005. Each of the carcasses were protected from animal scavenging through the use of wire. The primary objective of this study was to establish a practical insect succession model that could be used by regional law enforcement personnel to estimate PMI during medicolegal death investigations, compare decomposition rate data from this study to other data from both national and international locations, and establish basic data that would facilitate continued decomposition research in the region. Decay rate for the purpose of this study was based upon mass loss (the smaller the mass, the further through the decomposition process the carcass was). The results of this study showed a clear pattern of insect succession and colonization that featured two primary insect orders (Diptera and Coleoptera) and that decay (mass loss) occurred in a linearized fashion similar to other studies. Additionally, insect succession was organized through stages of decomposition that were determined based upon insect activity, girth of the carcass, and exterior color change (England, 2006). These decomposition stages were drawn from those presented in Anderson and VanLaerhoven (1996) (England, 2006).

Megyesi et al. (2005)

Megyesi et al. (2005) developed a supplemental method of determining PMI through scoring decomposition using a point-based system while taking into account temperatures in which the remains were exposed. The purpose of their project was to examine the ways that forensic anthropologists could improve their PMI estimates based on decomposition using a more quantitative and standardized approach. A total of 68 human remains cases were selected from varying regions across the United States and scored from photographs taken at the time the remains were recovered. Scoring was based upon modified categories of decompositions outlined by Galloway et al. (1989) (Megyesi et al., 2005). These categories include: fresh, early decomposition, advanced decomposition, and skeletonization (Galloway et al., 1989; Megyesi et al., 2005). Each category was than split into "stages" that describe the appearance and general characteristics of the remains. Each stage was assigned a point value, beginning at 1 and increasing with each subsequent stage to account for the total decomposition that had occurred. Due to the nature of decomposition, not all regions of the body decompose at the same rate, therefore the authors decided to split the remains into three separate anatomical scoring regions (head/neck, the trunk (torso), and the limbs) (Figure 2). Together, the point values from the three regions of the body equal the Total Body Score (TBS). The TBS is than inputted into a regression analysis equation to produce an estimated Accumulated Degree Days (ADD) range (Megyesi et al., 2005). ADD is the sum of consecutive average daily temperatures to correlate stages of decomposition (Megyesi et al., 2005; Vass et al., 1992). By calculating and computing the sum of the average daily temperatures above 0°C prior to the date the remains were scored, an estimated PMI range can be created. The authors found that scoring decomposition quantitatively and using the score to calculate ADD is a reliable and accurate method of estimating PMI. Additionally, this study found that 80% of variation in decomposition could be attributed to a combination of elapsed time and temperature as is reflected in ADD (Megyesi et al., 2005).

Sharp Force Trauma (SFT)

The presence or absence of perimortem trauma has long been thought to influence rate of decomposition due to the presence of additional openings in the skin for insects to colonize and scavengers to exploit (Mann et al., 1990; Micozzi, 1986; Smith, 2014). The early studies by Micozzi (1986) and Mann et al., (1990) suggested that decomposition rate is indeed influenced by trauma to the remains. Despite these studies being limited in nature (small sample sizes and uncommon animal proxies used) the assertion that decomposition rates are affected by the presence of perimortem trauma was generally accepted (Smith, 2014). However, recent studies by Smith (2014); Cross and Simmons (2010); Kelly et al., (2009); and Kelly (2006) all provide results to the contrary. These studies have recorded no statistically significant differences in the rate of decomposition between intact and trauma inflicted remains (Cross and Simmons, 2010; Kelly, 2006; Kelly et al., 2009; Smith, 2014). Instead, Smith (2014) found that there was a difference in pattern of decomposition associated with trauma inflicted remains. Through study of eight domesticated pig carcasses (Sus scrofa) (six of which were inflicted with sharp force trauma) it was observed that remains without trauma decayed from the facial region and progressed caudally (Smith, 2014). In the pigs with SFT, desiccation began at the site of trauma infliction and radiated outward, which was attributed to insect colonization of the wound sites (Smith, 2014). Smith (2014) suggests that these results could indicate that early researchers mistook pattern change of decomposition for changes in rate of decomposition. Overall, more research is needed to study the relationship of trauma to decomposition and confirm the observations and results of new studies that contradict traditional decomposition theory (Smith, 2014).

Hypotheses

1.

H1 – Decomposition in the Willamette Valley of Oregon during the cold/wet season (winter) will more closely align with scoring models presented in Anderson and VanLaerhoven (1996) than those presented in Megyesi et al. (2005).

H2- Decomposition in the Willamette Valley of Oregon during the cold/wet season (winter) will more closely align with scoring models presented in Megyesi et al. (2005) than those presented in Anderson and VanLaerhoven (1996).

H0- Decomposition in the Willamette Valley of Oregon during the cold/wet season (winter) does not align with either Anderson and VanLaerhoven (1996) or Megyesi et al. (2005).

2.

H1- Decomposition rates in the cold/wet season (winter) will be slower in comparison to decomposition rates in the warm and dry season (summer) within Oregon according to data on decomposition available from McLaughlin (2003).

H2- Decomposition rates in the cold/wet season (winter) will speed up in comparison to decomposition rates in the warm and dry season (summer) within Oregon according to data on decomposition available from McLaughlin (2003).

H0- There will be no difference in decomposition rates between the cold/wet season (winter) and the warm/dry season (summer) within Oregon according to data on decomposition available from McLaughlin (2003).

3.

H1- Increase in number of open wounds (SFT) will be associated with accelerated rate of decomposition and increased insect activity when compared to more intact remains.

H2- Increase in number of open wounds (SFT) will be associated with decelerated rate of decomposition and decreased insect activity when compared to more intact remains.

H0- Increase in number of open wounds (SFT) will have no effect on rate of decomposition or insect activity when compared with more intact remains.

Methods

Participants and Sample Size

Six domesticated pig (Sus scrofa) heads were purchased from Carlton Farms, a regional meat processing facility located in Carlton, Oregon. Carlton Farms was one of the first USDA Total Quality Control recognized meat processing plants in the United States ("From our family to your table. – Carlton Farms Gourmet Meats," n.d.). Each head was individually numbered H1-H6 (Appendix 2). All animals were euthanized in an ethical manner and strictly comply with standards set forth by the Institutional Animal Care and Use Committee (IACUC). The selected pigs from which heads were obtained weighed approximately 270 to 280 lbs (122.47 to 127.01 kg). Schoenly et al. (2007) states that pigs weighing between 50-60 lbs (23-27 kg) are optimal for decomposition research as the thoracic cavity (chest cavity) is roughly the same size as humans. The selected pigs from which heads were obtained from for this study were larger than initially expected, however, they are still within the range of human body weight (McLaughlin, 2003). The heads themselves weighed about 15 lbs (6.8 kg). All heads were obtained from animals destined for consumer use and possessed a large SFT wound where the head was severed from the neck. The remains were acquired as close to time of death as possible and were never frozen. The heads were approximately 75% hairless, with some remaining tufts of hair along the frontal and nasal regions.

Placement of Remains, Enclosure, and Research Location

The remains were placed in an upland disturbed meadow environment owned by Lane Community College (Eugene, Oregon) on January 14, 2019 (the same day as procurement from the meat processing plant) (Appendix 3 and 4). Lane Community College is approximately 480 feet above sea-level ("Google Earth," n.d.). The remains were placed within a 50 ft x 50 ft chain link fenced enclosure in order to inhibit large animal scavenging of the remains throughout the observation period (Appendix 5). The fencing used for the enclosure is approximately 6 ft tall and includes a 12 ft wide drive-through gate along the eastern side. Inhibiting large animals from scavenging the remains allowed for a more controlled environment for experimentation and prevented the remains from being displaced from the experiment site. Avian scavenging of the remains was allowed throughout the observation period as birds (especially turkey vultures (Cathartes aura)) have been found to be a primary contributor to scavenging of remains within the Willamette Valley of Oregon and thus are highly influential on decomposition rate (McLaughlin, 2003). Allowing these scavenging activities to occur enabled this study to remain relatively realistic to what could be expected to occur in an outdoor death scene the Willamette Valley of Oregon.

The remains were placed approximately 12 to 34 feet away from each other in an attempt to reduce insect sharing between remains, although winter insect activity was not anticipated. Field practices set for by carrion researchers suggests remains should be placed at least 33 ft apart from each other in order to discourage insect allocation between remains, however, the spacing constraints of the enclosure prevented spacing of remains at this distance (Payne, 1965; Schoenly et al., 2007). The heads were placed in three distinct sub-environments within the enclosure: Armenian blackberry (Rubus Armeniacus); Scott's Broom (Cytisus scoparius); and open. The Armenian blackberry is an invasive non-native species that is common throughout the valley. The Scott's broom is a woody shrub that is one of Western Oregon's most widespread non-native invasive shrubs (Holmes, 2019). The open sub-environment is characterized by various short grasses (Schedonorus arundinaceus; Bromus rigidus (or diandrus); Holchus lanatus) and a lack of shrubbery, bushes, or other barriers that could prevent environmental agents from reaching the remains. One control and one experimental head were placed in each of the three sub-environments. The heads were placed on the ground surface with the large open wound facing down and their snouts in line with a stake marking the original placement location. Stakes were placed as markers to track movement of remains in the case of animal scavenging.

Duration and Visitation Schedule

The remains were placed on-site on January 14, 2019, which is considered Day 0 for observational purposes. The observation period was a total of 60 continuous days and concluded on March 15, 2019 (Appendix 6-11). Following procedures set forth in McLaughlin (2003), the remains were visited daily from Day 1 to Day 18 and every other day from Day 18 until Day 60. McLaughlin (2003) chose to visit the remains in her study once a week from Day 40 to Day 60. This aspect of the methodology was not followed for this study due to the dynamic nature of the decomposition that was observed prior to Day 40 and that the remains were not yet skeletonized. Due to scavenging activity, the facility was visited daily to place the heads back in their original deposition location for camera viewpoint purposes as well as ensuring that all the heads remained within the enclosure.

Data Collection Procedures

Decomposition Stages

Progress of decomposition was recorded upon every observational visit to the remains. This project directly compares decomposition scoring from McLaughlin (2003), who modified Anderson and VanLaerhoven (1996) stages of decomposition model to exclude insect succession information. This model was developed using an oceanic and Mediterranean environment in British Columbia, making it ideal for a study conducted in the Willamette Valley. McLaughlin (2003)'s modified table (Figure 1) was utilized during this study, due to insect collection not being a primary aspect of this research. Utilizing the same decompositional model helped eliminate unneeded variables and allowed for a more accurate and direct comparison. When discussing scoring, Anderson and VanLaerhoven's (1996) modified decomposition model will be denoted as AV.

Total Body Score (TBS)

Megyesi et al. (Megyesi, Nawrocki, and Haskell) (2005) will be denoted as MNH when referring to decomposition scoring within this study. MNH used a supplemental method of determining PMI based on scoring of decomposition using a point-based system (total body score (TBS)). The remains within this study were scored for TBS on every observational visit to the site. This specific study only used the head/neck scoring chart for TBS calculation as this is the only applicable chart for this project due to the nature of the research sample. AV's stages of decomposition model and MNH’s TBS method were compared in order to validate and examine the accuracy and applicability of each scoring model to the Willamette Valley of Oregon.

Rainfall, Temperature, and Humidity

Rainfall, temperature, and humidity were recorded for the entire duration of the observation period (Appendix 12). Specifically, average daily temperature was recorded in order to calculate ADD. A local weather station, located on the LCC campus and adjacent to the research site, was utilized for the purpose of this research. The choice to use a local weather station located in close proximity to the research site and operated by LCC staff instead of the nearest National Weather Service station is in accordance with recent research on the inaccuracies of National Weather Service data for estimating PMI using Megyesi et al.’s ADD formula (Dabbs, 2010). Dabbs (2010) discussed the incongruencies associated with using data from National Weather Service stations for decompositional research, due to differences in weather between off-site stations and the data collection location. These inconsistencies were observed even when using stations that are located less than 10 miles from the research site (Dabbs, 2010). Although it would have been preferential to have the weather station located on site, the distance between the research site and LCC is only 0.55 miles (0.89 km), making it much closer than the off-site stations that Dabbs (2010) examined in their study which were 3.542 miles (5.7 km) and 6.152 miles (9.9 km) off-site.

Scavenging

Scavenging was not a direct component of this research, however, small animal and avian scavengers were observed on the remains throughout the study period.

Scavenger presence during the observation period was confirmed through on-site game camera footage and movement of the remains. Camera footage will allow scavenger species, frequency of scavenging activities, and scavenger preference/behaviors to be evaluated in a concurrent project currently underway. In the case that the remains were moved from their original location (with the snout aligned with the stake), the movement was measured, and the remains were placed back in their assigned location, in order to continue game camera observations. Movement was measured from the stake at the original location to the tip of the snout at the displaced location.

On-Site Game Cameras

Game cameras were utilized in this study to collect photographic and video evidence of the decompositional process as well as monitor animal activity within the enclosure and around the heads. The specific cameras utilized were Bushnell Trophy Cameras HD model # 119836C (Appendix 13). Cameras were set to field scan mode to automatically take photos at one-hour intervals, 24-hours a day. In addition to the field scan setting, all cameras were also set for motion activation in order to record movement by scavengers, visitors to the site, and extreme weather conditions (wind, heavy rain, snow, etc.). Heads 2, 3, 5, and 6 (H2, H3, H5, H6) each had a camera aimed at them the entire 60-day observation period. Head 1 and 4 (H1 and H4) (open sub-environment) had cameras starting Day 13 due to scavenging activity. Additional cameras were placed inside and outside the facility to monitor the overall site activity.

Inter-Observer Error

Observers outside of the primary researchers were invited to the site throughout the observation period in order to collect data on inter-observer error in the methods tested. These observers ranged in experience level with the methodologies. For the purpose of this study, the following categories were created to distinguish the observers. Beginners were those who have never taken an anthropology course or an anthropology course directly relating to the project material (i.e. Introduction to Forensic Anthropology, Taphonomy, etc.). Intermediate observers are those who have taken at least one anthropology class directly relating to the material and are familiar with the concepts/stages of decomposition but have never used this knowledge or the methodologies in practice. Advanced observers are those who are familiar with the different decompositional processes and have used this knowledge and methodologies in practice. Beginner observers were given a brief 5-10 minute primer (by the primary researcher) about the stages of decomposition, photographic examples, the specific methodologies being analyzed, and how to score the remains using the descriptors included within the methods. The observers were than provided with forms for scoring (Appendix 14 and 15). The total number of participants was 11 individuals consisting of: 7 beginners observers, 3 intermediate observers, and 1 advanced observer.

Sharp Force Trauma Infliction

Three pig heads (H4-H6) had additional sharp force trauma (SFT) wounds (besides the saw marks to remove their head from the rest of the body) inflicted upon them in order to test variance in rate of decomposition and insect activity between remains with more open wounds (SFT) and more intact remains.

Trauma Wounds

The wounds inflicted upon this group were incised and punctured in nature. “Incised wounds are defined medically as those where the length is greater than its depth” (Symes et al., 2002). Puncture wounds are medically defined as those that are deeper than it is long on the skins surface (Prahlow, 2016). On each of the three heads three open wounds were created: 1) an approximately 6-inch-long incised wound, making contact with the bone, located over the masseter muscle contacting the ramus of the mandible diagonally; 2) an approximately 6-inch-long incised wound, making contact with the bone, located over the levator nasolabialis muscle contacting the nasal bones horizontally; and 3) a puncture wound, making contact with the bone, located over the center of the frontal bone (Appendix 16).

Trauma Equipment

A separate instrument was used on each of the three heads: 1) a Gerber Gator Machete was used on H4 and purchased from Cabela’s located in Springfield, Oregon; 2) a Buck Knives 119 Special fixed-blade hunting knife was used on H5 and ordered from Amazon.com; and 3) a Mercer Culinary M22608BL Millenia 8- inch Chef’s Knife was used on H6 and ordered from Amazon.com (Appendix 17). Instruments were chosen based on accessibility within the Willamette Valley of Oregon.

Infliction Procedure

The trauma was inflicted manually with each instrument by the primary researcher. Manual trauma infliction has been justified by other researchers due to forensic cases often resulting in trauma that is inflicted in an irregular manner (Capuani et al., 2013). Due to human error involved in this methodology of trauma infliction, each of the wounds inflicted are distinct in nature. The wounds were inflicted as close to the intended methodologies as possible and speed and force were maintained as consistent as reasonably possible. Furthermore, due to human error, there were multiple occurrences of "misses" during the trauma infliction.

The heads were placed on the ground in a position that was most convenient for each trauma infliction. Each head was laid on its right side with the left side facing upwards towards the sky in preparation for the 6-inch long incised wound to the masseter muscle to be inflicted. After infliction of the masseter wound, the heads were then laid with the large SFT wound from decapitation on the ground and their frontal facing upwards. It was in this position that the 6-inch long incised wound to the nasals and the puncture wound to the frontal was inflicted.

H4: The first swing of the machete resulted in missing the masseter muscle and partially cut a piece of flesh off the posterior portion of the head, sharing a border with the decapitation wound. This cut was superficial in nature. The first attempt at inflicting the puncture wound to the frontal resulted in missing the frontal in its entirety and puncturing the skin on the right side of the head. This wound was of medium depth but did not make contact with the bone.

H5: The first attempt at inflicting the puncture wound to the frontal resulted in missing the "middle" of the bone. This wound was fairly shallow, and it was indeterminable if the knife actually made contact with the bone. A second attempt was successful in both being situated in the middle of the frontal and making contact with the bone.

H6: All cuts were successfully inflicted upon the first attempt.

Analysis and Evaluation

Scoring models between AV and MNH were statistically and qualitatively analyzed in order to study which model more closely aligned with decomposition observed throughout the course of this study. Regression analysis was conducted in order to determine how much of the variation in the scores can be accounted for by accumulated time. Subsequent analysis of residuals was conducted for two other variables hypothesized to influence decomposition within the WV, temperature and precipitation. The resulting PR > F values were considered significant if <0.05, suggestive if between 0.05 and 0.10, and not significant if > 0.10. If the variable had multiple significant or suggestive head values, it was determined that more of the variation in scores can be accounted for by that variable.

The data recorded for the purpose of examining inter-observer error is irregular due to visiting observers not recording scores for every day of the observation period. Due to this irregularity, a simple agreement vs. disagreement statistic was run. Visiting observers scores for each head on each visit was compared to the primary researchers score for "agreement". When analyzing the data from AV, it was determined that a score within 0.5 stage was considered to be in agreement. The data from MNH was considered to be in agreement if the point value assigned was within 1 point of the primary researchers score.

The reasoning behind MNH having more flexibility in their agreement scores versus AV is due to the fact that MNH has more stages listed within their scoring model (13 possible pts) and thus the point value weight is smaller than AV (5 stages/categories of decomposition or 5 possible pts). The number of agreed upon scores was than compared with the total number of observations for the scoring group (beginners or intermediate/advanced scorers) to get a percentage of agreement for each scoring model.

Results

Hypothesis 1

Decomposition observed throughout this study during the cold/wet season (winter) did not closely align with scoring tables presented in either Anderson and VanLaerhoven (1996) (AV) or Megyesi et al. (2005) (MNH). Analyses of statistical, qualitative, and inter-observer error suggests that neither scoring method is a good fit for the Willamette Valley (WV) of Oregon.

Quantitative Analysis

Regression analysis of the head/neck scores from MNH scoring tables found that less than 50% (average r2 = .45 or 45% for H1-H6) of the variation in scores can be explained by accumulated time. Analysis of residuals showed that more of the variation can be accounted for through precipitation (one significant value, four suggestive values, and one non-significant value that was close to being suggestive) (Figure 3). Residual analysis of temperature resulted in no significant values (Figure 3). Thus, it can be assumed that temperature did not account for any of the variation in scoring. This contradicts MNH that found 80% of the variation in decomposition could be accounted for by the combination of elapsed time and temperature.

Analysis of scoring from AV's stages of decomposition table found that, much like MNH, less than 50% (average r2 = .44 or 44% for H1-H6) of the variation in scores can be explained by accumulated time. Analysis of residuals resulted in an inverse result from MNH, with more of the variation in scores being accounted for through temperature rather than precipitation (Figure 3). Residual analysis for temperature resulted in one significant value, four suggestive values, and one not significant value. In contrast, residual analysis of precipitation found no significant values (Figure 3).

Qualitative Analysis

The relationship between time since death and decomposition score/progress has been described as curvilinear, if one variable increases the other follows suit (Megyesi et al., 2005; Suckling et al., 2015). Decomposition observed throughout the duration of this study was not curvilinear in nature (Figures 4 and 5). Winter conditions resulted in a decomposition pattern that included partial mummification and/or drying of the remains due to low temperatures that inhibited the decomposition process. Additionally, there was a lack of precipitation/moisture in the environment during these times. Prior to mummification, the remains progressed through early decomposition and appeared to be approaching advanced decomposition when stasis occurred. These periods of stasis were often reversed through precipitation and moisture being reintroduced to the tissues. In these cases, the remains appeared to rehydrate back to a “fresher” stage of decomposition. The pattern of partial mummification and rehydration led to scores that would increase and decrease with precipitation throughout the observation period. The remains in this study were characterized by a red/orange coloring of the flesh that eventually morphed into browns and blacks (with an underlying red color still present).

Interobserver Error

Analysis of agreement versus disagreement in decomposition scores from observers of varying experience levels found a difference between beginner scorers and intermediate/advanced scorers. Additionally, a difference in agreement was observed in beginner scores between Anderson and Vanlaerhoven's (1996) (AV) stage of decomposition model and Megyesi et al.'s (2005) (MNH) head/neck scoring chart. Beginners scoring remains with AV's model agreed with the primary researcher's score 29% of the time (37 out of a total of 126 observations agreed). Intermediate and advanced scorers agreed 91% of the time using the same model (412 out of a total of 454 observations agreed). Beginners scoring remains with MNH's head/neck scoring chart agreed with the primary researcher's score 52% of the time (62 out of a total of 120 observations agreed). Intermediate and advanced scorers agreed 92% of the time (413 out of 450 observations agreed). The total agreement between all experience levels using AV's model was 77% (449 out of 580 observations agreed). Total agreement using MNH's chart between all experience levels was 83% (475 out of 570 observations agreed). However, the high average is likely due to the low number of beginner scores in comparison to the intermediate/advanced scores (120 observations versus 450 observations).

Statistically, scores were more consistent from intermediate and advanced scorers, with a high level of agreement. This is indicative of the value of being intimately familiar with the stages of decomposition prior to recording decomposition scores. Beginner scorers had better agreement using Megyesi et al.'s (2005) chart in comparison to Anderson and VanLaerhoven's (1996) model. Megyesi et al.'s (2005) chart also had higher total agreement between all observers.

Hypothesis 2

Decomposition rates in the cold/wet season (winter) were slower in comparison to decomposition rates in the warm/dry season (summer) within Oregon according to data on decomposition from McLaughlin (2003) (Figures 5 and 6). During this study the remains peaked at Stage 2 (AV) of decomposition on Day 15 of the study and remained in that stage until the conclusion of the observation period (Day 60), while McLaughlin's (2003) hogs were all in Stage 4 of decomposition by Day 13 of the study and remained in that stage until the conclusion of the observation period (Figure 5 and 6). Although the remains in this study stayed in the "bloat" stage or Stage 2 of the decomposition model for the majority of the observation period, true bloating of the heads was not observed.

Hypothesis 3

In this study, increase in number of open wounds (sharp force trauma (SFT)) had no effect on rate of decomposition or insect activity when compared with more intact remains. The decompositional trends observed in the SFT heads (H4-H6) showed no consistent patterning that separated them from the control heads (H1-H3) (Figures 5 and 6). H6 exhibited an overall slower rate of decomposition in comparison with the other heads. Insects, when present, preferred natural orifices (mouth, nose, and cranial cavity) to those artificially made (SFT wounds).

Discussion

Preliminary data show that neither Anderson and VanLaerhoven's (1996) (AV) nor Megyesi et al.'s (2005) (MNH) scoring tables are an adequate fit for the WV. Contradicting results from residual analysis suggests a need for research that conducts a more in-depth statistical comparison of the two models in order to identify and further evaluate what the major variables are that influence decomposition in the WV. MNH's method suggests that the primary influencers of decay are accumulated time and precipitation, while AV's method suggests that temperature and accumulated time are the driving forces of variation. Overall, these incongruencies imply that neither method is ideal for this region at least within a winter environment.

The pattern of partial mummification and rehydration observed throughout this study contradicts the inherent concept of biological decay where remains are expected to progress through the stages of decomposition without regressing to previous stages. In regard to AV and MNH, neither scoring chart/study accounted for this patterning of decomposition. Other studies have recorded rehydration of mummified tissue however they were conducted in much more arid environments than that of the WV (Suckling et al., 2015). Mummification observed in the WV was similar to that described in Central Texas and Arizona where the dehydrated skin became hard and leathery, forming a thick shell over the remains that may or may not protect moist and decomposing tissues underneath (Galloway et al., 1997; Suckling et al., 2015).

Throughout the observation period, a predominant red coloring of the skin on the remains was observed. This coloring was noticeably absent from the qualitative descriptors in MNH's head and neck scoring chart. In fact, the coloring denoted in the scoring chart focuses on a gray/green discoloration for early decompositional processes, progressing into a brown/black coloring in later stages (Megyesi et al., 2015). The coloring of the remains in this study were characterized by reds and oranges that eventually morphed into browns and blacks (with an underlying red color still present). This color patterning was also observed by Keough et al. (2017) in pigs (Sus scrofa), suggestive that the color discrepancies might be associated with the use of an animal proxy. However, this coloring has been observed on human remains in the WV by forensic professionals and in human decomposition studies in Colorado (Connor et al., 2019; McLaughlin, personal communication, 2019). Some of the discrepancies in color of the remains can be explained through growth of colored fungus and bacteria that was observed throughout this study, however, the underlying color differences were still present. Future research should address these color discrepancies in decaying remains within the WV, using full bodied pigs and eventually humans, in order to characterize if these observations were unique to this study or if they represent a defining characteristic of decay in this region. Additionally, judging of color is a subjective endeavor and different individuals can have different perceptions of colors. Future studies should test various color systems (i.e. the Munsell color system) in order to test how well they align with the qualitative properties of decomposition.

Scoring of the remains, was much more consistent between intermediate and advanced scorers, with a high level of agreement. Beginner scorers had a higher percentage of agreement when using MNH’s chart in comparison to AV’s model. Based on conversations with these scorers, MNH’s chart was easier to use due to the descriptive and precise explanation of each subtle observational change that the remains were likely to exhibit when compared with the five broad stages of decomposition used in AV's model. MNH's chart also had a higher total agreement between all observers. These preliminary results suggest that in the case of creating a scoring system for the WV, the decomposition scoring chart should be more specific than AV's (1996) model, and more similar to MNH's (2005) chart.

Winter decomposition recorded during this study occurred at a slower rate when compared to data on summer decay from McLaughlin (2003). McLaughlin's (2003) carcasses all reached Stage 4 of decomposition using AV's model by day 13 of the observation period. The remains in the current study peaked at Stage 2 (AV's model) on Day 15 and remained in this stage until the conclusion of the observation period (Day 60). The winter decomposition that was observed in this study was also more variable than the summer decomposition presented in McLaughlin (2003). In the 2003 study, pigs progressed through each stage of decomposition (Stages 1-4) without the stasis and regression that was observed in the winter decay of this study. Additionally, although the remains in this study stayed in Stage 2 of AV's decomposition model for the majority of the observation period, true bloating of the heads was not observed. This could be associated with the lack of abdominal organs that release gases initiating bloating in the research sample or that bloating has been recorded to be reduced in colder months due to the slowing of bacterial activity (Roberts and Dabbs, 2015). The deceleration of decomposition observed in this study during the winter in comparison to summer decomposition rates is congruent with other research that has been conducted across the United States (Bass, 1997; Galloway et al., 1997).

Originally, it was hypothesized that increase in number of open wounds in the flesh of the remains would enable insects to colonize more openings of the remains, thus accelerating decay. However, this was not the case for this study as there was minimal insect activity throughout the duration of the observation period and when insects were present, they preferred natural orifices (mouth, nose, and cranial cavity) to those artificially made (SFT wounds). This could be explained through infliction of trauma postmortem which does not result in bleeding and moisture that could potentially have attracted insects and scavengers. Observations from this study are consistent with previous research conducted by Smith (2014) and Galloway et al. (1997). The SFT wound to the mandible did enable scavengers to tear off pieces of the cheek flesh more easily which resulted in the first occurrence of skeletonization (non-decompositional related). Additionally, scavengers used the torn cheek "flaps" as a handle to more easily move the remains away from their original deposition location.

A considerable amount of small animal and avian scavenging of the remains occurred throughout this study. All skeletonization observed (predominately after the conclusion of the observation period) was due to scavenging of the remains and not decompositional processes. In most cases, the scavenging of the remains propelled decomposition forward due to loss of mass. Scavenging also restricted insect growth due to eggs laid by insects in more open areas being predated by birds and small animal scavengers such as skunks. The significance of scavenging in influencing decomposition has been recorded by other studies across the United States (McLaughlin, 2003; Pokines and Pollock, 2018; Spies et al., 2018; Steadman et al., 2018; Suckling et al., 2015). These studies have also suggested that scavenging is more likely to occur in winter conditions due to limited availability of food sources for wildlife (Spies et al., 2018; Steadman et al., 2018). Multi-seasonal research is needed at MORTIS in order to determine if the scavenging that occurred during the duration of this project is at a higher than average rate due to winter conditions or if the scavenging is typical of the area year-round. Scavenging is a component of taphonomic processes that affect remains in an outdoor setting within the WV. A majority of forensic anthropology cases found outdoors in the WV involve remains being scavenged by various vertebrate species (McLaughlin, personal communication, 2019). Thus, although scavenging was not a focus of this study, it does make the results more realistic of what would be expected if human remains were deposited in the area.

Remains were placed in three separate sub-environments during this study. Throughout the observation period and during data analysis, it became clear that there was a difference in the decomposition rate between the heads placed in the Armenian blackberry (Rubus Armeniacus) bushes and the other sub-environments. Remains in the blackberry sub-environment (H3 and H6), progressed at a slower rate of decomposition than the other heads (Figures 4 and 5). This can be attributed to the fact that the blackberry bushes provided the most shelter from the sun and other environmental elements out of all three sub-environments, which resulted in the remains staying at a lower scoring stage longer than the other heads. Additionally, due to protection from the sunlight, the temperature in this environment can reasonably be assumed to be slightly lower than the other sub-environments. Temperature has been suggested to be a major influencer in decompositional processes and MNH and Vass et al. (1992) believe that it is the driving force in decomposition.

Comparison of decomposition trend between H3 and H6 shows that H3 progressed at a quicker rate than H6 and followed a trend that is more comparable to the rest of the remains. This discrepancy can likely be attributed to H3 being scavenged more frequently than H6, thus advancing the rate of decomposition. Although the overall loss of mass was different between the two heads, similarities in qualitative characteristics (moist decomposition, reduced mummification, and less intense coloring) of decay between H3 and H6 set them apart from their counterparts in other sub-environments. The disparity in scavenging between H3 and H6 is likely due to the fact that H3 was only about 50% surrounded by blackberry bushes and thus was slightly easier to access by scavengers, while H6 was 75% surrounded by blackberry bushes with very limited access for scavengers.

Insect activity was relatively minimal during the course of the observation period. Flies were observed on the remains beginning the day of death, but were overall, few and far between. Following various warmer/sunnier periods during the study, fly eggs (unidentified species) were observed in the natural orifices on the heads (nose, roof of the mouth, eyes, ears). Despite the presence of eggs, the freeze/thaw cycle appeared to constrain larval growth, at least externally. Limited external larval growth was also influenced by scavenger predation of eggs laid in open areas such as the eyes. For the majority of the study, external maggot activity was absent from the remains and there was no evidence of breaking through the skin of the heads. H1 was the first and primary head that exhibited evidence of purging and maggots developing to mass, apparently from the inside of the cranial cavity, perhaps due to the skin remaining intact.

This event was also recorded by Bass (1997) who discussed maggots leaving the skin as a protective layer away from the sun, wind, rain, and snow.

Limitation

Pigs as Proxies for Humans

This study used pigs (Sus scrofa) as proxies for human remains to study decomposition trends in the Willamette Valley (WV). Recent research has raised concerns with the use of animal proxies to model human decomposition (Cockle and Bell, 2015; Connor et al., 2018; Dautartas et al., 2018; Notter et al., 2009; Steadman et al., 2018). Initial concerns with using pigs were raised by Notter et al. (2009) which found that the total fatty acid composition of pigs was significantly different than that of humans because of differences in fatty acid concentrations. Cockle and Bell (2015) echoed Notter et al.'s concern by stating that up until 2015, there had not yet been a study that primarily focused on whether or not there was a significant difference in pig versus human decomposition with adequate sample sizes. Studies conducted by Connor et al. (2018), Dautartas et al. (2018), and Steadman (2018) found that decomposition rates between humans and pigs were significantly different. However, Dautartas et al. (2018) and Steadman (2018) found that pig decomposition more closely modeled human decomposition when compared to the decomposition of other animal proxies (i.e. rabbits). Thus, pigs could be useful for establishing baseline decomposition data and preliminarily analyzing general trends in decomposition for a region (Connor et al., 2018; Dautartas et al., 2018; Steadman et al., 2018), which is the purpose of this study.

Additionally, pigs have been used as proxies for humans in a multitude of previous studies across an array of sub-disciplines within forensic taphonomy (Anderson and VanLaerhoven, 1996; Cammack et al., 2016; England, 2006; Keough et al., 2017; McLaughlin, 2003; Nawrocka et al., 2016; Payne, 1965; Ribéreau-Gayon et al., 2018; Roberts et al., 2015; Schoenly et al., 2007; Shean et al., 1993; Smith, 2014; Spies et al., 2018). Pigs were chosen as surrogates for humans in these studies due to the similarity of internal anatomy, fat distribution, chest cavity size, omnivorous diet, and lack of heavy fur. Furthermore, pigs are easier to procure in large numbers and at a low cost which allows for studies with higher samples sizes. Studies with higher sample sizes elicit statistical analyses that are more accurate and precise as well as showing repeatability of qualitative observations (Schoenly et al., 2007). Pigs were determined to be adequate proxies for the purpose of this study due to the availability of remains within the region, ability to obtain Institutional Animal Care and Use Committee (IACUC) approval, cost, and that pigs have been shown to be the closest animal proxy to humans and can result in data that is useful for establishing baseline/preliminary decomposition data (Connor et al., 2018; Dautartas et al., 2018; Steadman et al., 2018).

Use of Pig Heads

The use of pig heads for this study is a limitation due to the inability of obtaining a total body score (TBS) and scoring decomposition trends for whole carcasses. TBS requires decomposition to be scored in three separate anatomical regions of the remains (head/neck, trunk (torso), and limbs), thus requiring an entire carcass. This is due to the fact that decomposition is highly variable and often results in differential decomposition between anatomical regions of the body (Megyesi et al., 2005). Other studies have used pig heads for their research including Jordana et al. (2013), Kieser et al. (2008), and Calce and Rogers (2007). These studies are primarily focused on trauma analysis and the role that taphonomic variables have on skeletal trauma. Pig heads were chosen as proxies for humans in these studies do to the similarities of skin and bone structure between pig and human heads (relatively hairless and skulls with three layers) as well as not being concerned with measuring the force necessary to damage human bone (Calce and Rogers, 2007; Jordana et al., 2013; Kieser et al., 2008). The use of pig heads for this study had advantages including that it better represents a scavenging model which typically involves disarticulation of the head from the rest of the body. Additionally, the use of heads simulates real life scenarios of decapitation that occur through human intervention. Finally, the use of pig heads in previous studies conducting trauma research aligns with this study's inclusion of sharp force trauma (SFT) and its effects on the decomposition process (Calce and Rogers, 2007; Jordana et al., 2013; Kieser et al., 2008).

Sample Size

The sample size for this study is relatively small (n=6). Research conducted by Dautartas et al. (2018) and Steadman (2018) involved the use of 45 pigs, rabbit, and human subjects across three seasons. However, the sample size for this project is larger than or comparable to other taphonomic studies conducted within the Pacific Northwest (PNW) and also larger than many studies conducted in other regions of the world (Spies et al., 2018 (n=3); Schoenly et al., 2007 (n=4); England, 2006 (n=2); McLaughlin, 2003 (n=4); Anderson and VanLaerhoven, 1996 (n=7); Shean et al., 1993 (n=2)). Future research should aim to have larger sample sizes similar to studies conducted by Connor et al. (2018) (n=39), Dautartas et al. (2018) (n=45), Steadman (2018) (n=45), and Keough et al. (2017) (n=20).

Precipitation

Precipitation data was recorded from the KEUG weather station located at Mahlon Sweet Field (Eugene Airport) which is 11.86 miles (19 km) from MORTIS. On-site precipitation recording is preferable for research due to variation in rainfall within small distances (Dabbs, 2010), thus making this a limitation of this study. Although not a perfect substitute for on-site data, KEUG shows general trends in precipitation for the region, which is useful in preliminary analyses, such as this study.

Comparison to McLaughlin (2003)

This study compared the differences between summer decay rates and winter decay rates within the WV through direct comparison of data recorded by McLaughlin (2003). Although both studies were conducted within the WV and within the same county, the comparison is not perfect due to the research locations being different. McLaughlin's (2003) study sites included environments that ranged from clearcuts to areas that were heavily forested. The current study's enclosure is in an upland disturbed meadow environment and lacks a forested environment (Holmes, 2019). While a perfect replica environment would have been preferable for this study, the current research location does closely mimic the clearcut environment from McLaughlin (2003). Additionally, both environments are representative of those often found within Western Oregon and the WV (Taylor and Hannan, 1999). Future studies should use whole hogs for greater comparability between studies and incorporate forested/wooded environments in order to test how regional environmental variation influences decomposition.

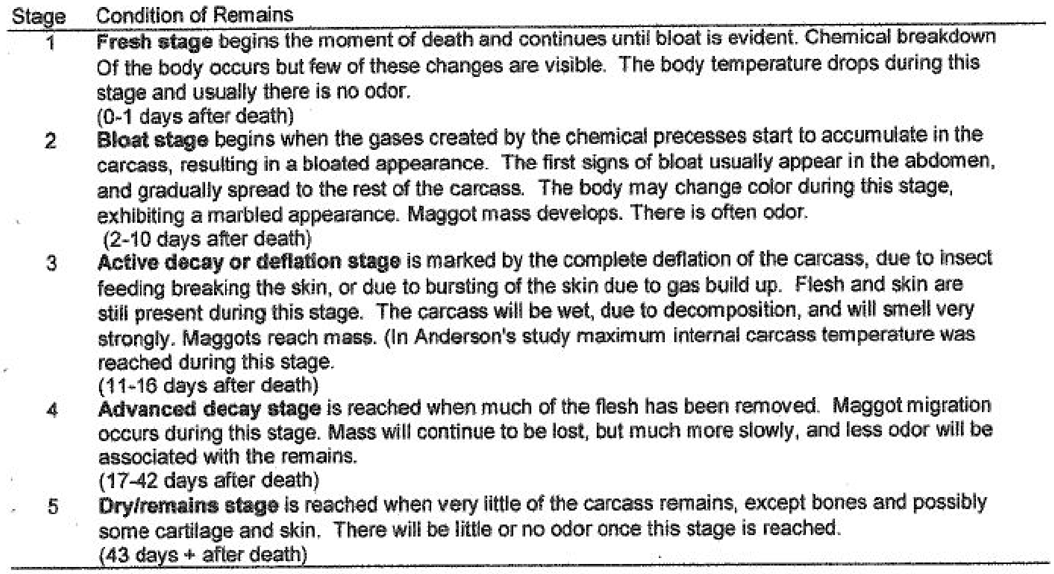
Future Research

This pilot study shows that decomposition within the WV is highly variable and differs from other regions of the United States. More longitudinal research is needed in order to further understand the distinct nature of decomposition in the WV and the variables that produce such results. The only longitudinal studies that have been conducted within the WV are in summer and winter environments. Prospective projects should analyze the spring and fall environments within the WV. Future research should address the limitations of this study through the use of whole pigs for full TBS scoring and subsequent ADD analysis, increased sample size, on-site precipitation data, and data drawn from an environment that is forested and more comparable to McLaughlin (2003). Additionally, future studies should focus on obtaining inter-observer data that is less irregular in order to more intensively analyze inter-observer error rates between various decomposition scoring models. AV's stage of decomposition model includes estimated days that each stage will be reached. Future studies could analyze how accurate these estimations are for correctly predicting stage succession timeframe within the PNW. Regional differences in decomposition should be continually analyzed in future studies and the development of a region-specific decomposition model using data from decomposition in the WV should be created. Multiple studies have called for the implementation of regional models for decomposition and PMI estimation (Christensen et al., 2014; Connor et al., 2019; Connor et al., 2018; Keough et al., 2017; Suckling et al., 2015; Wescott, 2018). In the case that a regional model was implemented within the WV, it should be based off research that used a human sample, was longitudinal in nature, had a large sample size, and involved methodology that is easy to use for practical applications (Connor et al., 2019). Finally, future research should aim to use a human sample in order to validate preliminary findings from studies using non-human animals as proxies.

Conclusion

This study found that decomposition in the WV during the cold/wet season (winter) did not closely align with either Anderson and VanLaerhoven (1996) or Megyesi et al. (2005). Analyses of statistical, qualitative, and inter-observer error suggests that neither scoring method is a perfect fit for the WV. Winter decay was found to occur at a slower pace when compared to summer decay and was overall more variable. Partial mummification and rehydration of the remains was observed multiple times during this study, influencing the overall decomposition trend that deviates from the standard curvilinear form. Increase in number of SFT wounds did not influence rate of decay. However, sub-environmental differences were found to have an effect on decomposition rate. A considerable amount of small animal and avian scavenging of the remains occurred throughout the study. Scavenging influenced rate of decay through loss of mass that propelled decomposition forward. Overall, more research on taphonomic processes in the WV is needed in order to gain further insight into the much larger question of decomposition processes and their patterning within this region. The establishment of MORTIS, as an outdoor taphonomic research facility, will enable future research to occur and will also serves as a valuable resource to researchers across an array of academic disciplines and varying academic levels (undergraduates to forensic professionals). Although this study is preliminary in nature, it does show that the WV contains a unique ecological system that results in distinctive patterns of decomposition that set this region apart from other regions in the United States, where decomposition research has been conducted.

Figures:



Stage	Condition of Remains
1	**Fresh stage** begins the moment of death and continues until bloat is evident. Chemical breakdown Of the body occurs but few of these changes are visible. The body temperature drops during this stage and usually there is no odor. (0-1 days after death)
2	**Bloat stage** begins when the gases created by the chemical precesses start to accumulate in the carcass, resulting in a bloated appearance. The first signs of bloat usually appear in the abdomen, and gradually spread to the rest of the carcass. The body may change color during this stage, exhibiting a marbled appearance. Maggot mass develops. There is often odor. (2-10 days after death)
3	**Active decay or deflation stage** is marked by the complete deflation of the carcass, due to insect feeding breaking the skin, or due to bursting of the skin due to gas build up. Flesh and skin are still present during this stage. The carcass will be wet, due to decomposition, and will smell very strongly. Maggots reach mass. (In Anderson's study maximum internal carcass temperature was reached during this stage. (11-16 days after death)
4	**Advanced decay stage** is reached when much of the flesh has been removed. Maggot migration occurs during this stage. Mass will continue to be lost, but much more slowly, and less odor will be associated with the remains. (17-42 days after death)
5	**Dry/remains stage** is reached when very little of the carcass remains, except bones and possibly some cartilage and skin. There will be little or no odor once this stage is reached. (43 days + after death)

Figure 1: Anderson and VanLaerhoven (1996) modified by McLaughlin (2003)

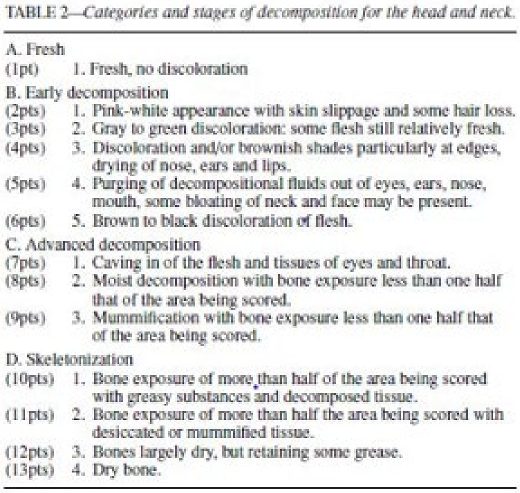


TABLE 2—*Categories and stages of decomposition for the head and neck.*

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.

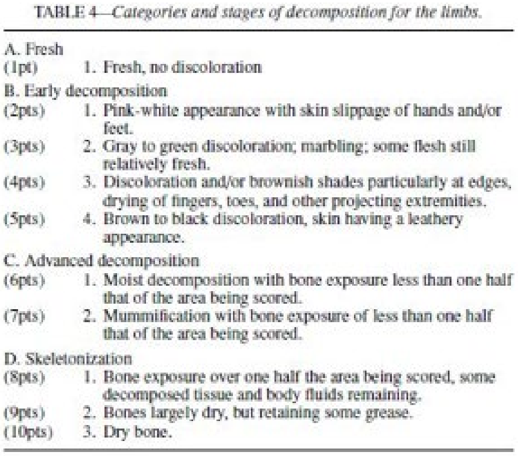


TABLE 4—*Categories and stages of decomposition for the limbs.*

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.

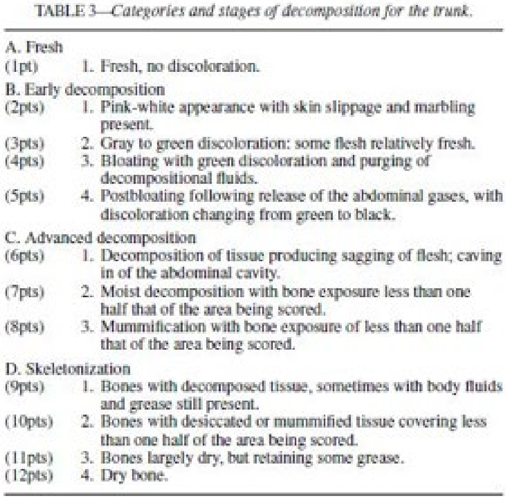


TABLE 3—*Categories and stages of decomposition for the trunk.*

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.

Figure 2: Megyesi et al. (2005) TBS Scoring Charts

	MNH Accumulated Time vs. Head/Neck Scores	MNH Residual Analysis Temp vs. Head/Neck Scores	MNH Residual Analysis Precip vs. Head/Neck Scores	AV Accumulated Time vs. Head/ Neck Scores	AV Residual Analysis Temp vs. Head/Neck Scores	AV Residual Analysis Precip vs. Head/Neck Scores
H1	0.59	0.32	0.07	0.43	0.05	0.28
H2	0.39	0.43	0.09	0.46	0.04	0.48
H3	0.27	0.37	0.02	0.36	0.07	0.14
H4	0.51	0.44	0.06	0.43	0.05	0.28
H5	0.46	0.56	0.06	0.43	0.05	0.28
H6	0.42	0.91	0.11	0.54	0.23	0.38

Figure 3: Regression and Residual Analysis

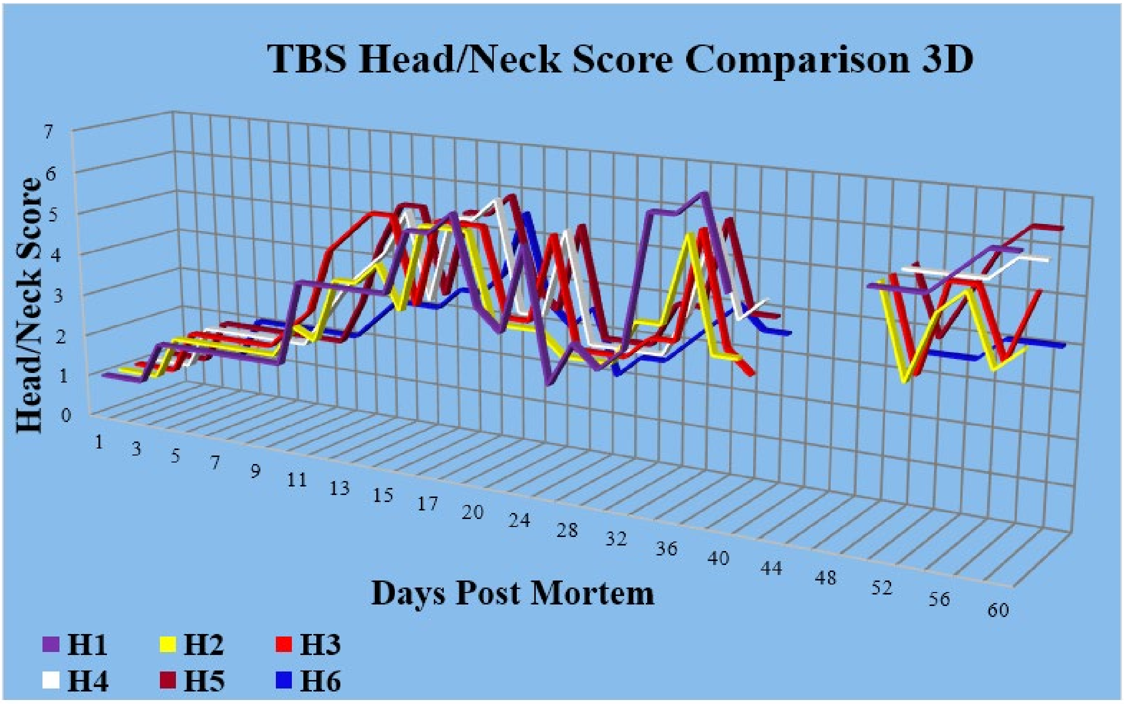


Figure 4: TBS Head/Neck Score Comparison 3D

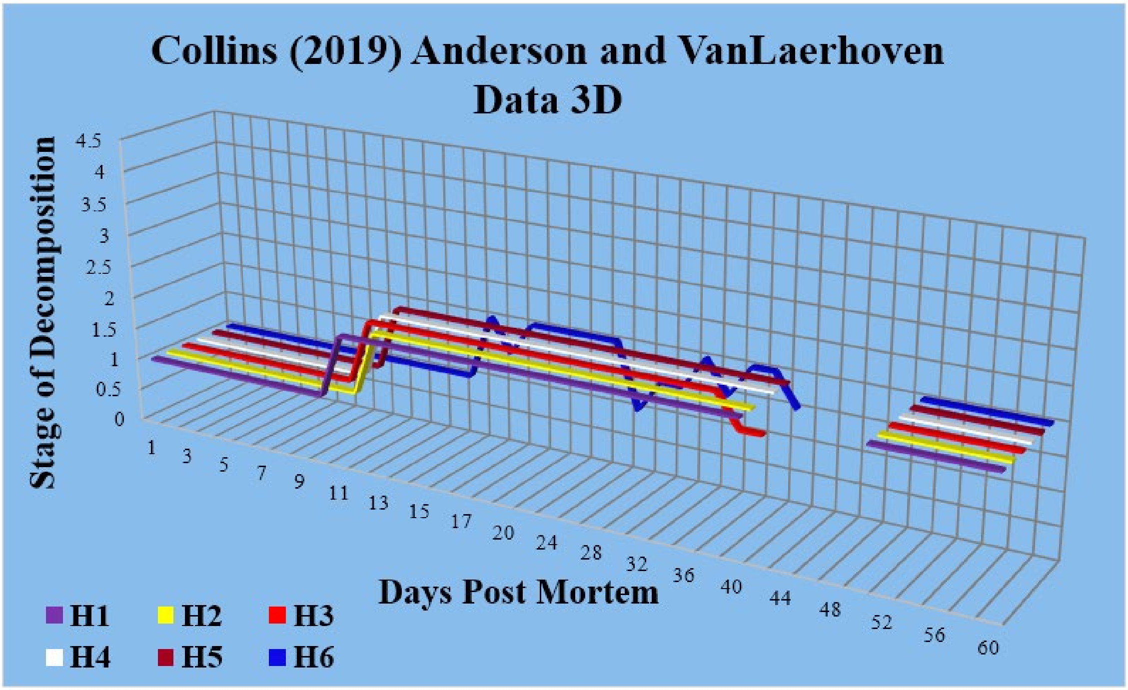


Figure 5: Collins (2019) Anderson and VanLaerhoven (1996) Data 3D

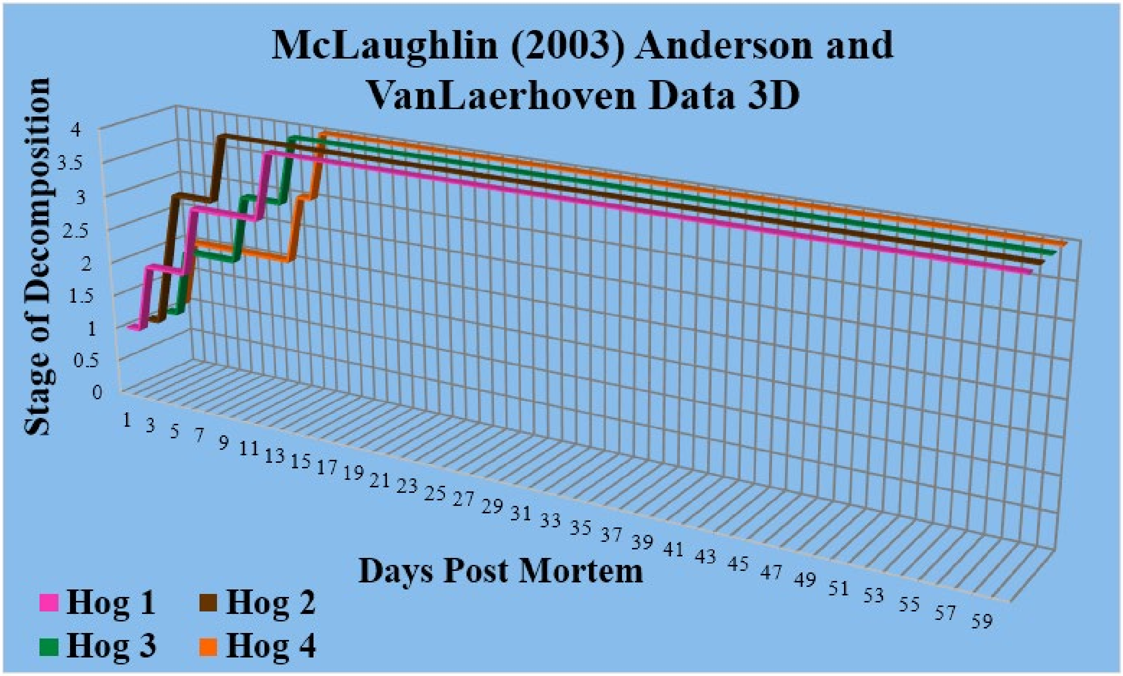


Figure 6: McLaughlin (2003) Anderson and VanLaerhoven (1996) Data 3D

Appendices:

Species	**Common Name**	**Life History Pattern/Habit**	**Distribution & Relative Abundance**	**Exotic Invasive Native**
Cytisus scoparius	Scott's broom	Perennial evergreen shrub	Even Patchy/Dominant	Exotic Invasive
Rubus armeniacus	Armenian blackberry	Perennial +/- evergreen shrub	Even Patchy/Dominant	Exotic Invasive
Schedonorus arundinaceus	tall red fescue	Perennial grass	Even Patchy/Dominant	Exotic Invasive
Bromus rigidus (or diandrus)	ripgut brome	Perennial grass	Even Patchy/Dominant	Exotic Invasive
Dipsacus fallonum	teasel	Perennial herb/shrub	Even Patchy/Dominant	Exotic Invasive
Holchus lanatus	velvet grass	Perennial grass	Even Patchy/Not Dominant	Exotic
Valerianella corniculate	European corn salad	Annual herb	Even Patchy/Dominant	Exotic
Geranium molle	dovefoot geranium	Annual herb	Even Patchy/Dominant	Exotic
Rumex salicifolia	willow dock	Perennial herb	Scattered Patchy/Not Dominant	Native
Plantago lanceolate	narrow-leaf plantain	Perennial herb	Scattered Patchy/Not Dominant	Exotic
Chrysanthemun leucanthemum	oxeye daisy	Perennial herb	Even Patchy/Dominant	Exotic Invasive
Daucus carrota	Queen Anne's lace	Perennial herb	Even Patchy/Dominant	Exotic Invasive
Hypochaeris radicata	hairy cat's ear	Perennial herb	Scattered Patchy/Not Dominant	Exotic Invasive

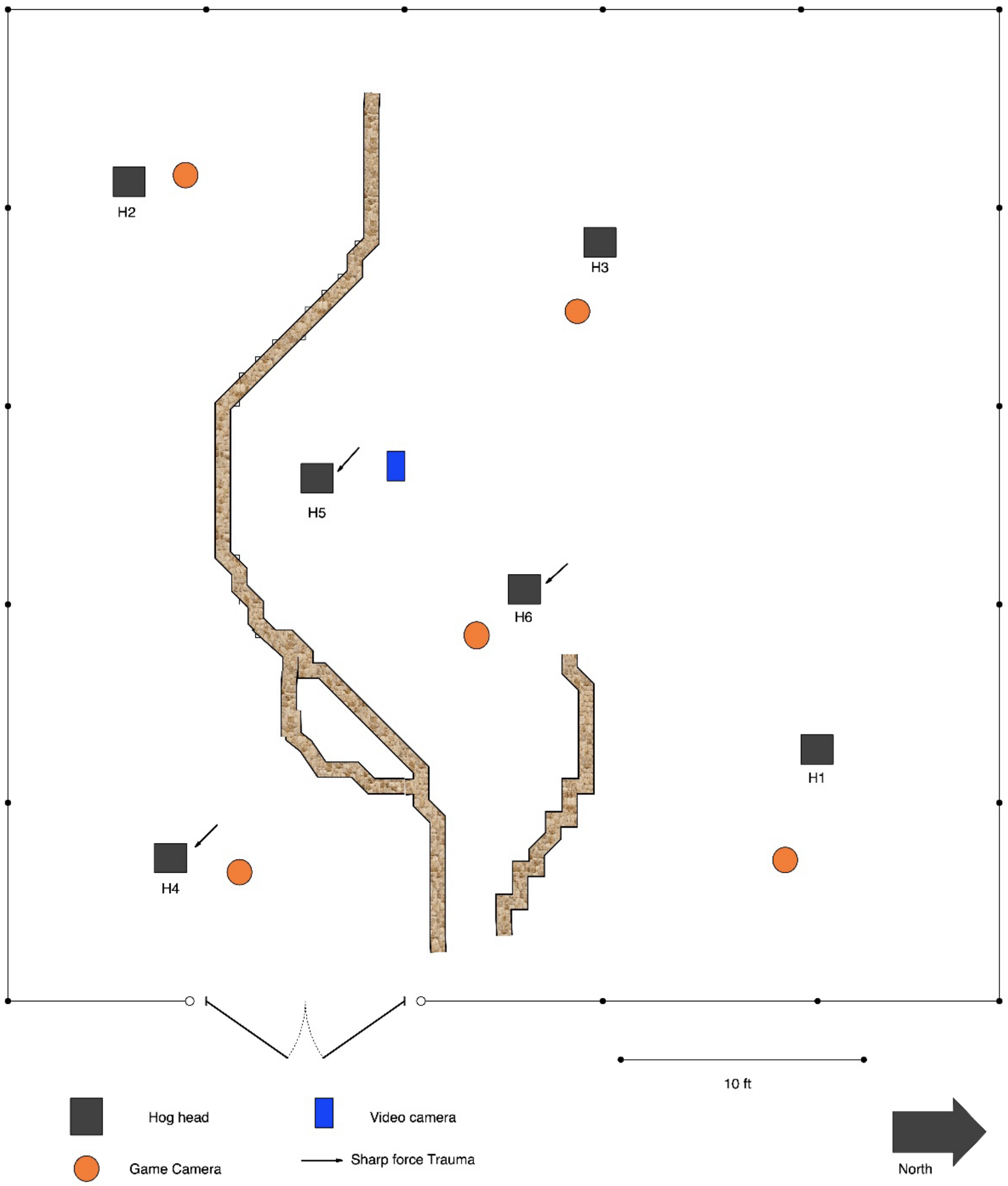
Appendix 1: Taphonomy Field Site Habitat Assessment (Holmes, 2019)

Plants characterized by habit (herb shrub tree), life history pattern (annual, perennial, deciduous, evergreen), and Distribution (even, patchy) & Relative Abundance (D=dominant ND=not dominant, potential for % categories). Vegetation monitoring will reveal more species with seasonal progression.

Appendix 2: Pig Heads Day 0

Appendix 3: Lane Community College (LCC) Land

Appendix 4: MORTIS Aerial View



Appendix 5: Placement of Remains within Enclosure

Appendix 6: H1 Throughout Observation Period

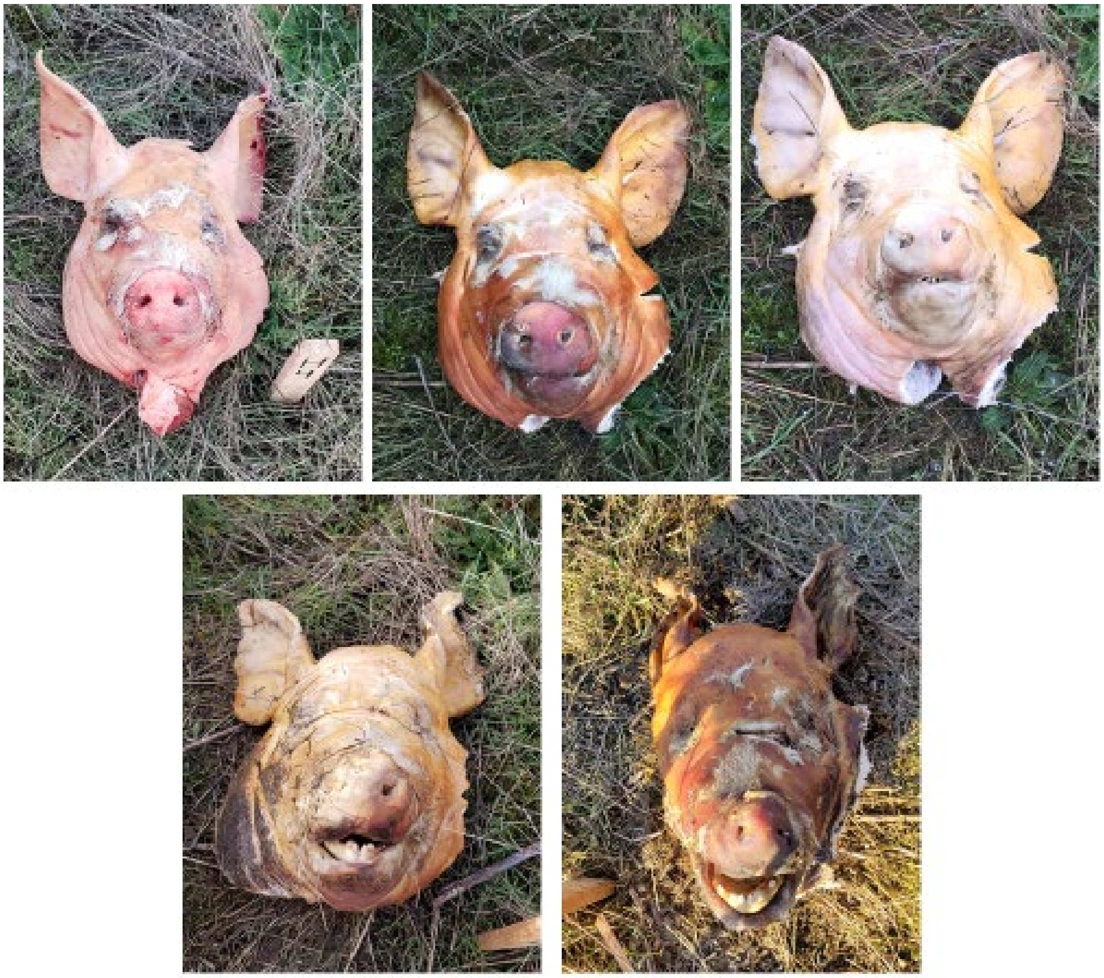
(Top Left- Day 2; Top Center- Day 18; Top Right- Day 20; Bottom Left- Day 34; Bottom Right- Day 60)

Appendix 7: H2 Throughout Observation Period

(Top Left- Day 2; Top Center- Day 18; Top Right- Day 20; Bottom Left- Day 34; Bottom Right- Day 60)

Appendix 8: H3 Throughout Observation Period

(Top Left- Day 2; Top Center- Day 18; Top Right- Day 20; Bottom Left- Day 34; Bottom Right- Day 60)



Appendix 9: H4 Throughout Observation Period

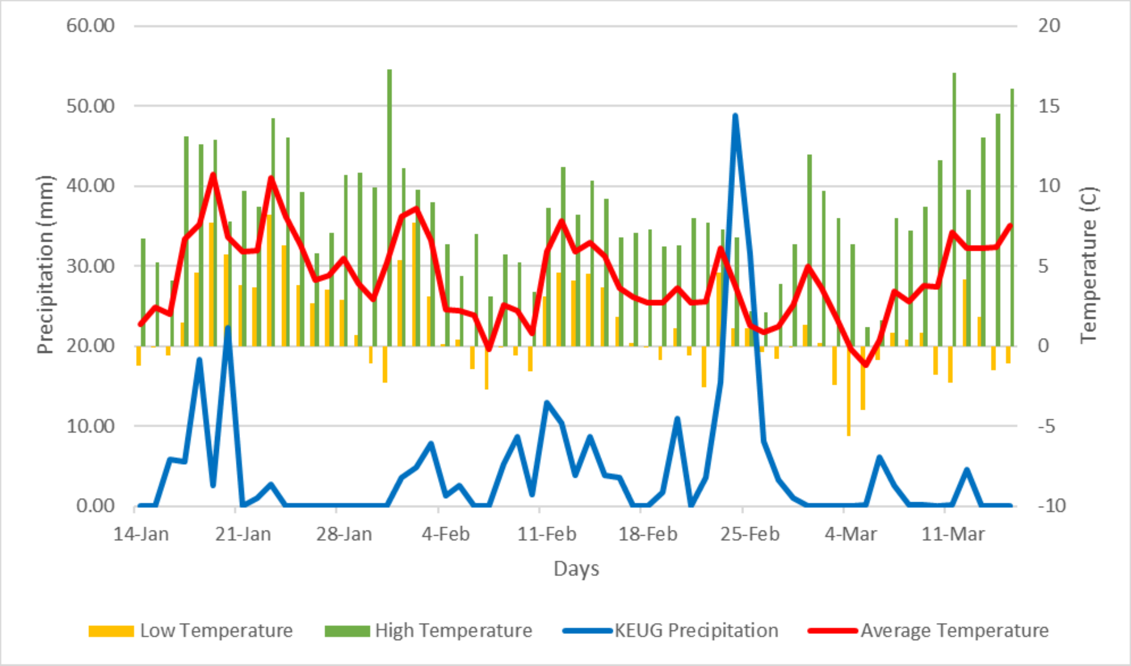
(Top Left- Day 2; Top Center- Day 18; Top Right- Day 20; Bottom Left- Day 34; Bottom Right- Day 60)

Appendix 10: H5 Throughout Observation Period

(Top Left- Day 2; Top Center- Day 18; Top Right- Day 20; Bottom Left- Day 34; Bottom Center- Day 60 Side A; Bottom Right- Day 60 Side B)

Appendix 11: H6 Throughout Observation Period

(Top Left- Day 2; Top Center- Day 18; Top Right- Day 20; Bottom Left- Day 34; Bottom Right- Day 60)



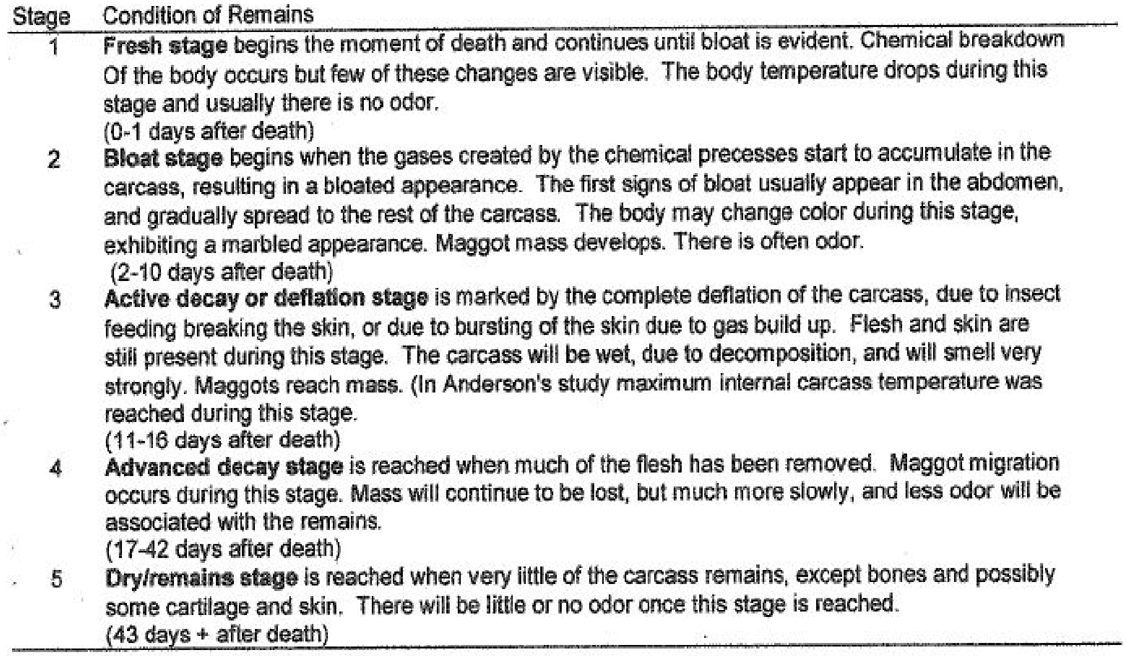
Appendix 12: Weather Data for Observation Period using Ruscher (2019) Data (Created By: B. Falconer (2019))

Appendix 13: Bushnell Trophy Cam HD

Anderson and VanLaerhoven Decomposition Data Sheet

Recorder:
Date:

Individual	Fresh	Bloat	Active Decay	Advanced Decay	Dry/Remains	Comments



Stage	Condition of Remains
1	**Fresh stage** begins the moment of death and continues until bloat is evident. Chemical breakdown Of the body occurs but few of these changes are visible. The body temperature drops during this stage and usually there is no odor. (0-1 days after death)
2	**Bloat stage** begins when the gases created by the chemical precesses start to accumulate in the carcass, resulting in a bloated appearance. The first signs of bloat usually appear in the abdomen, and gradually spread to the rest of the carcass. The body may change color during this stage, exhibiting a marbled appearance. Maggot mass develops. There is often odor. (2-10 days after death)
3	**Active decay or deflation stage** is marked by the complete deflation of the carcass, due to insect feeding breaking the skin, or due to bursting of the skin due to gas build up. Flesh and skin are still present during this stage. The carcass will be wet, due to decomposition, and will smell very strongly. Maggots reach mass. (In Anderson's study maximum internal carcass temperature was reached during this stage. (11-16 days after death)
4	**Advanced decay stage** is reached when much of the flesh has been removed. Maggot migration occurs during this stage. Mass will continue to be lost, but much more slowly, and less odor will be associated with the remains. (17-42 days after death)
5	**Dry/remains stage** is reached when very little of the carcass remains, except bones and possibly some cartilage and skin. There will be little or no odor once this stage is reached. (43 days + after death)

Appendix 14: Anderson and VanLaerhoven (1996) Decomposition Data Sheet

Total Body Score Data Collection Form and Hypothetical TBS/ADD Scores

Recorder:
Date:

Individual	Head & Neck	Comments

Hypothetical TBS Scores:

Individual	Head & Neck	Trunk	Limbs	TBS	ADD	Comments

ADD Formula:

$$ADD = 10^{(0.002TBS+1.81)} \pm 388.16$$

Estimation:

$10^{[\,(0.002)\,(\qquad\qquad)]\,+\,1.81}$ = _______________ + 388.16 = _____

- 388.16 = _____

Appendix 15 (Side 1): Megyesi et al. (2005) TBS Head/Neck Scoring Data Sheet

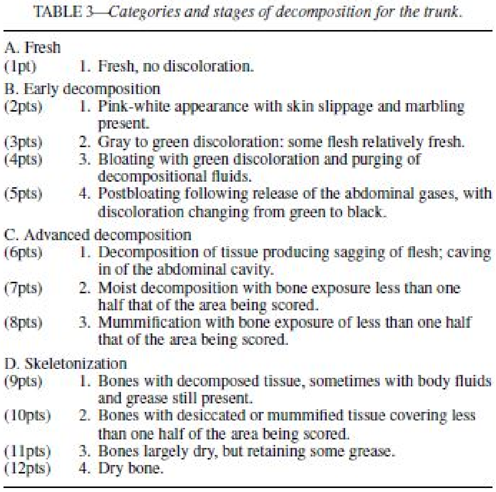


TABLE 3—*Categories and stages of decomposition for the trunk.*

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.

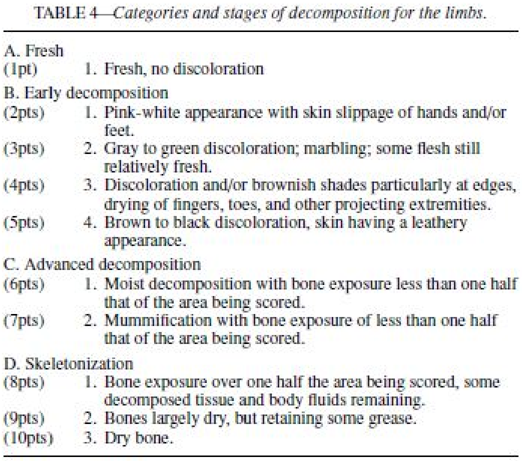


TABLE 4—*Categories and stages of decomposition for the limbs.*

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.

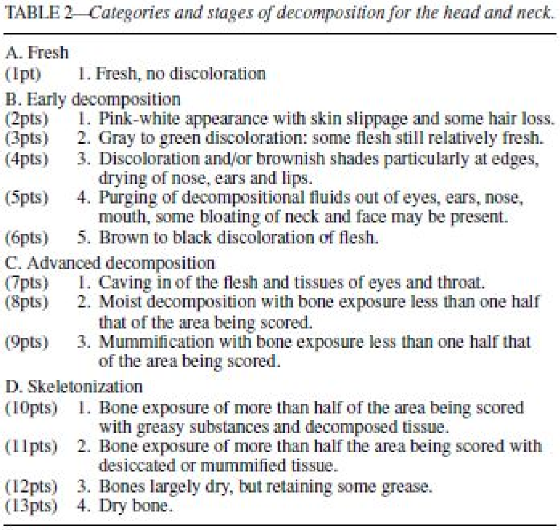
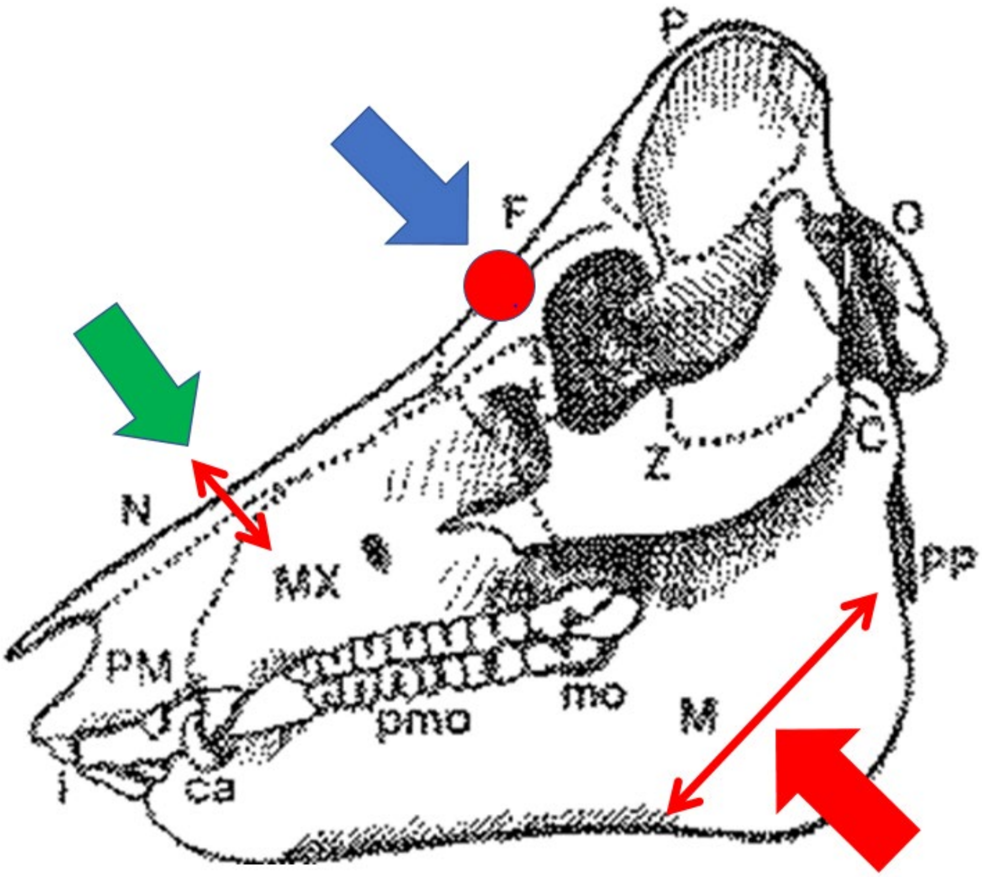


TABLE 2—*Categories and stages of decomposition for the head and neck.*

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.

Appendix 15 (Side 2): Megyesi et al. (2005) TBS Head/Neck Scoring Data Sheet



Appendix 16: SFT Infliction Diagram

Appendix 17: SFT Equipment

From top to bottom: Gerber Gator Machete; Buck Knives 119 Special; Mercer Culinary M22608BL

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