Decomposition Rates and Taphonomic Changes Associated with the Estimation of Time Since Death in a Summer Climate: A Case Study from Urban Nova Scotia

by

Courtney R.S. Brown

A Thesis Submitted to Saint Mary's University, Halifax, Nova Scotia,
in Partial Fulfillment of the Requirements for the
Degree of Master of Science in Applied Science

June 2010, Halifax, Nova Scotia

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ABSTRACT

Estimating time since death has an integral role in missing persons and found human remains cases; therefore it is necessary to understand decomposition rates and taphonomic changes for the environment in which a body is found. Most research related to rates of human decomposition has been conducted in environments that do not reflect the temperate climate of Nova Scotia. The lower temperatures, present in Nova Scotia, slow the decomposition processes and taphonomic changes increasing the apparent postmortem interval. Research was carried out in an urban Nova Scotia environment. It examined the decomposition rates of four domestic pigs (*Sus scrofa*) deposited on the ground surface and allowed to decompose naturally. Results from this study indicate that skeletonization begins between days 64 and 80. Results from this study also indicate the rate of decomposition occurs logarithmically. The slower decomposition rates indicate the necessity of regional data to assist in forensic investigations.

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CHAPTER 1

INTRODUCTION

This study presents the first anthropological investigation into decomposition rates and taphonomic changes of human remains in Nova Scotia. The principle objectives of this research are to (1) establish decay rates for one summer season in Nova Scotia, (2) identify patterns and sequences of decomposition for a site within the Halifax Regional Municipality (HRM), (3) identify the effects of clothing on test subjects (pig model) and, (4) provide data to aid in the estimation of time since death for bodies under a specific set of environmental conditions.

Cases of found human remains, currently investigated in Nova Scotia, have to utilize data from other regions, with different climates, to complete the taphonomic analyses when determining time since death. Therefore, completion of this project will provide a preliminary data set for estimating time since death and potentially, increase the number of missing persons identified. There have been 27 found human remains cases recorded at the Nova Scotia Medical Examiner Service between 2005 and 2009. The availability of research data regarding regional decomposition and taphonomy would be valuable for answering question surrounding time since death.

The identification of missing persons provides necessary information for law enforcement personnel who are investigating the events surrounding a death. Not only will taphonomic analyses increase the number of missing persons identified, but it will also provide a narrower time frame surrounding the individual's disappearance and demise. This will allow law enforcement to corroborate or refute witness and suspect testimony. Objectively confirming details will enable officers to charge criminals with the crimes they commit and exonerate those who were wrongly accused.

This study is a pilot study for future research. Even though this study has a small sample size the data generated from this study will begin to help increase operational effectiveness, in law enforcement, by providing a narrower time frame surrounding the individual's disappearance and demise, thus beginning to decrease the people-power needed to accomplish the final goal, i.e. closing a case. Identification of an individual and the closing of the case will also provide closure to families and allow for a proper dignified disposition for the deceased.

This project is invaluable because Nova Scotia is known as the missing persons capital of Canada (Rogers, personal communication November 18, 2008). There is also a significant number of missing persons within Canada. As of 2005, there were 4,800 missing persons in Canada – excluding children – increasing by 270 individuals annually which remain unsolved (http://ww2.ps-sp.gc.ca/publications/news/2005/20050401-2_e.asp). This project will provide data not previously available for the area that will aid investigations into unknown human remains and missing persons.

CHAPTER 2

BACKGROUND

The estimation of time since death (TSD) has long been a crucial component in cases of found human remains (Mann et al., 1990; Prieto, 2004). Assessing TSD is based on decomposition rates of the human body and on taphonomic changes seen on the bones after death (postmortem). In cases where tissues are present and autopsies can be performed, TSD estimations are performed by forensic pathologists and entomologists. Entomological analyses, for estimating TSD, have been accepted for many years (Arnoldos et al., 2005). However, in cases of human skeletal remains, or where very limited tissue remains on the decomposed body, the TSD estimations are performed by forensic anthropologists.

Research into decomposition rates and taphonomic changes associated with human death is in its infancy. Until recently, the majority of research was published as anecdotal accounts cited in medical examiner and coroner cases (Komar, 2003; Nordby, 2002). A small number of studies have examined human remains cases, to determine TSD estimations, however, these studies are based on the day the person went missing and therefore timeframes developed using this type of study are not exact. Recent studies developed more precise TSD estimations by taking into account timelines from the dumping of a body and tracking of the time it takes to decompose. Almost all experimental studies that investigate the rates of human decomposition utilize non-human surrogates. Studies that utilize pig cadavers can provide data relevant to humans. The pig has a similar weight and amount of body hair as humans, and is thought to be an acceptable surrogate for humans in this context (Shean et al., 1993; Weitzel, 2004). Other animal species, such as squirrels, rats, rabbits and dogs have also been used. However, research using other species only provides direction for future studies since the data collected cannot be directly applied to rates of human decomposition.

2.1 Time Since Death

Time since death (TSD) is the length of time between the death event and the discovery of the remains. This interval can be narrowed down by analyzing the decomposition stage or the condition of skeletal remains. As a body decomposes it progresses through specific stages in a patterned fashion the nature of which depends upon the location of the remains. In cases of found human remains that still possess a large amount of tissue, an estimation of TSD can be completed using entomological techniques (Anderson and VanLaerhoven, 1996; Arnoldos et al., 2004; Campobasso et al., 2001; Hewadikaram and Goff, 1991; Leblanc and Strongman, 2002; Sharanowski et al., 208; Schoenly et al., 1991; Simpson and Strongman, 2002). However, in cases where little or no tissue remains on the body, an assessment of the decomposition stage and taphonomic changes must be conducted by a forensic anthropologist. This type of analysis is also crucial in cases where tissue may still be present but insects are no longer significant and cannot be utilized reliably.

An accurate assessment of TSD aids in the search for missing persons, as it provides a more accurate window of time when a person died, and allows investigators to corroborate suspect and witness testimony, and increases the cost effectiveness of the agency investigating the missing person case. Not only can an accurate assessment benefit a case from the investigative standpoint, but it also provides closure for families with missing loved ones and allows the family to provide a final resting place for their loved one.

2.2 Forensic Taphonomy

Taphonomy is the study of changes that occur to organisms after death. These changes manifest in visible macroscopic changes as well as microscopic changes to bones and soft tissue. The macroscopic changes can appear in the form of alterations in colour or staining of the bone, cracks and breaks, drying, flaking, bleaching, and scavenging. Changes are time dependant, thus, an estimation of time since death can be conducted based on the presence or absence of specific characteristics. Forensic taphonomic analyses enable the reconstruction of the death event as well as the events and processes following death (Haglund and Sorg, 1997b).

Taphonomic characteristics used to estimate TSD are, (1) the amount of tissue present, and (2) changes in the bones, i.e. colour, texture, structure, and their overall condition. Haglund and Sorg (1997a:2) indicate that an estimation of postmortem interval (PMI) can be generated by considering the smell and colour of bones, insects, and amounts of adhering earth or associated flesh, weathering, and animal damage. A taphonomic assessment can reveal whether or not the location where the human remains were discovered is the site where the death occurred. The estimation of PMI, based on taphonomic changes, can also determine if a body has been moved from one location to another, providing a continuity of events from before death, to after death, and disposal (Shean et al., 1993).

Data is available for the decomposition of human remains in regards to disarticulation sequences, scavenging, weathering and fluvial transport of skeletal elements (Haglund and Sorg, 1997a; Ubelaker, 1997). Weathering patterns are caused by the response of the bone to the immediate environment, e.g. sun and soil (Ubelaker, 1997). There are six progressive stages of bone weathering (Table 2.1). Depending on the circumstances, Stages 2 through 5 may take many months or even many years to complete. The environment in which remains are deposited has a substantial influence on taphonomic processes, therefore, taphonomic research data are only applicable to the region in which the research is conducted.

Table 2.1: Bone weathering patterns

Weathering Patterns	
Stage 0	Bone surface shows no sign of cracking or flaking due to weathering. Usually bone is still greasy. Marrow cavities contain tissue; skin and muscle/ligament may cover part or all of the bone surface.
Stage 1	Bone shows cracking, normally parallel to the fibre 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
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.
Stage 3	Bone surface is characterized by patches of rough, homogenously weathered compact bone, resulting in a fibrous texture. In these patches extend to cover the entire bone surface. Weathering does no penetrate deeper than 1.0 mm to 1.5 mm at this stage, and bone fibres are still firmly attached to each other. Crack edges usually are rounded in cross section. Tissue rarely present at this stage.
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.
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.

(Adapted from Ubelaker, 1997; based on Behrensmeyer's 1978 model).

2.3 Decomposition Processes

Decomposition of a body begins immediately after death and involves the processes of autolysis, putrefaction and decay (Clark et al., 1997; Dent et al., 2004; Vass et al., 1992). Autolysis is the self digestion of soft tissues, manifesting as fluid filled blisters on the skin and skin slippage usually not becoming apparent until a few days after death (Clark et al., 1997; Vass, 2001). Putrefaction follows autolysis. It is the destruction of the soft tissues of the body by microorganisms already present in the body or derived from those present in the surrounding soil (Dent et. al., 2004; Vass 2001).

The aerobic organisms, depleting the body tissues of oxygen, create favourable conditions for the anaerobic microorganisms that continue the decomposition processes (Dent et. al., 2004). Putrefaction is normally not observed until 48 to 72 hours after death. The stomach, intestines, accessory organs of digestion, blood, and heart muscle are typically the first tissues to decompose. Gas and fluids accumulated during decomposition usually purge via the rectum, however, the pressure can be sufficient to tear apart the skin (Vass 2001). Air passages, lungs, kidneys, the bladder, brain, and nervous tissues are the next tissues to decompose, respectively (Gill-King 1997). After putrefaction fats and proteins decompose and electrolytes leach out of the body (Vass 2001). It is during this time that large numbers of aerobic and anaerobic bacteria are present and insect and animal activity begins. The body's tissues and organs decompose and degenerate, finally becoming liquefied (Dent et. al., 2004). Liquefaction and disintegration proceeds, leaving the skeleton articulated only via ligaments. Hair will often remain on the body after death due to the fibrous protein, keratin, found in the skin. Hair also resists degeneration by enzymes remaining long after death (Dent et. al., 2004).

The saponification of adipose tissue occurs throughout the decomposition process producing a soap like substance referred to as adipocere. Adipocere forms via the hydrolysis and hydrogenation of tissue fats (Mellen et al., 1993; O'Brien and Kuehner, 2007). The process usually occurs in nearly anaerobic conditions within various environments (O'Brien and Kuehner, 2007). The basic requirements for adipocere are aquatic or moist environments, bacterial enzymatic action and warm temperatures (Mellen et al., 1993; O'Brien and Kuehner, 2007).

2.4 Variables Affecting Decomposition

The time frame for decomposition and skeletonization of the human body is dependent upon many factors. Is the body interred in a coffin? Deposited on the surface? Buried directly in the soil? Decomposition of an embalmed body progresses at a slower rate, and in a different pattern, than bodies that are not embalmed (Mann et al., 1990; Sledzik and Micozzi, 1997). One notable example is a case reported by Bass (1997) of a Civil War Officer that was interred for 113 years, however the body displayed only decomposition changes associated with a timeframe of 1 year. Bodies in direct contact with soil will decompose differently. The rate at which decomposition, skeletonization, and taphonomic changes occur is dependent on a number of variables. These include temperature, humidity and aridity, access by insects, rainfall, burial and depth, animal activity, trauma, body size and weight, the presence of clothing, the nature of the surface on which the body is placed, soil pH, embalming and exsanguination perimortem (Campobasso et al., 2001; Clark et al., 1997; Komar, 1998; Mann et al., 1990; Micozzi, 1986; Prieto et al., 2004; Rhine and Dawson, 1998; Shalaby et al., 2000; Vass, 1992;

Weitzel, 2005).

Many studies have found that these variables are not independent. Some variables have a greater influence on the rates of decay and taphonomic changes than others (Table 2.2; Mann et al., 1990). In the estimation of TSD, these variables cannot be examined separately since they share a relationship within the natural environment. Due to this relationship research must be conducted in the natural setting, i.e. an uncontrolled environment; to accurately replicate any of the natural processes that occur during decomposition and be applicable to real forensic science cases.

Table 2.2. Variables affecting decomposition rates

Variable	**Effect on Decomposition Rate**[a]
Temperature	5
Access by insects	5
Burial & depth	5
Carnivores/rodents	4
Trauma(penetrating/crushing)	4
Humidity/aridity	4
Rainfall	3
Body size & weight	3
Embalming	3
Clothing	2
Surface placed on	1
Soil pH	unknown

[a] Subjective criteria based on a 5-point scale with 1 being not influential and 5 being most influential. **(Adapted from Mann, Bass and Meadows 1990)**

2.5 Decomposition and Skeletonization Rates

Over 22 years of decomposition studies carried out at the University of Tennessee, Knoxville Anthropology Research Facility (ARF), utilizing donated human cadavers, have determined that temperature, access by insects, and burial and depth of body burial are the most influential factors in the decomposition rates of decomposing human remains (Cattaneo, 2007; Mann et al., 1990). The effects of animal activity, freezing of the body, hanging of the body, shading, mechanical injury, aqueous environments, and insect activity have all been researched (Adlam and Simmons, 2007; Aturaliya and Lukasewycz, 2005; Campobasso et al., 2007; Haglund, 1997; Leblanc and Strongman, 2002; Mann et al., 1990; Micozzi, 1986; Prieto, 2004; Schoenly et al., 1991; Shalaby et al., 2000; Sharanowski et al., 2008; Shean et al., 1993; Simpson and Strongman, 2002; Tersigni, 2007; Weitzel, 2005). Each research variation provides insight into the processes involved and the effects that they have on the rates at which decomposition occurs. Taphonomic patterns and changes are also affected by the same variables that influence the rate of decomposition (Table 2.3).

Table 2.3: Stages of human decomposition.

Categories and Stages of Decomposition
A. Fresh
1. Fresh, no discolouration or insect activity
2. Fresh burned
B. Early Decomposition
1. Pink-white appearance with skin slippage and some hair loss
2. Gray to green discoloration; some flesh relatively fresh
3. Discolouration to brownish shades particularly at fingers, nose, and ears; some flesh still relatively fresh
4. Bloating with green discolouration
5. Post bloating following rupture of the abdominal gases, with discolouration going from green to dark
6. Brown to black discolouration of arms and legs; skin having leathery appearance
C. Advanced Decomposition
1. Decomposition of tissues producing sagging of the flesh; caving in of the abdominal cavity, often accompanied by extensive maggot activity
2. Moist decomposition in which there is bone exposure
3. Mummification, with some retention of internal structures
4. Mummification of outer tissues only with internal organs lost through autolysis or insect activity
5. Mummification with bone exposure of less than one half the skeleton
6. Adipocere development
D. Skeletonization
1. Bones with greasy substances and decomposed tissue, sometimes with body fluids still present
2. Bones with desiccated tissue or mummified tissue covering less than one half the skeleton
3. Bones are largely dry, but still retaining some grease
4. Dry bone
E. Extreme Decomposition
1. Skeletonization with bleaching
2. Skeletonization with exfoliation
3. Skeletonization with metaphyseal loss, with long bones and cancellous exposure of the vertebrae

(Adapted from Galloway et al.1989)

Decomposition rates vary with the climate and region in which they are located. Research conducted at the ARF has documented varying rates of skeletonization. In the summer, complete skeletonization can occur in as little as two weeks. In contrast, it may be very slow in the winter as the soft tissues may dehydrate and turn leathery (Bass, 1997). A retrospective review, conducted in Arizona, found that skeletonization occurred in an open air setting in approximately two months (Galloway, 1997:144 – 145; Galloway et al., 1989:611). Galloway (1989:61) also found that skeletonization could occur in an extremely warm house in seven days. In Arizona, during the summer months, it takes one-fifth the amount of time to complete skeletonization as during the winter months (Galloway et al., 1989:612). Similarly, Rhine and Dawson (1998:152) found skeletonization to occur in as little as three weeks, in a New Mexico summer, with soft tissues completely absent after 12 weeks. In contrast, skeletonization occurs in Edmonton, Alberta, in approximately 6 weeks during the summer months and in as short as 4 months during the winter time (Komar, 1998:59).

An experimental study from Edmonton, Canada, investigated the decomposition of buried remains and found that skeletonization took 3 to 5 weeks when bodies were buried in June, whereas, it took 5 weeks to 3 months to reach skeletonization when buried in May (Weitzel, 2005:5). The depth of burial also slowed the decomposition rates (Weitzel, 2005). Research conducted in Spain, found that the minimum length of time for skeletonization to occur was 24 weeks although there was one case of skeletonization occurring in eight weeks; however, there was carnivore activity present during the eight week skeletonization process (Prieto et al., 2004:5). The study in Spain does not specify the season in which the results occurred, therefore making comparison difficult. A recent study, in New York State, collected decomposition data and the variables affecting skeletonization in a cold climate (Bunch, 2009). At one site, skeletonization occurred in six weeks where as the other two sites did not show skeletonization beginning until seven months after exposure to the elements (Bunch, 2009:40).

Animal activity increases the speed of decomposition. The removal of tissue and exposure of internal organs causes the body to decay at a faster rate (Campobasso et al., 2001; Galloway, 1997; Rhine and Dawson, 1998; Sledzik, 1998). A study conducted in Edmonton, Alberta by Komar in 1998 indicates that 80% of individuals, all recovered from an outdoor environment and not buried, experienced some form of animal activity (Komar, 2003:523). A second study conducted by Komar (2003:523) in New Mexico only showed 43% of individuals experienced animal activity. The 2003 study by Komar included a large number cases to which the individuals were recovered from environments and location that could have hindered or prevented animal scavenging from occurring which could be the reason for the variation animal activity.

Rodents tend to damage extremities, such as fingers and toes, as well as the facial structure – nose, ears, and lips – because they are easily accessible for chewing (Mann et al., 1990). Insects colonize orifices – eyes, mouth, nasal cavity and injuries – first to provide protection for their eggs (Campobasso et al., 2001; Sharanowski, 2008; Sledzik, 1998). Any orifices and injuries will also be colonized immediately as they provide an easy location for rodent feeding (Mann et al., 1990). Carnivores are attracted to limbs because they are easily removed from the body and carried to their dens. Canids are known to carry body segments back to dens for consumption and also to play with the cranium like a ball (Galloway et al., 1989; Galloway, 1997; Mann et al., 1990).

Ubelaker (1997) has documented that bone-chewing is not confined to carnivores. Cattle, red deer, reindeer, Muntjac deer, camels, giraffes, wildebeest, kudu, gemsbok, and antelopes have been documented to produce alterations on bones in chewing-like patterns. Animal scavenging exposes more of the cadaver which increases the surface area to volume ratio and therefore increases the decomposition rates.

Taphonomic artefacts, from animal activity may be present on the bones in the form of teeth marks. These provide insight into the type of animal that caused the damage, for example, rodents leave distinctive parallel striae markings on bones (Galloway, 1997). Multiple studies have shown that animal activity increases the decomposition rates, however, no specific research has been conducted that shows the amount of increase (Galloway et al., 1989; Galloway, 1997; Haglund and Sorg, 1997b; Komar, 2003; Mann et al., 1990; Rhine and Dawson, 1998; Sledzik, 1998; Ubleaker, 1997).

Investigation into the effects of frozen versus fresh cadavers has shown that previously frozen cadavers decompose more rapidly than fresh cadavers (Micozzi, 1986). Disarticulation sequences remain the same in both frozen and fresh cadavers; however, the speed with which it occurs is slower in fresh cadavers than in previously frozen bodies. Micozzi (1986) found that fresh cadavers decompose from the "inside-out" predominately via putrefaction (anaerobic decomposition caused by bacteria and or fungi) whereas thawed cadavers decompose from the "outside-in" predominately via decay (aerobic decomposition). Because this research was conducted using rats, these data are not directly applicable to human decomposition. Further research needs to be conducted using a more suitable experimental model.

Variations in the rates of decomposition have been found within the group of individuals who died by hanging. The hanged body experiences a delayed progression through the stages of decomposition. Shalaby et al. (2000) suggests that the slowed rate of decomposition is, firstly, attributable to internal temperatures more closely approximating ambient air temperatures, caused by air surrounding all sides, and secondly, by maggots falling off the maggot mass, on the hanging carcass, that cannot return to the body; a body deposited on the ground surface is still accessible to any maggots that fall onto the ground. Large maggot masses are also not able to form due to the maggots falling off the body, therefore also helping keep the internal temperatures lower relative to non-hanged bodies (Shalaby et al., 2000). Shalaby et al. (2000) conducted their study using 9.2 and 10.7 kg pigs which raises the applicability again.

Bodies in a shaded area also display slower rates of decomposition. Research conducted in coastal Washington State found that pig carcasses in an exposed environment decompose faster due to the higher air temperatures (Shean et al., 1993). Ambient air temperatures affect the feeding of calliphorid larvae and their relative rates of development. Shean et al. (2000) found this to be the primary influence in the decomposition rates in their study. Higher temperatures increase the size of maggot masses and ultimately the decomposition rate (Mann et al., 1990; Shean et al., 2000). However Shean et al.'s (2000) methodology used single pigs in each study condition therefore study results may not be replicable.

Simpson and Strongman (2002) examined shaded versus exposed sites and found that carrion insect activity varied between the two sites and was also dependent on whether the location was rural or urban. The exposed carcasses at the rural site tended to yield very similar insect populations compared to the urban site. The shaded sites – both rural and urban – yielded lower insect populations and the urban site yielded a richer blow fly community. In contrast to previous research, Bunch (2009) found sun exposed carcasses decomposed at a much slower rate than shaded carcass.

Aqueous environments alter the rate of decomposition as well. The disarticulation sequence is also modified and distinct. Decomposition rates vary based on the type of fluvial environment. For example there would be a difference in decomposition rates in a sequestered environment, such as a sunken car, from an open water environment (Haglund, 1993). The changing temperatures, depths, and currents present in an aqueous environment allow bodies to move in a three dimensional manner not possible on land. The sequence of disarticulation is influenced by the nature and relative anatomical position of the joint involved. Less flexible joints, e.g. the vertebral column remain anatomically attached longer than flexible joints, e.g. the shoulder (glenohumeral joint). Research conducted by Haglund (1993) found that the rate of decomposition increases when bodies are in an aqueous environment. However, this study is of limited applicability since it is a retrospective case review and therefore timeframes are not exact and further experimental research needs to be conducted. The consensus from previous research is that types of water bodies and their location cause the water environments and temperatures to change thus affecting the decomposing body. For example, a lake and a river would cause differing decomposition rates and patterns.

2.6 Nova Scotia Research

Taphonomic research that has been conducted in Nova Scotia has only addressed the variation between populations of carrion insect activity in rural versus urban sites during the fall months (Leblanc and Strongman, 2002; Simpson and Strongman, 2002). The four major species collected were *Dryomyza sp*, *Calliphora vicina, C. vomitoria and*

C. terraenovae (Leblanc and Strongman, 2002). *Calliphora* spp. were dominant in the fall however, *P. Regina* and *L. Illustris* were dominant in the summer. The factors that effect the change in seasonal species within Nova Scotia are not known, but the change in composition is known to take 4 to 6 weeks (Leblanc and Strongman, 2002:150).

A second study conducted in the same region found that there were important differences in the species composition between urban and rural sites (Simpson and Strongman, 2002). The urban site yielded a richer blow fly community of seven different species. The rural site yielded only four different blow fly species. *Phaenicia sericata* was collected from the rural site only and was also collected more frequently from the exposed carcasses (Simpson and Strongman, 2002). However, decomposition rates gathered from these studies are not comparable to the present research due to the size of the pig carcasses used. The pigs for one study conducted by Leblanc and Strongman (2002:146) ranged from 0.75 – 1.70 kg and 14 – 37 kg in the second study conducted by Simpson and Strongman (2002:124). These pig carcasses are not representative of the average size of adult humans and therefore this data is only applicable for carrion insect species composition and occurrence.

2.7 Climate Dependence

Past research has established that decomposition rates are dependent on the region and environment in which the body is located (Bass, 1997; Galloway, 1997; Galloway et al., 1989; Komar, 1998; Mann et al., 1990; Prieto, 2004; Weitzel, 2005). The environments in which the research was conducted are not reflective of Nova Scotia's climate. Therefore, the timelines developed in previous research may not be applicable to Nova Scotia. Tennessee, Alberta, Arizona and New Mexico are hotter and more humid climates than Nova Scotia. These climates also lack the precipitation present in Nova Scotia. Taphonomic research, specifically conducted in Nova Scotia is confined to entomological studies of dominant insect species associated with carrion.

CHAPTER 3

MATERIALS & METHODS

3.1 General Subject Information

Pigs are an accepted and appropriate model for human decomposition studies due to their size and the amount of body hair that they possess (Shean et al., 1993; Weitzel, 2005); an adult pig weighs approximately the same amount as an adult human and both have similar amounts of body hair. Numerous studies have utilized pigs for human comparison studies and therefore, comparable data sets are available. Four pigs (*Sus scrofa*), weighing approximately 50 kg each, were utilized for this research. The pigs were obtained from Quality Meats, located in Windsor, Nova Scotia. The pigs were slaughtered using a bolt gun on June 2, 2009, immediately prior to transport to the study site. Approximately 1.5 hours lapsed between death and placement at the site on June 2, 2009.

Four pigs were placed in the same environment with approximately one meter distance between each (Figure 3.1).The pigs were placed in two-inch square wire mesh cages to prevent large carnivores from disturbing them and carrying them away from the site, yet, still allowing insect activity and small animal scavenging to occur. This size of wire mesh was large enough to allow bird and rodent activity to proceed naturally while still eliminating large carnivore activity. The cages were secured to the ground by attaching metal bars to their long axes and placing large boulders on top of the bars. This configuration is designed to reduce the chance of scavenging by large carnivores. All cages were labelled with the following information:

Research conducted by: Saint Mary's University

Supervised by: Dr. Tanya Peckmann

(902) 496 – 8719

Figure 3.1: A view of the research site with the placement of the pigs.

The pigs were labelled #1, #2, #3 and #4 from left to right. All pigs were placed in the right lateral position inside the cages. Pigs #1 and #4 were clothed with blue one hundred percent cotton t-shirts and shorts. Pigs #2 and #3 were not clothed. Pigs #1, #2 and #3 were pink skinned and pig #4 was black skinned. Pigs #1, #2, and #3 experienced more sun exposure than pig #4. Pig #4 was more shaded due to the tree cover in relation to the direction of the sunrise and set.

3.2 Location

This research was conducted on Department of National Defence property within the Halifax Regional Municipality, Nova Scotia, Canada. The site was accessible via an access road that is not in use. It is not visible from the highway or the side road that provides entry to the access road leading to the site. The pigs were placed under tree cover. The ground was covered with low grass and moss. There was also low brush cover – which included leaf litter from previous seasons – around the site, however, it was not dense enough to neither hinder walking nor surround the pigs once they were placed on the ground. The trees, within the site, are deciduous trees that have a high canopy and do not provide low coverage. The site also takes advantage of natural features; it is downhill from a road and accessible at night. These are all features of a body dumpsite, and thus offers a better approximation of true conditions that one may find in the field. To ensure confidentiality of the site, all supplies were transported to the site by the researcher.

3.3 Materials

Cages

The cages were constructed out of plastic coated wire in two-inch square mesh by Rainbow Nets and Rigging, of Dartmouth, Nova Scotia. The cages were five-sided, measuring 152 cm by 76 cm by 46 cm, secured together using metal clamp fasteners.

Clothing

The clothing was purchased from Wal-Mart. Blue one hundred percent cotton t-shirts and shorts were used to ensure matching clothing on both pigs and to eliminate any variation in the decomposition rates caused by differences in the clothing colour and materials.

Photographic Equipment

The camera was a Nikon® D200 digital single lens reflux camera provided by the Nova Scotia Medical Examiner Service. It has a 10.2 megapixel resolution providing clear detailed pictures of the pig carcasses, insect activity, decompositional changes and features visible to the human eye.

3.4 Data Collection

The scene was visited daily at 8:30 am to document all the changes that occurred during the decomposition process. This time was chosen to ensure adequate daylight and to avoid the warmer temperatures that occur in the afternoon. Four standard photographs of each pig were taken during each visit: ventral, anterior, posterior, aerial view. Distinctive photographs were also taken to document any noteworthy change or novel finding. Photographs of animal activity artifacts were also taken.

An assessment of the decomposition stages was carried out utilizing a scoring system adapted by Megyesi (2005) from Galloway et al. (1989) (Appendix A). The decomposition process was divided into four main stages. Within each stage separate steps are recognized. Each separate step received a score ascending from 1 at the first step of the first stage to "x" at the last step of the last stage. A separate decomposition table is used for each of the three sections of the body: head, trunk and limbs. This is to account for the variation between each body section, since decomposition is characterized by different processes. Decomposition scores were recorded daily for each pigs' head, trunk, and limbs. In any instance when the decomposition step varied across the anatomical area being scored, the lower valued score was assigned as the score should reflect the amount of decomposition overall. A Total Body Score (TBS) was also calculated by adding the sums of the scores for each of the body sections.

At the end of the study period, multiple photographs of the remains were taken to document the final decompositional stages. These photographs included overall photos of the pigs, and close ups of each section of the body. For the clothed pigs the clothing was cut open to reveal the decomposition stage beneath. Photographs were taken of the remains once the clothing was removed to document the final stage of decomposition.

The environmental data recorded for the site includes temperature, precipitation and weather conditions. A log of the weather conditions was also recorded, documenting the occurrence and amount of daily precipitation, heat waves, and fog.

All data was input into Microsoft Access 2007. Graphs of specific data sets were created using Microsoft Excel 2007. Graphical comparisons of the decomposition rates were also carried out to determine if there was a significant difference in the decomposition rates found within the complete research sample and within the specific groupings of clothed and non-clothed pigs. Decomposition rates from this study were compared to previous studies such as Anderson and VanLaerhoven 1996; Bass, 1997; Bunch, 2009; Galloway, 1997; Galloway et al., 1989; Komar, 1998; Shean et al., 1993.

Many difficulties were encountered before the study even began. A shortage of pig producers and suppliers in Nova Scotia caused additional problems. Three weeks prior to the start of the project, the farm, from which the initial purchase arrangements were made, declared bankruptcy. To ensure the study would continue, another farm was sought out. The limited time frame did not permit the researcher the ability to have as much control over the specimens obtained; the author was only able to request a certain size of pig.

It was difficult to secure an appropriate site that was not near a residential development and not accessible to the general public. The site chosen was located on Department of National Defence (DND) land and therefore strict limitations to access were placed on the researcher. The site was visited once during the winter months, during snow cover, to assess the environment and applicability for this project. After this initial visit, the grounds were not accessible prior to June 2, 2009, the start of the study. The site was also not accessible any other time during the day other than for a one-hour period every morning from June 2, 2009 until September 30, 2009. The limited site access decreased the ability to assess the exact locations for pig placement prior to the start of the study. As the set up was conducted during the early afternoon, in full sun, it was not possible to determine any variations in sun exposure for the specific locations of the pigs, one-meter apart, on the site.

CHAPTER 4

RESULTS

4.1 Decomposition of Pigs #1, #2, #3 and #4.

The early, advanced and skeletonization stages of decomposition were reached at different times for the separate body sections (Table 4.1). The early decomposition stage was reached at the same time for pigs #1, #2 and #3; however pig #4 remained in the fresh stage for a longer period of time. A main indicator of early decomposition is change in skin colour. This change was not possible to observe for pig #4 due to its natural black skin pigmentation. The progression into the advanced stage showed little overall variation across the sample. Similar to the early decomposition stage, pigs #1, #2 and #3 reached the skeletonization stage at approximately the same time, however the trunk and limbs of pig #4 remained in the advanced stage for more than 2 weeks longer. The decomposition of all four pigs progressed much more rapidly in the head than in the rest of the body.

Table 4.1: Summary table showing the first day that each body section of the entire sample, Pigs #1, #2, #3 and #4, reached the different stages of decomposition.

		First day in decomposition stage (Stages adapted from Galloway et al., 1989)		
Pig	**Body Section**	**Early**	**Advanced**	**Skeletonization**
		Non-Clothed Sample: Pigs #2 and #3		
#2	Entire Body	5	28	64
	Head	4	14	30
	Trunk	4	26	64
	Limbs	5	28	35
#3	Entire Body	5	29	64
	Head	4	14	35
	Trunk	4	28	64
	Limbs	5	29	40
		Clothed Sample: Pigs #1 and #4		
#1	Entire Body	5	28	64
	Head	4	15	30
	Trunk	4	24	64
	Limbs	5	28	43
#4	Entire Body	7	29	80
	Head	7	14	35
	Trunk	7	22	80
	Limbs	7	29	80

Slightly more variation was present between pigs #1, #2, #3 and #4 reaching the skeletonization stage, in comparison to the variation across the sample reaching the early and advanced decomposition stages (Table 4.2). The heads of pigs #1 and #2 achieved skeletonization at the same time. Likewise the heads of pigs #3 and #4 achieved skeletonization at the same time but at a later time than pigs #1 and #2. The trunk of pig #4 showed the most variation, not reaching skeletonization until 17 days after the other three pigs. The most variation in the sample achieving the skeletonization stage was seen in the limbs. Skeletonization was achieved for the four pigs on different days spanning a 9 day period.

Table 4.2: Summary of skeletonization stages for the head, trunk and limbs for pigs #1, #2, #3 and #4.

Number of days that each pig remained in the skeletonization phase				
Body Section	**Pig #1**	**Pig #2**	**Pig #3**	**Pig #4**
Head	30 – 121	30 – 121	35 – 121	35 – 121
Trunk	64 – 121	64 – 121	64 – 121	80 – 121
Limbs	43 – 121	35 – 121	40 – 121	43 – 121

All four pigs achieved the same total body score (TBS) on approximately the same days (Table 4.3). Pigs #1, #2 and #3 maintained a similar progression of TBS for the duration of the study. Pig #4 varied from the other pigs once a TBS of 21 was reached. From TBS 21, until the end of the study, pig #4 progressed more slowly, ending the study period at a lower final score than pigs #1, #2 and #3.

Table 4.3: Progression of TBS for Pigs #1, #2, #3 and #4 throughout the study period. The table only shows TBS that were achieved by one or more pigs; scores that were not achieved by any pig were removed from the table.

Study days present at each TBS				
	Non-Clothed		Clothed	
Total Body Score	**Pig #2**	**Pig #3**	**Pig #1**	**Pig #4**
3	1 – 3	1 – 3	1 – 3	1 – 6
7	4	4	4	
9	5 – 6	5 – 6	5 – 6	
11	7 – 10	7 – 10	7 – 10	7- 10
12	11 – 13	11 – 13	11 – 13	11- 13
14			14 – 15	14
15	14 – 16	14 – 16	16	15 – 16
16	17	17	17	17
17	18 – 22	18		18
18	23 – 25	19 – 27	18 – 22	19 – 21
19	26 – 27	28	23 – 27	22 – 28
20	28 – 29	29 – 30	28 – 29	29
21		31 – 34		30 – 34
23	30 – 34		30 – 34	
24		35 – 39		35 – 39
25				40 – 42
26	35 – 39		35 – 41	43 – 44
27	40 – 56	40 – 59	42 – 56	45 – 65
28	57 – 58	60 – 63	57 – 59	66 – 79
29	60 – 63		60 – 63	80 – 121
30	64 – 79	64 – 79	64 – 79	
31	80 – 121	80 – 121	80 – 121	

The final decomposition stage achieved at the end of the study, day 121, was the same for all body sections of pigs #1 #2 and #3. The head of pig #4 reached the same final decomposition stage as the heads of the other three pigs. The trunk and limbs of pig #4 were one step lower in the decomposition stage in comparison to pigs #1, #2 and #3 (Table 4.4). The head and limbs were at the same step of the decomposition stage for pigs #1 #2 and #3. The trunk, of pigs #1, #2 and #3, remained one step lower than the head and limbs. No carnivore activity was observed. The cages were not disturbed which indicated no large carnivores gained access to the cadavers. Only one instance of predation was observed – the removal of a partly skeletonized hind limb, of pig #4, on day 28.

Table 4.4: Summary of the final decomposition stage reached for the separate sections of each pig.

Pig	Body Section	Score	Description
#1 #2 #3	Head	**12**	Bones are largely dry but still retaining some grease
	Trunk	**10**	Bones with desiccated or mummified tissue covering less than one-half the area being scored
	Limbs	**9**	Bones are largely dry but still retaining some grease
#4	Head	**12**	Bones are largely dry but still retaining some grease
	Trunk	**9**	Bones with decomposed tissue sometimes with body fluids and grease still present
	Limbs	**8**	Bone exposed over one-half the area being scored, some decomposed tissue and body fluids remaining

The presence of flies was first documented on day 2 for all pigs. Maggots were not observed until day 5. Maggots first appeared in the mouth of pig #4. During the first month of the study, more maggots were observed on pigs #3 and #4 whereas more beetles were observed on pigs #1 and #2. Beetles were also more prevalent than maggots on pigs #1 and #2. Maggots were present on all four pigs by day 15. There was an observed increase in fly and insect activity, on all pigs, by day 24; flies were observed all over the corpses.

The stages of decomposition were very similar in appearance and timing for pigs #1, #2 and #3. The three pigs had green discolouration, first appearing around their eyes, on day 4. The discolouration progressed to include more of the face and the throats by day 5, as well as the abdomen. Marbling began on the legs and ears of pigs #1, #2 and #3, progressing to include the abdomen on day 9. As time progressed, the intensity of the discolouration increased. Discolouration was not visible on pig #4 due to its natural black skin colouration. The black skin of pig #4 changed colour during the decomposition process. Change in colour began around the eyes first. The skin of pig #4 was a dark brown colour instead of black on day 12. By day 13, the head and neck of pig #4 were no longer black (Figure 4.1). Decompositional changes were difficult to see on pigs #1 and #4 due to the presence of clothing on both pigs.

Figure 4.1: Photograph showing the change in skin colour on the head of pig #4. Face is red-brown in colour and no longer solid black.

Insect egg masses were present on the faces of all pigs on day 9. On day 10, pig #3 had a short segment of sigmoid colon eviscerated out of the anus (Figure 4.2). A white frothy substance which contained some maggots was present around the heads of all pigs at different times during the decomposition process (Figure 4.3). Skin slippage was first visible on the heads of all pigs, then progressing to the legs, abdomen and the rest of the body between days 18 and 22. The head of pig #3 had maggot masses which obscured the researcher's ability to record the precise date of skin slippage for this specimen. Beetle larvae colonization began at the same time as the skin slippage appeared on the entire body. A small number of maggots were present under the abdominal skin on pig #2 on day 18 and on pig #3 on day 22, however this was not observed with the exposed abdominal skin on pigs #1 and #4. Masses of beetle larvae were present by days 28 and 29 (Figure 4.4). Qualitative differences in the composition of the insect fauna were observed. For most of the study period, beetle larvae were a more important component of the insect fauna. A detailed analysis of this observation was deemed outside the scope of the present study. Maggot masses never covered the entire body of any pig. Pig #3 had the most maggots, and the largest maggot mass, however it only covered potions and not the entire body surface.

Figure 4.2: Day 10: Photograph of pig #3 showing the evisceration of sigmoid colon from the anus.

Figure 4.3: Photograph of pig #2 showing an example of the white frothy substance present during decomposition.

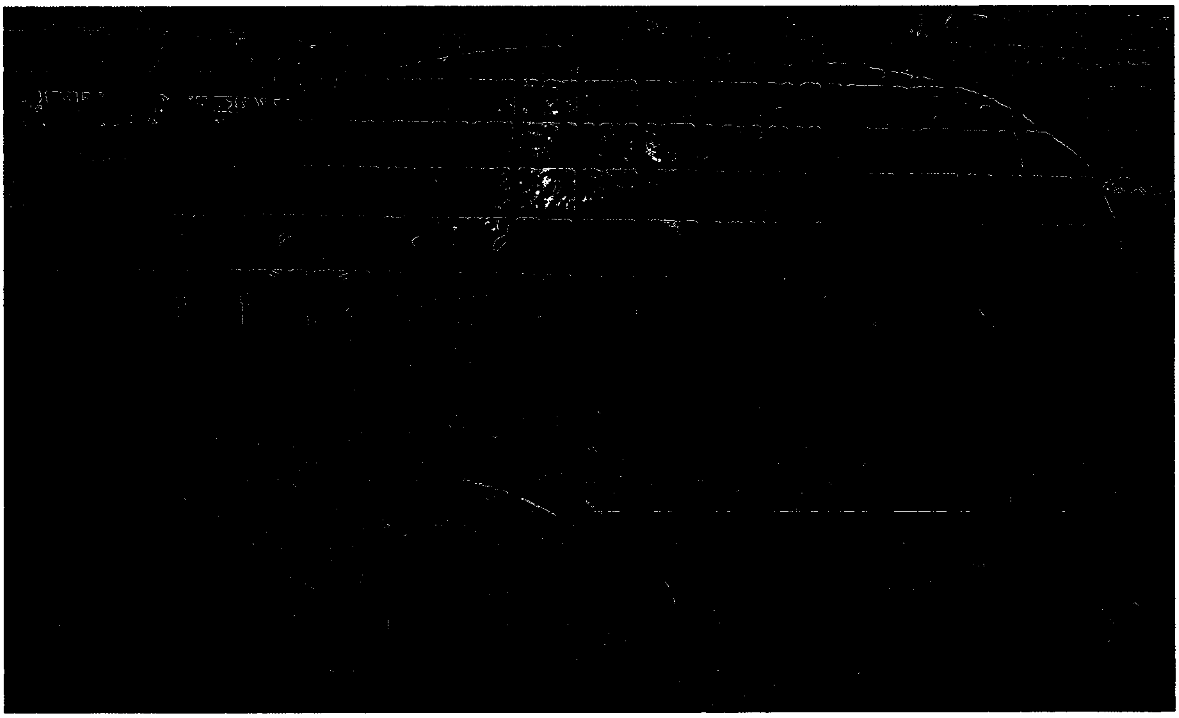

Figure 4.4: Photograph of pig #3 showing an example of the beginning of a beetle larvae mass.

The green discolouration, present on the throat and abdomen of pigs #1, #2 and #3, began to turn black starting with the front limbs. Between days 24 and 26, the green discolouration present had completely disappeared and was now replaced by black discolouration (Figure 4.5). The skin on pig #4 did not display the green discolouration, but colour changes were observed. Pig #4 showed an increase in colour change on the areas of exposed skin, visible as pink patches of skin instead of black (Figure 4.6). The pink patches progressively increased in size on day 21.

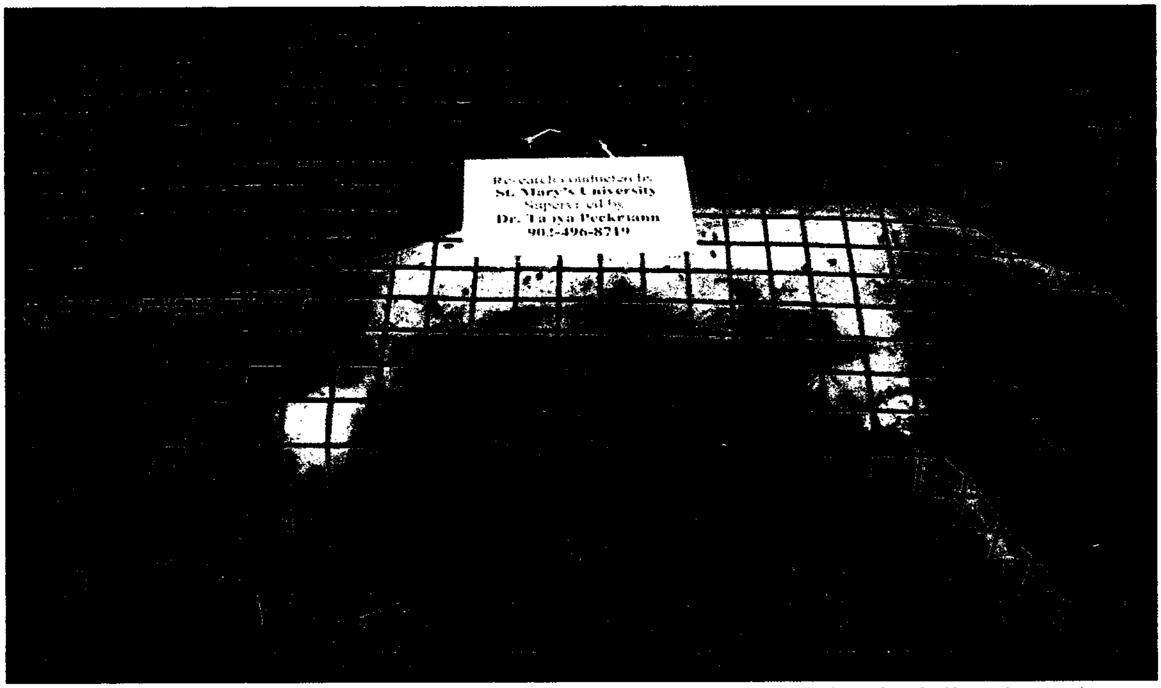

Figure 4.5: Day 24: Photograph of pig #2 showing the black abdominal discolouration.

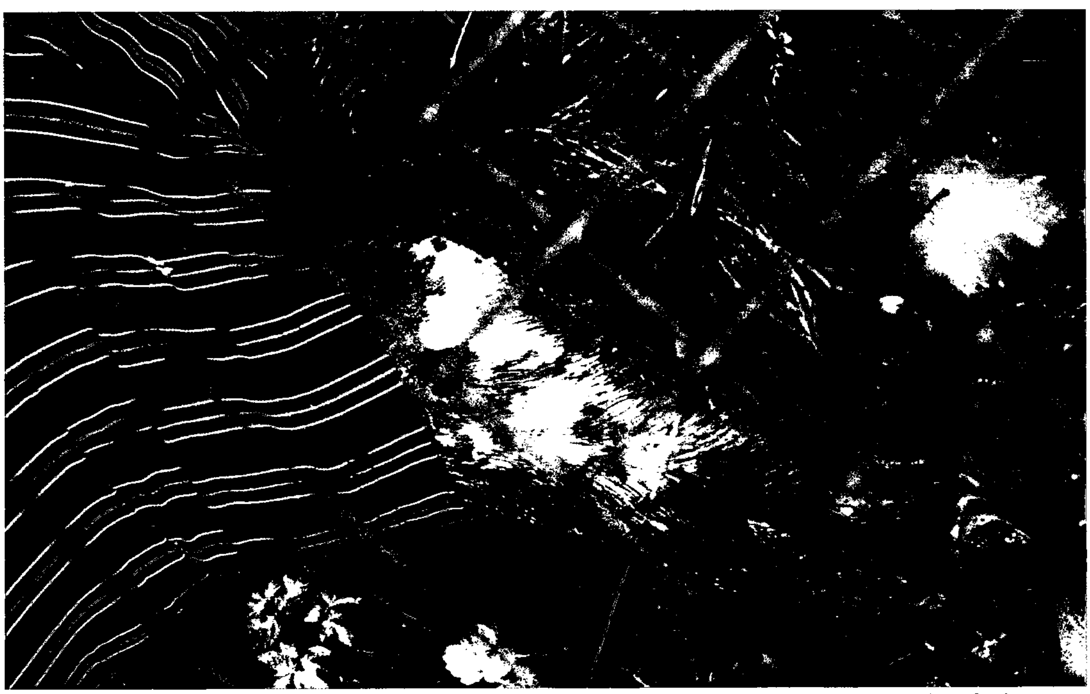

Figure 4.6: Photograph showing the colour change of the right hind limb of pig #4

The skin, on pigs #1, #2 and #3, that was not affected by the marbling during the early decompositional changes, began to dry and turn brown in patches on day 24 (Figure 4.7). The change in skin colour, from pink to brown, continued to cover more of the body and increased in colour intensity until day 27. The surface area of the skin of pig #4, that changed colour increased in area by day 24. The front leg of pig #4, began to show loss of pigmentation and was visibly brown on day 24. On day 25, the pink skin on pig #4 began turning brown during decomposition similar to that demonstrated by pigs #1, #2 and #3 (Figure 4.8). The skin of pig #4 that turned pink and then brown in colour, in the same manner as pigs #1, #2 and #3, reversed to the pink colouration for a short period of time. The skin then returned to the brown colour which was a result of drying.

Figure 4.7: Photograph of pig #3 showing brown patches on the skin.

Figure 4.8: Photograph showing the change in skin colour of pig #4. The skin that turned pink then turned brown from drying of the skin, similar to the colour change of the skin of pig #1

The neck was the first region on the body to collapse due to loss of mass. Pig #2 was the first animal where this was observed, beginning on day 16. The necks of the three remaining pigs began to collapse on day 19. By day 27, the necks of all four pigs were collapsed and the shoulders began to slump towards the head (Figure 4.9). Wet decomposition, the liquefaction of tissues, progressed from the head and neck to the remainder of the body from day 27. Abdominal ruptures occurred on pigs #2, #3 and #4 at approximately the same time, days 26 and 27. The abdomen of pig #1 ruptured at the umbilicus earlier than the other three pigs, rupturing on day 21. Intestines eviscerated from the abdomen of pig #1 on day 22 (Figure 4.10). On day 30, pig #4 showed abdominal collapse with a rippled appearance of the skin at the waist (Figure 4.11) and the groin area began to lose mass.

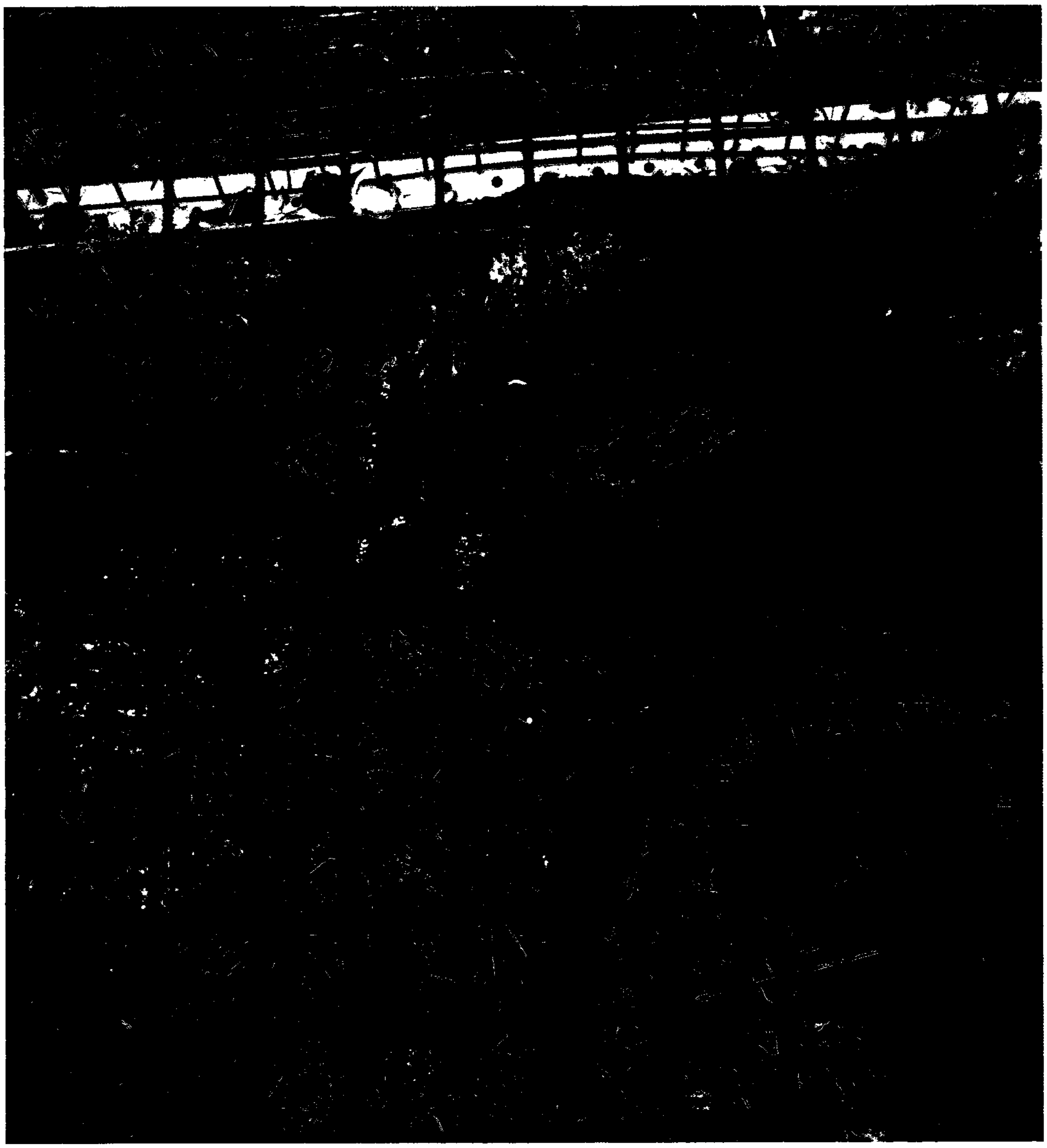

Figure 4.9: Day 27: Photograph of pig #2 showing an example of alteration in the normal external contours of the body.

Figure 4.10: Photograph showing the intestines eviscerating from the umbilicus of pig #1.

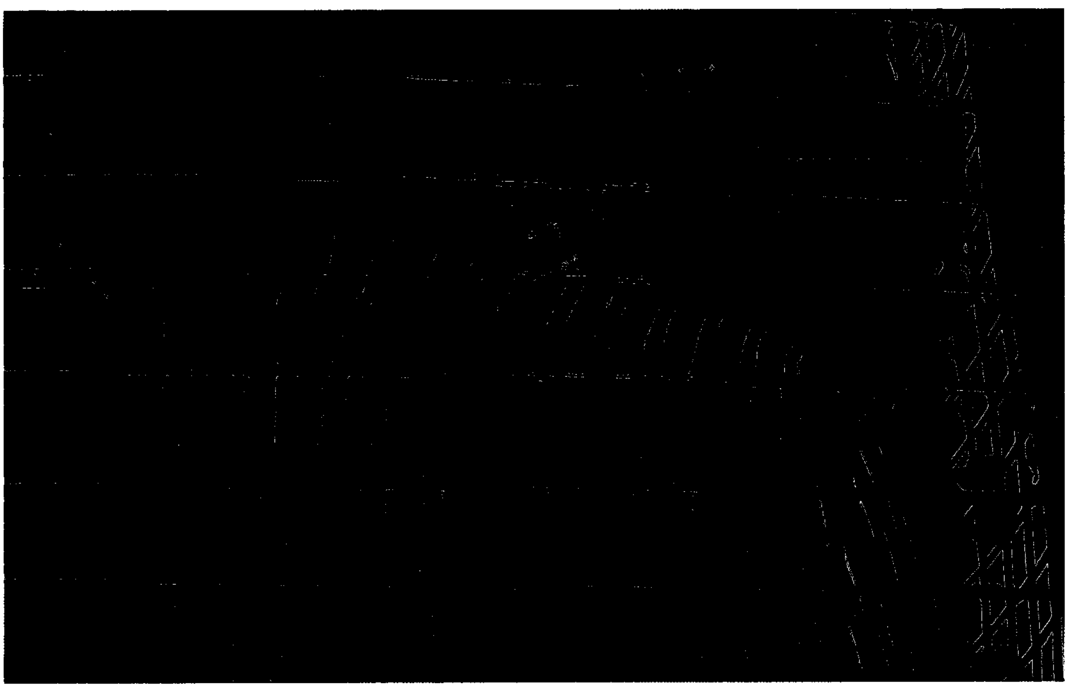

Figure 4.11: Photograph showing the collapsing abdomen and rippled appearance found on pig #4.

On all pigs, skeletonization progressed caudally from the shoulders to the pelvis (Figure 4.12). The shoulders began to skeletonize, on both pigs #2 and #3, between days 28 and 30. Due to the clothing on pigs #1 and #4, the skeletonization process was not viewable; however the process was visible appreciable as the contours of bones became discernible through the clothing. As skeletonization progressed, the outlines of more bones became visible through the clothing. Bone outlines were visible through the clothing on pig #1 on day 31, yet this was not visible on pig #4 until day 42 (Figure 4.13). The head of pigs #1, #2 and #3 were almost fully skeletonized by day 36 with the exception of liquefied tissue surrounding the bones and a small amount of mummified skin on the top of the head. The jaw of pig #3 also had a small amount of mummified skin on day 36 (Figure 4.14). The head of pig #4 was not fully skeletonized until day 40. The skeletonization stage for pigs #1, #2 and #3 was reached by the entire body on day 64; however, pig #4 did not reach the skeletonization stage until day 80.

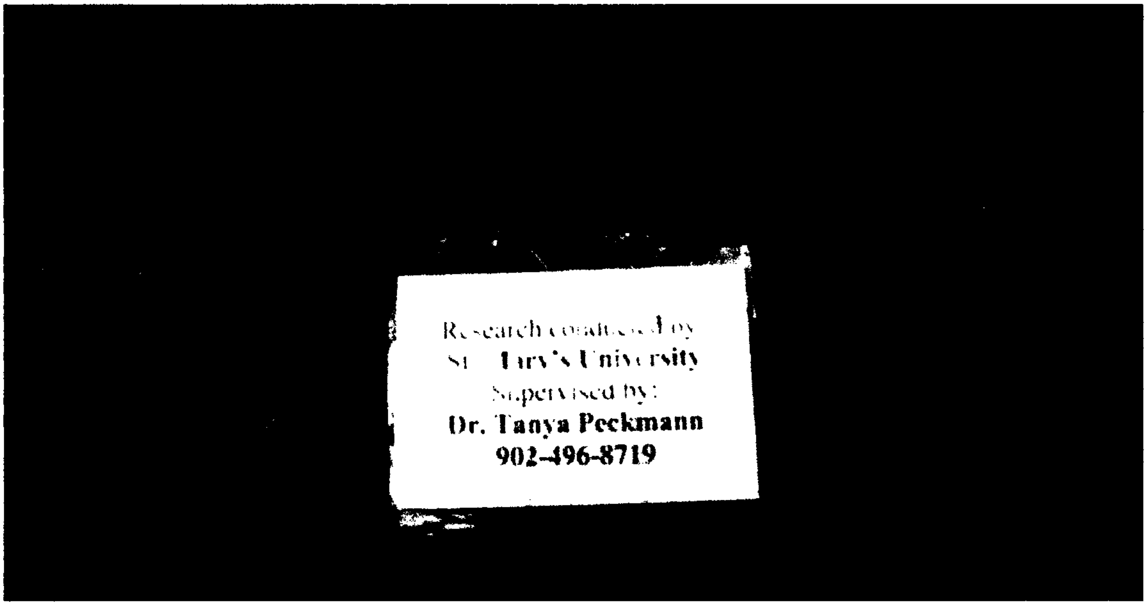

Figure 4.12: Photograph of pig #2 displaying the craniocaudal pattern of skeletonization.

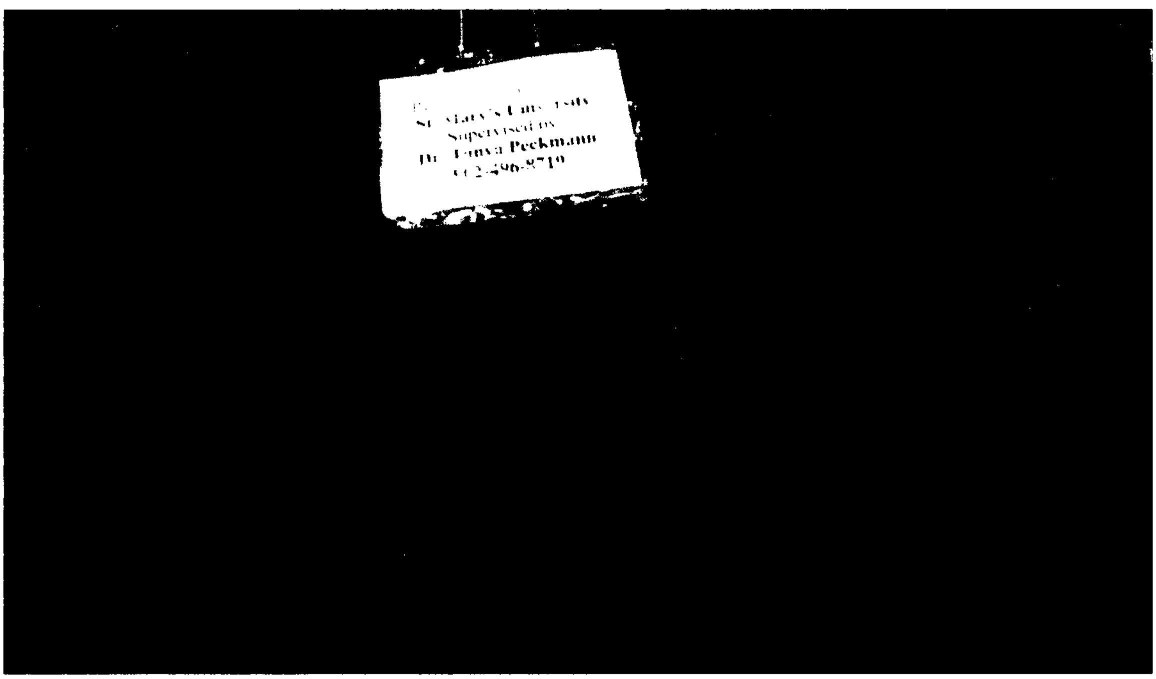

Figure 4.13: Photograph showing the contours of bones through the clothing of pig #1.

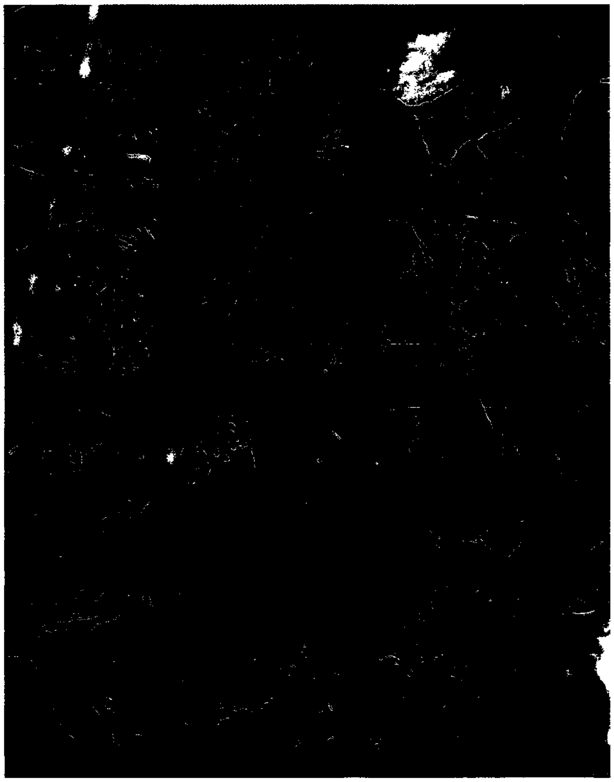

Figure 4.14: Photograph of pig #3 showing the complete skeletonization of the head. A small amount of mummified skin is visible on the jaw.

The exposed bones changed colour, appearing darker after periods of rain and remaining darker in colour until they dried. Once the bones were dry, they would appear lighter and bleached. This lighter colour was similar to the bone colour exhibited prior to the rain. This colour change between dark and light tones occurred with every rain and dry weather fluctuation.

Abdominal decomposition progressed differently for pigs #2 and #3. Abdominal decomposition was not observable on pigs #1 and #4 due to the clothing present on the bodies. The abdominal structures of pig #2 remained much more intact and decomposed slowly, whereas the abdominal tissue of pig #3 decomposed much more quickly. On day 47, an ovoid formation of firbofatty and loose connective tissue and associated structures began forming on pig #2 (Figure 4.15). The ovoid structure slowly disconnected from the spine by day 67 (Figure 4.16). The abdominal tissue of pig #3 had more maggot activity than pig #2. The same white frothy substance that surrounded the head of pig #3 also surrounded the abdomen. The abdominal skin of pig #3 was consumed by the insects in patch-like areas along the ventral side of the spinal column by day 54 (Figures 4.17). By day 57, most of the skin had been consumed along the spinal column of pig #3, however, tissue remained at the ventral aspect of the abdomen. The remaining abdominal tissue, of pig #3, slowly dried until it almost disappeared on day 69 (Figure 4.18). The tissue surrounding the pelvis of pig #2 was slower to decompose than pig #3.

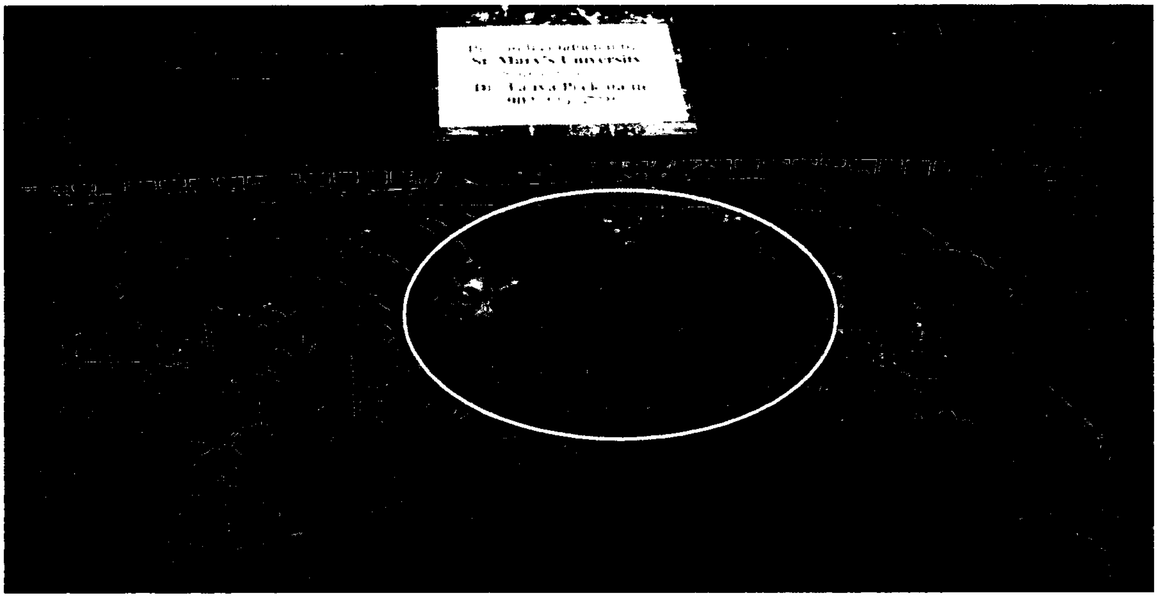

Figure 4.15: Day 52: Photograph showing the ovoid shape of the abdomen of pig #2. Tissue decomposed much slower in the abdomen than the rest of the body. Circle outlines abdomen.

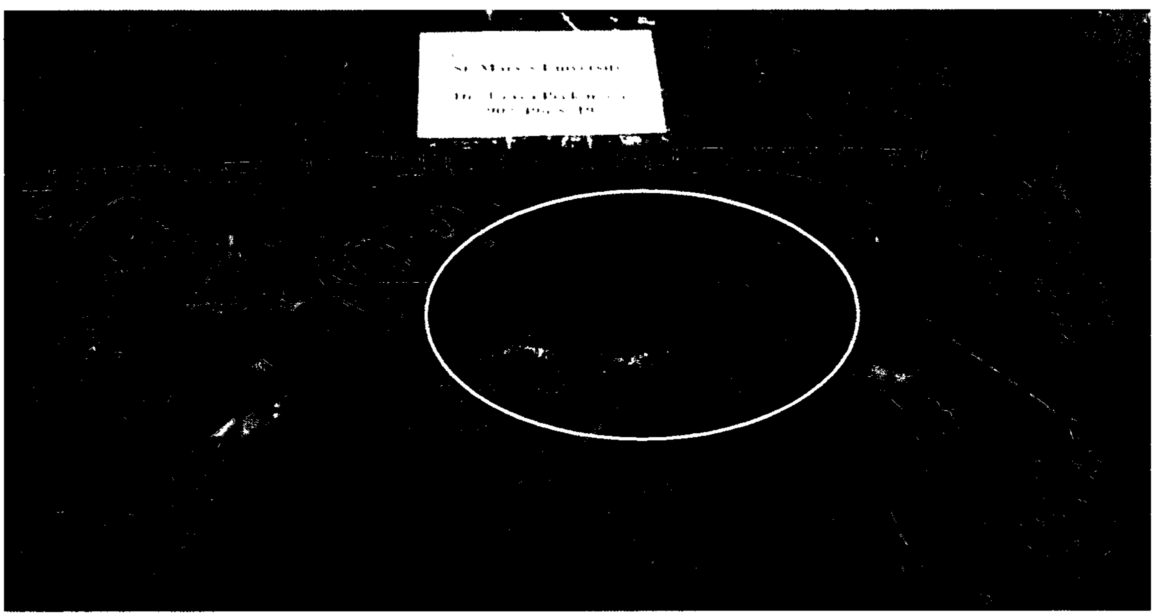

Figure 4.16: Day 66: Photograph showing the abdomen of pig #2 further through the decomposition process once it was no longer connected to the vertebrae. Circle outlining oval shape of the decomposing abdomen.

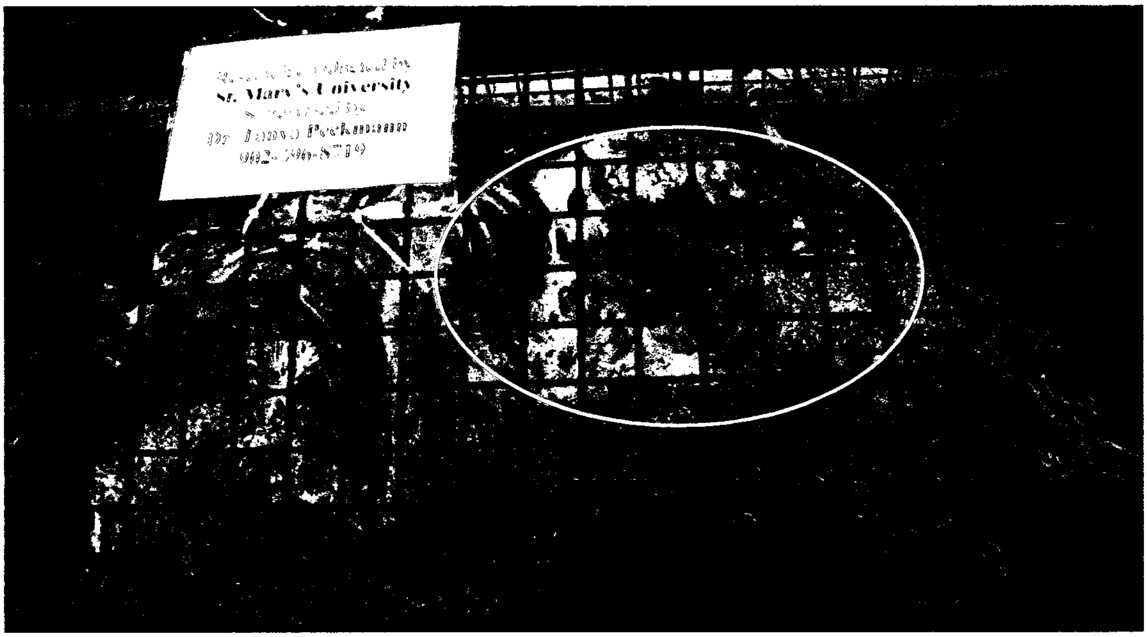

Figure 4.17: Day 54: Photograph of abdominal decomposition of pig #3. Circle shows the pattern of decomposition of the abdomen that is different than that illustrated by pig #2.

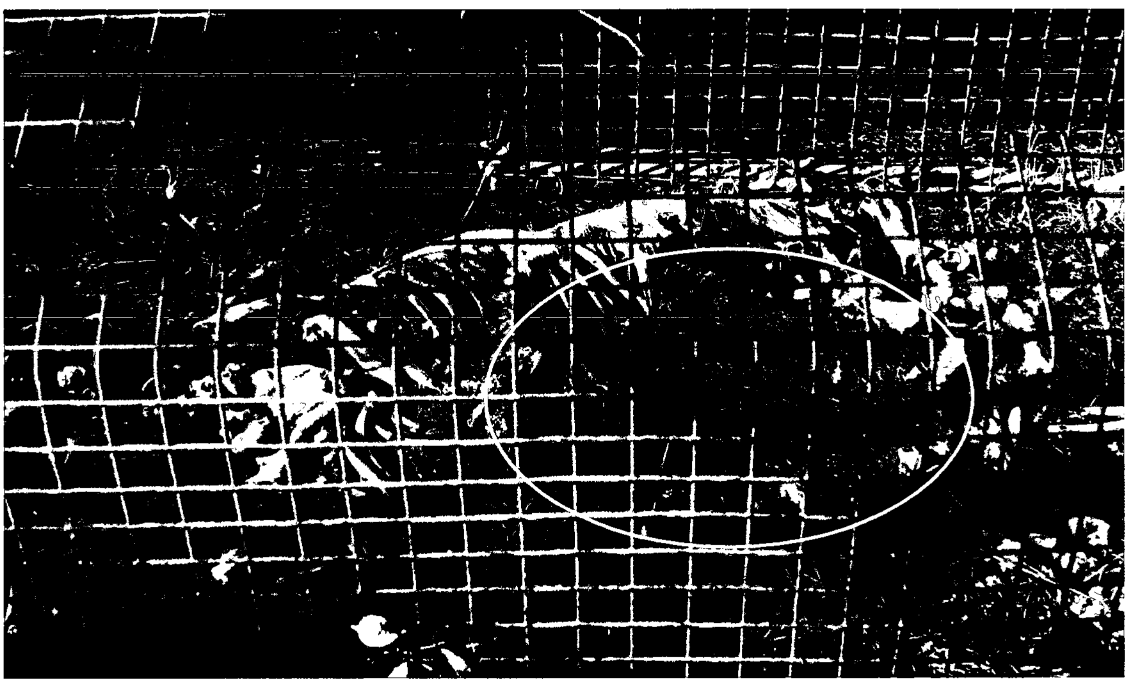

Figure 4.18: Day 69: Photograph of abdominal decomposition of pig #3. Circle shows the minimal remains of abdominal tissue.

At the end of the study, day 121, the heads of all four pigs were fully skeletonized, however, the bones still retained some grease. All exposed bones were partly dried but none of the bones from either pig were completely absent of grease. White mold was present on the cervical and thoracic vertebrae of pig #1 and the thoracic vertebrae and ribs of pig #4. White mold was present mainly on the long bones of pigs #2 and #3. There was some white mold also present on a few vertebrae of pig #2. When the clothes were cut open on day 121, it was revealed that the bones of both pigs that were protected inside the clothes from sun exposure were stained darker brown than the bones that were exposed to the natural elements. The clothing covered bones also retained more grease. Minimal skin was present on pigs #2, #3, and #4. The skin was leathery and some hair was present. The skin remained on a portion of the jaw as well as over some ribs and vertebrae in the thoracic and lumbar region on pigs #1, #2 and #3. Pig #2 also retained a small amount of skin over one humerus and over a portion of the innominate bone. Very little skin was present on the right hind limb of pig #4. Adipocere was present on all four pigs. The clothed group of pigs had more adipocere than the non-clothed group pigs. Adipocere remained on the spine of pig #2 and throughout parts of the abdominal area. Pig #3 had less adipocere present; minimal amounts were observed on the lumbar vertebrae and a very small amount in the location of the abdomen. Pig #1 had adipocere surrounding the pelvis, femora and ribs. Pig #4 had adipocere around limb bones protected by the clothing, along the spine, and in the location of the abdomen (Figures 4.19 – 4.22). Pig #4 had the largest volume of adipocere in the sample.

Figure 4.19: Day 121: Photograph showing the final stage of decomposition for pig #2.

Figure 4.20: Day 121: Photograph showing the final stage of decomposition for pig #3.

Figure 4.21: Day 121: Photograph showing the final stage of decomposition for pig #1.

Figure 4.22: Day 121: Photograph showing the final decomposition staged for pig #4.

Graphical analyses of decomposition trends show minimal variation in decomposition rates across the sample with pig #4 showing the most variation (Figures 4.23 – 4.26). The variation is present in the trunk, limb and Total Body Score (TBS). The variation in decomposition rates within the sample is illustrated by separate lines on the graphs. Pig #4 remained one step lower in the skeletonization stage of decomposition for the trunk and limbs. All four pigs show the same pattern of increase in decomposition scores regardless of achieving the same score (Figures 4.23 – 4.26). The lower decomposition score, maintained by pig #4 in comparison to pigs #1, #2 and #3, occurred from approximately the 2-month point of the study onward. The trend is most apparent when comparing the total body scores of all pigs (Figure 4.23).

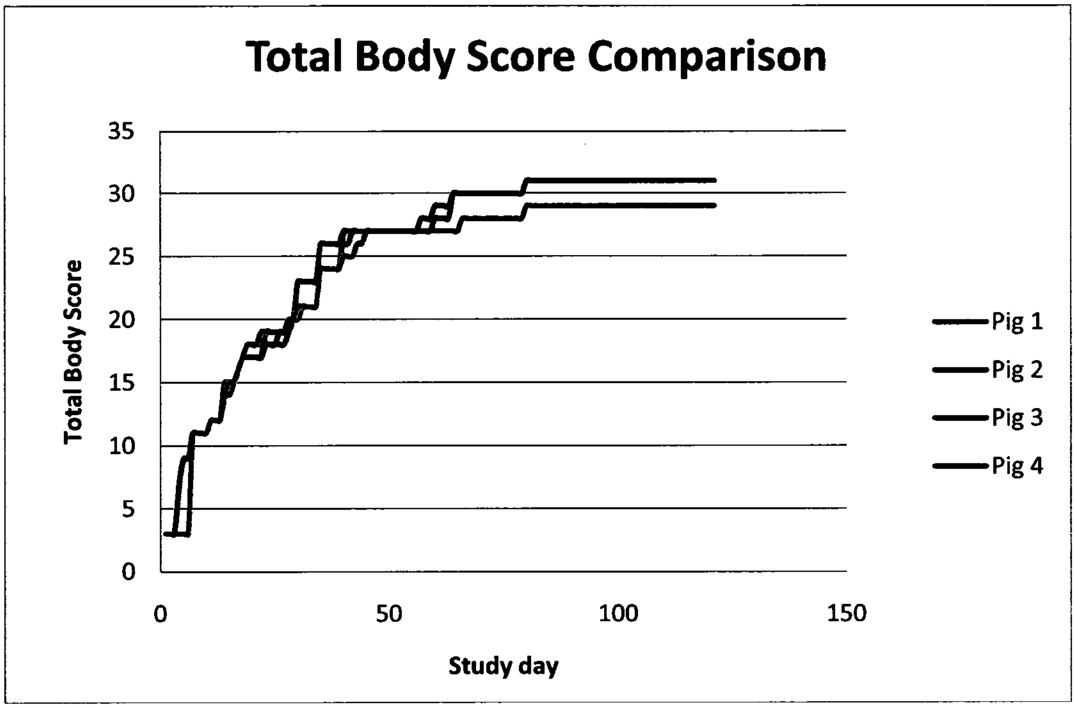

Figure 4.23: Graph showing the relationship of TBS for pigs #1, #2, #3 and #4.

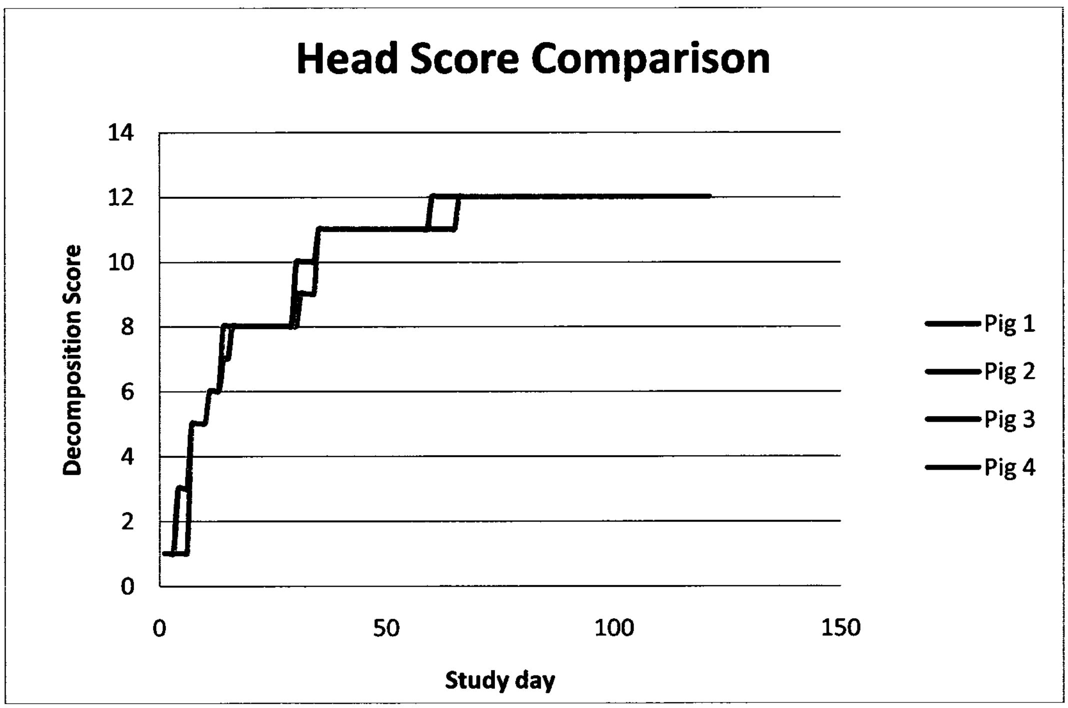

Figure 4.24: Graph showing the relationship of the head scores for pigs #1, #2, #3 and #4.

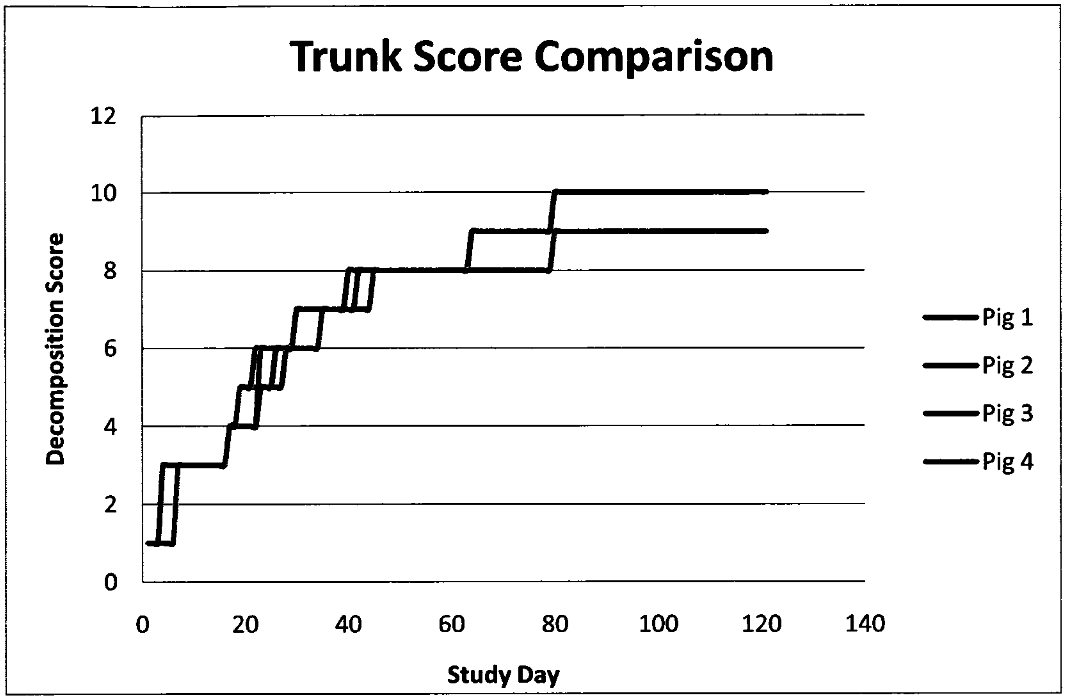

Figure 4.25: Graph showing the relationship of the trunk scores for pigs #1, #2, #3 and #4.

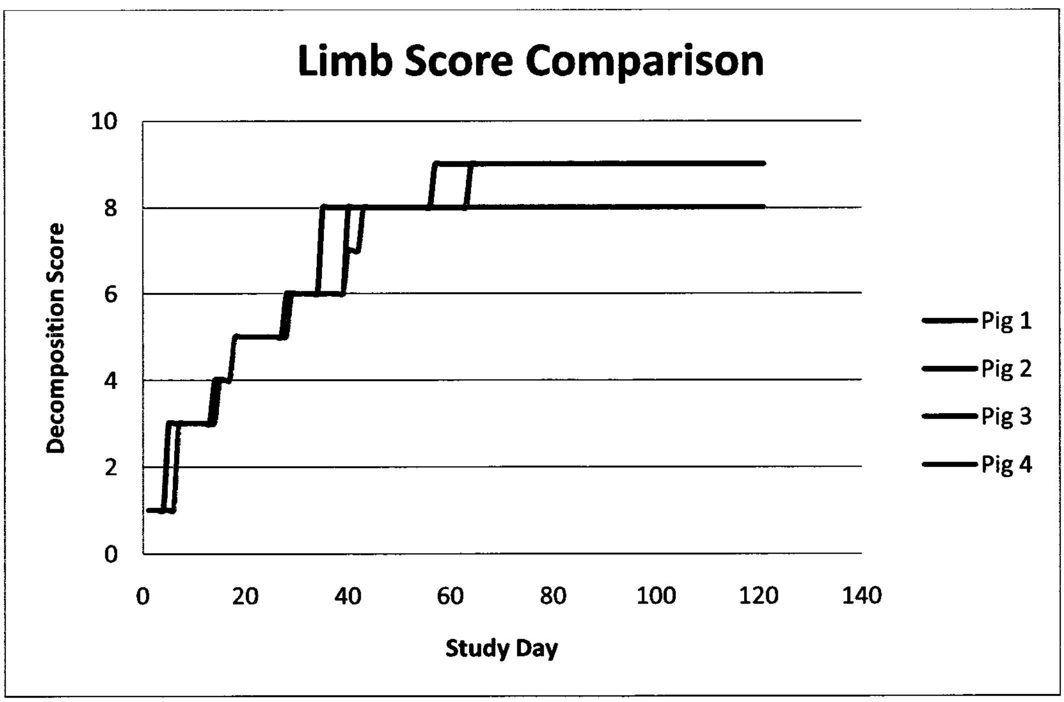

Figure 4.26: Graph showing the relationship of the limb scores for pigs #1, #2, #3 and #4.

Comparison of the average TBS for the clothed pigs (#1 and #4) with the non-clothed pigs (#2 and #3) show very similar progress between decomposition stages, however, after day 63 the clothed group remains at a slightly lower TBS than the non-clothed group (Figure 4.27). The decomposition rates are almost identical – seen on the graphs when only one line is present. After the first 63 days of the study, the two groups show increases in decomposition scores in the same pattern, but vary somewhat. The non-clothed group consistently has higher scores than the clothed group.

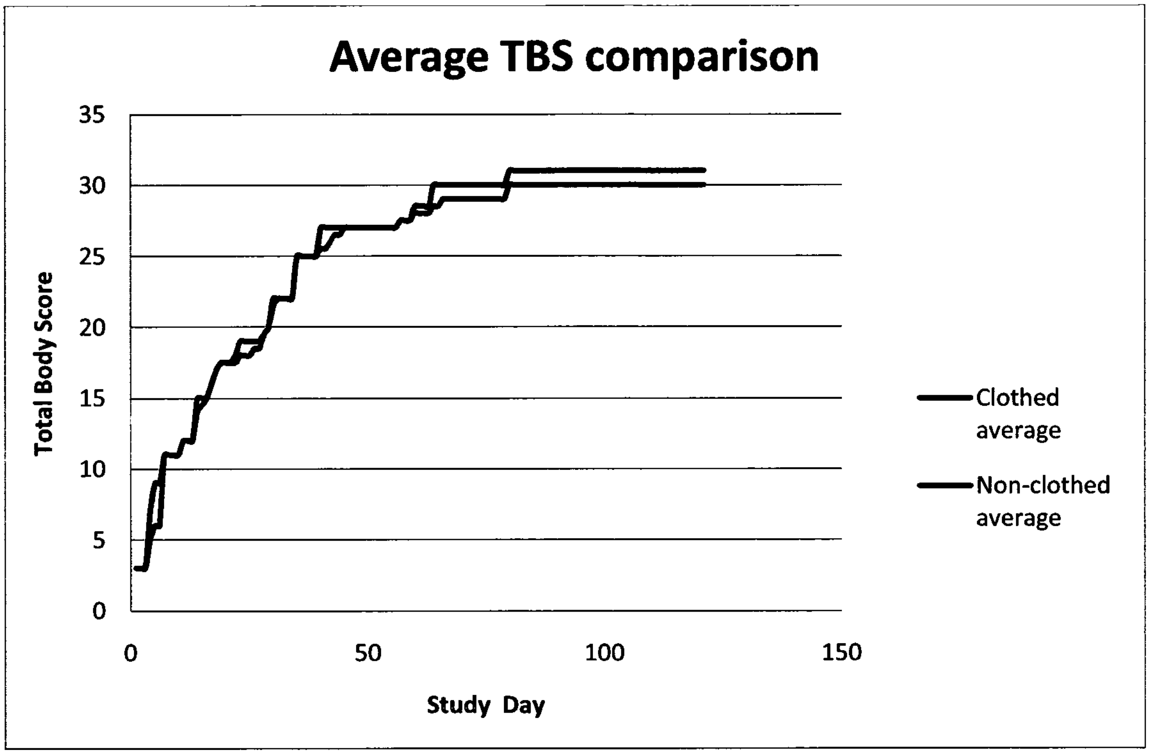

Figure 4.27: Graph showing the relationship of TBS averages between clothed pigs (#1 and #4) and non-clothed pigs (#2 and #3).

Pigs #1, #2 and #3 progressed at the same rates of decomposition, however, pig #4 did not decompose at the same rate. The heads of all pigs decomposed almost identically. The trunk and limbs of pig #4 were slower to decompose that those of pigs #1, #2 and #3. Pig #4 had traits that made it unique: skin pigmentation and location. Pig #4 was black skinned. This pig was located in a more shaded area than pigs #1, #2 and #3.

Due to the unique traits summarization of decomposition rates for estimating time since death was conducted in two groupings. The entire sample, pigs #1, #2, #3 and #4, was assessed as one group, and assessment of a second group was carried out on pigs #1, #2 and #3. Decomposition rates were summarized on the adjusted group of pigs #1, #2 and #3 to assess the variation observed from pig #4.

The decomposition trends observed follow a logarithmic decay curve (Figure 4.28). Logarithmic trendlines of the average TBS for the clothed pigs reveal R^2 values of 0.9564 and for the non-clothed pigs reveal R^2 values of 0.9569. The mathematical equations for the decomposition of the clothed and non-clothed groups are different. The clothed equation is $y=7.5301\ln(x) - 4.4053$ whereas the non-clothed equation is $y = 7.758\ln(x) - 4.3345$.

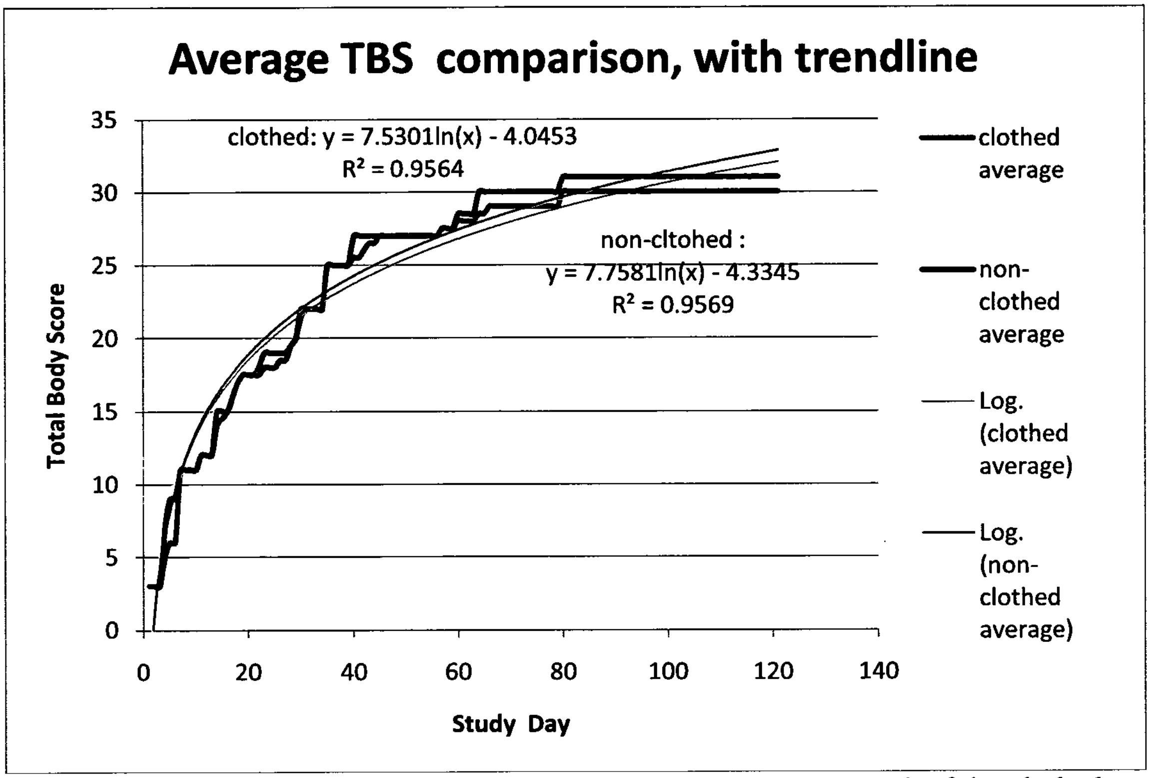

Figure 4.28: Graph showing the relationship between the average TBS of the clothed group (pigs #1 and #4) and the non-clothed group (pigs #2 and #3). Graph displays mathematical decay trendlines.

Logarithmic analyses of the average TBS, for all four pigs combined, produces an R^2 value of 0.9584 indicating that 95.8% of the data is predicted by the logarithmic trend (Figure 4.29). The equation of the line is $y=7.644\ln(x) - 4.1899$. The slope of this line, i.e. when all four pigs are combined, is between the slope values for the clothed and non-clothed pigs when analysed separately.

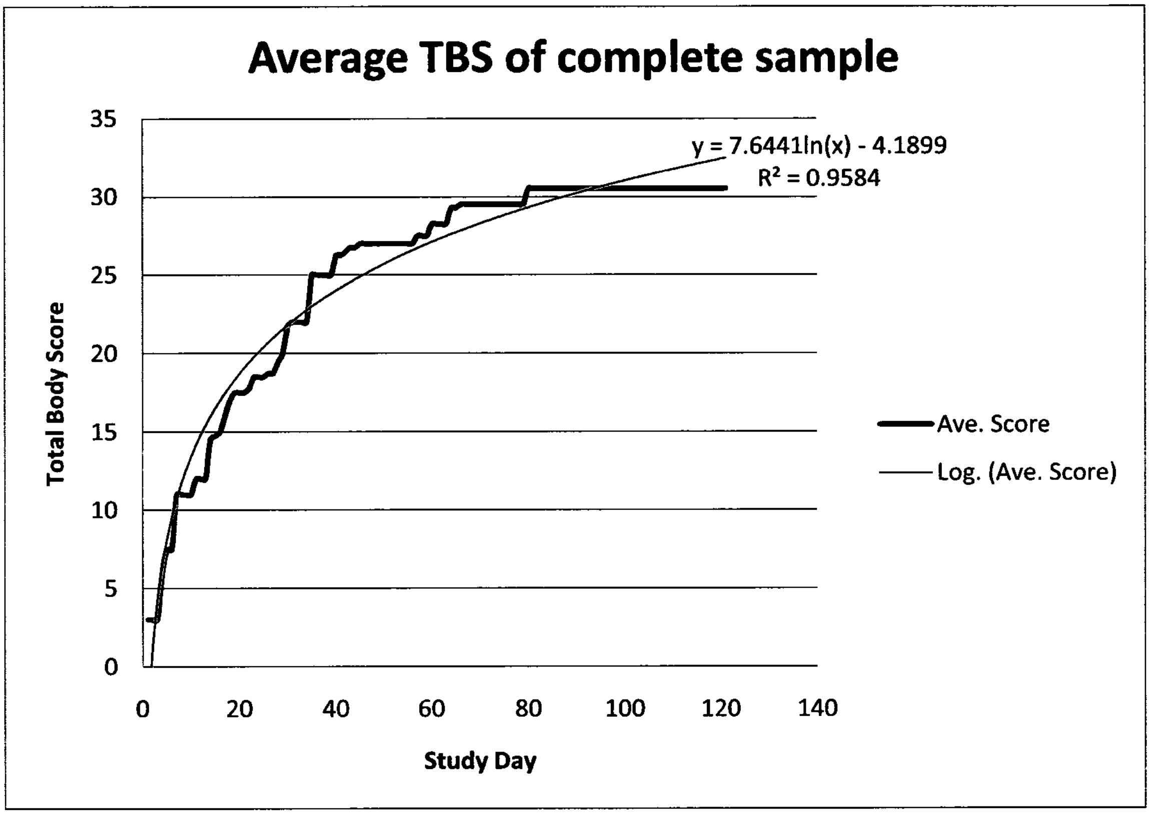

Figure 4.29: Graph showing the average TBS for the entire sample, pigs #1, #2, #3 and #4. Mathematical trendline shown.

Analyses of the TBS were also completed for pigs #1, #2 and #3 combined (Figure 4.30). Pig #4 was removed due to the variation in skin colour, i.e. it had natural black pigmentation, and the amount of shade present at the specific "body dump site" location. The R^2 value of the logarithmic trend for this data set is 0.9569. The equation is $y= 7.759\ln(x) - 4.2916$. This equation is much closer to the equation computed from the values presented by the non-clothed group. The variation between the complete sample and the adjusted sample, pigs #1, #2 and #3 only, shows that pig #1 decomposed at the same rate as the non-clothed group, regardless of clothing.

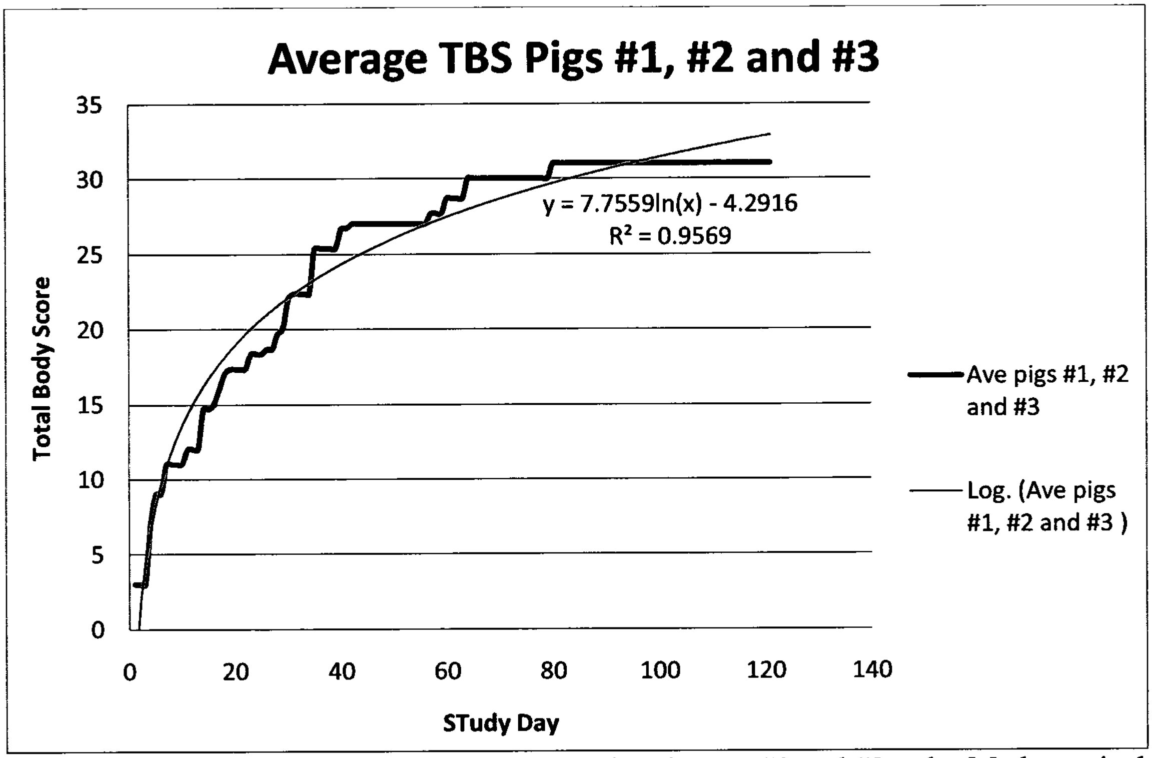

Figure 4.30: Graph showing the average TBS for pigs #1, #2 and #3 only. Mathematical trendline shows close relationship to the non-clothed group.

The overall decomposition rates were summarized for each decomposition stage in relation to each section of the pig – head, trunk and limbs – and for the whole body (Table 4.5). Two time ranges are provided. One decomposition rate summary is for the entire sample, pigs #1, #2, #3 and #4. A second summary is provided for the adjusted sample, pigs #1, #2 and #3. The summaries indicate the length of time required for each stage of decomposition. Variations between the two decomposition rate summaries occur in the fresh stage and advanced decomposition stage. The complete sample remained in the fresh stage between days 1 and 6, whereas the adjusted sample remained in the fresh stage between days 1 and 3 for the head and trunk, and days 1 and 4 for the limbs, and the body as a whole. The advanced decomposition stage was longer for the complete sample than the adjusted group. The complete sample remained in the advanced stage between days 24 and 79, whereas the adjusted sample remained in the advanced stage between days 24 and 63.

Table 4.5: Summarized time periods for each decomposition stage for the complete sample, pigs #1, #2, #3 and #4, and for the adjusted sample, pigs #1, #2 and #3. The time frames for each stage are provided for the separate sections of the pigs (head, trunk and limbs) and the whole body.

	Decomposition Stage	**Timeframe** (Pigs #1- #4)	**Timeframe** (Pigs #1- #3)
Head	Fresh	1 – 6	1 – 3
	Early Decomposition	4 – 14	4 – 14
	Advanced Decomposition	14 – 34	14 – 34
	Skeletonization	30 – 121	30 – 121
Trunk	Fresh	1 – 6	1 – 3
	Early Decomposition	4 – 27	4 – 27
	Advanced Decomposition	24 – 79	24 – 63
	Skeletonization	64 – 121	64 – 121
Limbs	Fresh	1 – 6	1 – 4
	Early Decomposition	5 – 28	5 – 28
	Advanced Decomposition	28 – 42	28 – 42
	Skeletonization	35 – 121	35 – 121
Total Body	Fresh	1 – 6	1 – 4
	Early Decomposition	5 – 29	5 – 28
	Advanced Decomposition	29 – 79	28 – 63
	Skeletonization	64 – 121	64 – 121

4.2 Environmental Conditions

During the four study months, June to September 2009, the volume of precipitation varied each month. The total precipitation for June was 100.4 mm, July was 59.8 mm, August was 163.4 mm, and September was 47.5 mm (Table 4.6). There was one hurricane and one tropical storm during the research period; these occurred on August 23rd, 29th, and 30th respectively. During both storms, extremely heavy rainfall was observed. This accounts for the increase in total precipitation during August 2009 as compared to Environment Canada climate normals. The total precipitation for August, disregarding the storms, was 43.4 mm. The volume of rain experienced during the study was not consistent during any month (Figure 4.31). No patterns were discernable between the volumes of precipitation and the decomposition rates observed for the pigs. Based on Environment Canada's climate normals –calculated from weather patterns between 1971 and 2000 – the study period had lower monthly accumulation of precipitation of rainfall than previously recorded (Table 4.6).

Table 4.6: Precipitation volumes from study period and expected normal amounts.

Precipitation (mm)	June	July	August	September
Study Period	100.4	59.8	163.4 (43.4)	47.5
Normal	108.0	105.9	98.3	107.1

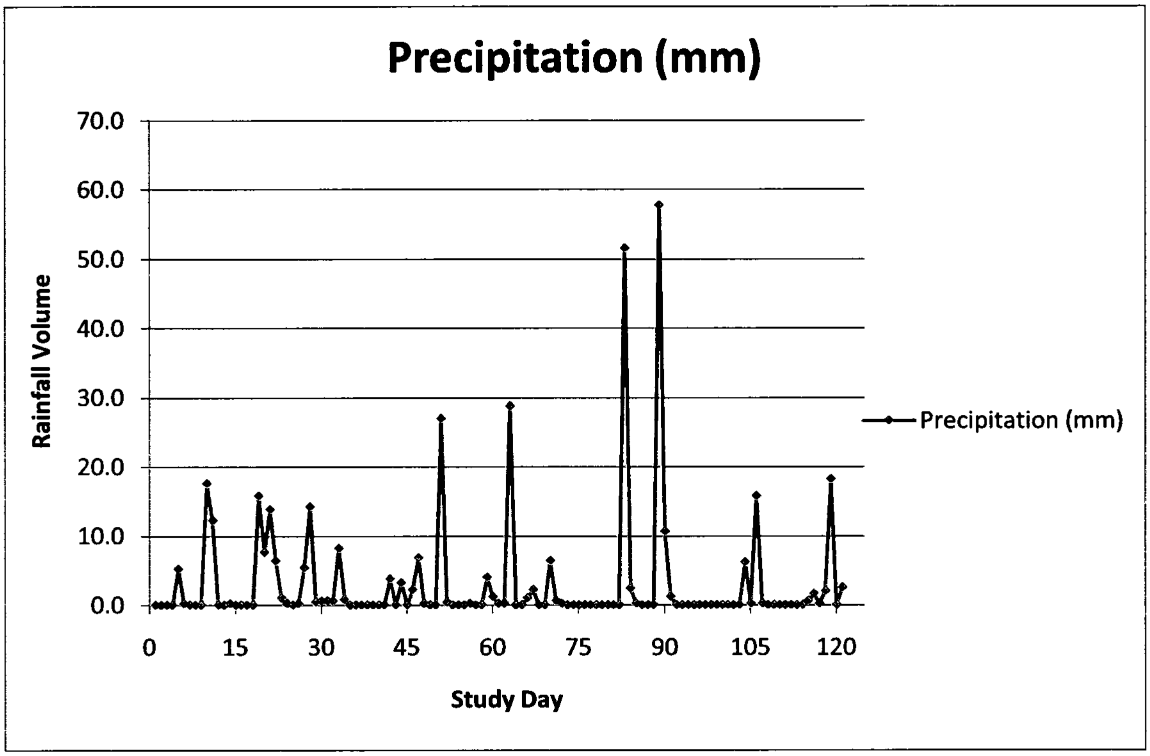

Figure 4.31: Graph showing the daily precipitation throughout the research period (June 1 – September 30, 2009).

Minimum, maximum, and average air temperatures were tracked during the four month study period. The minimum, maximum and average temperatures recorded fluctuate in the same pattern for all three variables (Figure 4.32). The air temperatures recorded for June and September had very similar minimums, maximums, and average air temperatures for the two months. June and September air temperatures were much more similar to each other than to either July or August. The same similarity in recorded air temperatures occurred during July and August, with these two months being much more related, in air temperature, to each other than to either June or September. August had a 4.9°C higher maximum temperature and a 1.8°C higher average temperature than July (Table 4.7). Environment Canada climate normals – calculated from weather patterns between 1971 and 2000 – show the same similarity in the relationship between monthly air temperatures for June and September, and July and August as the study period showed (Table 4.8). Minimum and maximum temperatures, during the study period, are more extreme than the climate normals. Minimum temperatures, during the study period, are at least 5°C lower than the recorded climate normals and maximums are at least 5°C higher. The monthly average air temperatures, recorded for the study period, are very similar to the expected temperatures based on the Environment Canada climate normals.

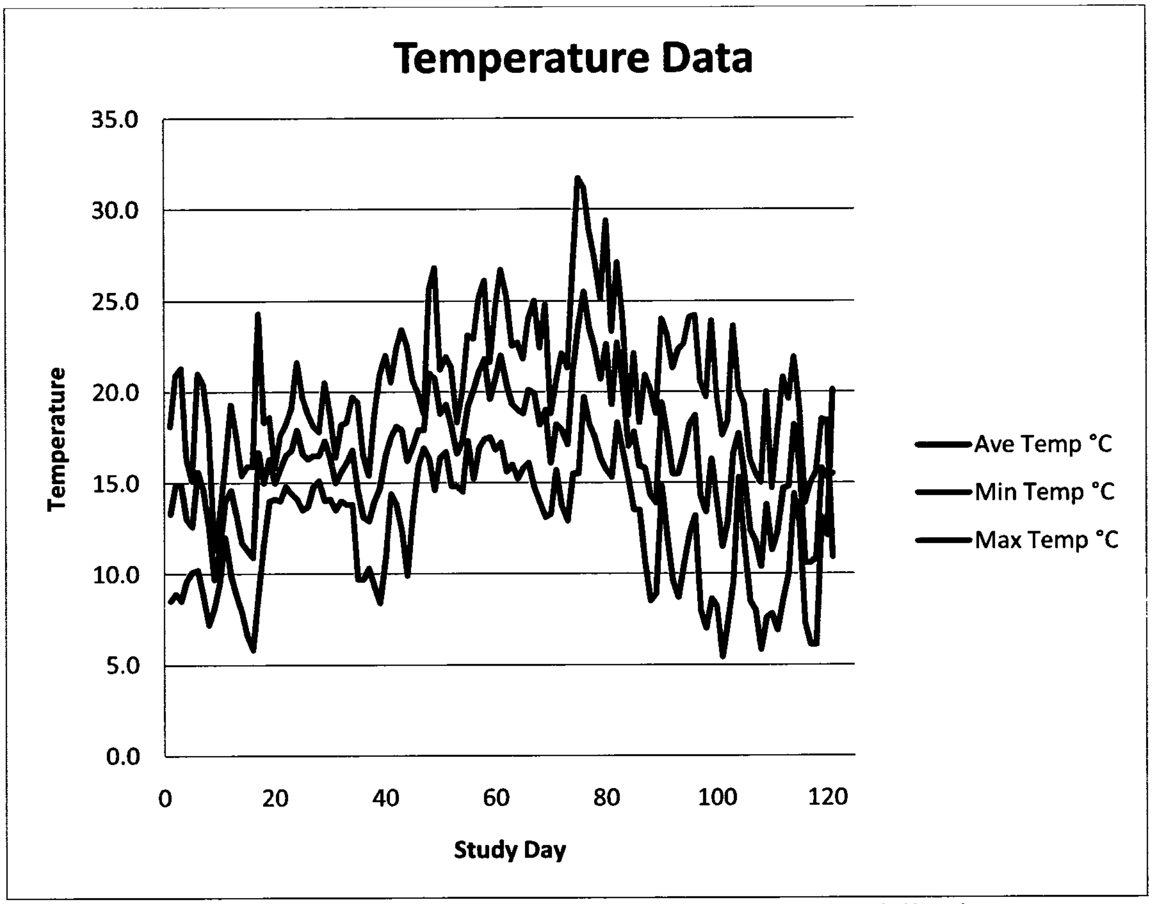

Figure 4.32: Graph showing the minimum, maximum and average daily air temperatures during the study period (June 1 – September 30, 2009) as recorded by Environment Canada.

Table 4.7: Temperature patterns for June to September 2009.

Temperature °C	June	July	August	September
Minimum °C	5.8	8.4	8.5	5.4
Maximum °C	24.3	26.8	31.7	24.2
Average °C	14.5	17.5	19.3	14.4

Table 4.8: Environment Canada climate normals for June to September 2009.

Climate Normals	June	July	August	September
Minimum °C	10.5	14.2	14.8	11.4
Maximum °C	19.4	22.9	23.0	19.0
Average °C	15.0	18.6	18.9	15.2

Temperatures fluctuated throughout the study period. There were no extended cold periods or extended hot periods during the study. The temperature fluctuations experienced during the study did not show any consistent temperature plateaus of higher or lower temperature. There was only one period, during the study, that had a slight plateau of higher temperatures than the surrounding days. There was a slight increase in temperature between August 14th and 23rd, study days 74 to 83. During these days, the temperature increase was between 5°C and 10°C above the expected normal maximum temperature, however, average temperatures did not reflect the same increase. The increase in average temperatures varied from the expected normal by only 4°C to 5°C. The increase in temperature began to drop between August 19th and 23rd, days 79 to 83. During days 79 to 83, the temperatures were still higher than the temperatures recorded for the rest of the month, however, lower than the temperatures recorded between August 14th and 18th. The temperatures between August 19th and 23rd varied between 2°C and 7°C higher than the expected maximum temperature based on climate normals. The average temperatures found during August 19th and 23rd were only 2°C to 4°C higher than the expected average temperature.

The rate of decomposition did not vary with ambient temperature in an appreciable way. When the temperature increase occurred, all four pigs had reached the stage of decomposition that they were in at the end of the study, with the exception of the trunks. The trunks of pigs #1, #2 and #3 were at a score 9 on day 64. The trunk of pig #4 remained at a score 8 on day 64 and did not increasing to a score 9 until day 79. The trunks of pigs #1, #2, #3 increased to a score 10 on day 79. All four pigs remained at these scores until the end of the study. The increases in the trunk decomposition scores do not appear to have been influenced by the temperature increase. There were no distinct changes in the rate of decay, or any abrupt changes in the step of the skeletonization decomposition stage for any of the four pigs.

CHAPTER 5

DISCUSSION

5.1 Decomposition Patterns

All four pigs followed the same morphological pattern of decomposition for the head, trunk and limbs, but varied somewhat in the time required to achieve the same decomposition stages. The heads were the first body section to reach each decomposition stage. By day 35, all of the heads were skeletonized with only a small amount of mummified tissue remaining. The trunks and limbs were slower to proceed through the stages. The advanced stage, for the limbs, was reached at the same time for all four pigs. The trunks, of all four pigs, reached the advanced stage over a seven day period. The limbs reached the skeletonization stage by day 43, whereas the trunks achieved skeletonization on day 80. Thus, early decomposition occurred at the same time and same rate for the trunks and limbs; however, by the beginning of the advanced decomposition stage, the limbs proceed at a much more rapid rate than the trunks. The limbs, therefore, decomposed at the same rate as the trunk until the advanced decomposition stage and then decomposed more rapidly than the trunk, achieving skeletonization earlier.

All four pigs showed adipocere formation from the advanced decomposition stage until the end of the study, day 121. Adipocere was commonly located along the spinal columns for all the pigs. The clothed group, pigs #1 and #4, had an increased mass of adipocere by the end of the study. Pig #4 had a larger mass of adipocere in comparison to pigs #1, #2 and #3. Both pigs #1 and #4 had an increased mass of adipocere in the areas where the clothing had covered the body in comparison to the same location on the non-clothed pigs. The increase in mass of adipocere is likely a result of the presence of clothing as this would increase the moisture content on the carcasses. Rodriguez (1997) found increasing amounts of adipocere formation when more moisture was present directly on the corpse. The cotton covering on pigs #1 and #4 may explain the increase in the amount of adipocere formed. Mellen et al. (1993) found that adipocere formation appeared more extensive when tissue was covered by cotton cloths.

5.2 Taphonomic Variation Between Clothed and Non-Clothed Pigs.

The rate of decomposition, for the two non-clothed pigs, proceeded in the same pattern and at the same time. There was variation in the decomposition rates of the clothed group, pigs #1 and #4. Pig #1 decomposed more rapidly and reached a final decomposition stage one step further in the skeletonization stage than pig #4. The decomposition rate of pig #1 followed the same rate as the non-clothed group, pigs #2 and #3. Pig #4 decomposed at a slower rate than pigs #1, #2 and #3. On day 121, pig #4 was one step lower in the decomposition stages achieved for all body sections except the head, in comparison to the other pigs. Pigs #1, #2 and #3 are discussed separately from pig #4 due to the unique traits that affected only pig #4. Pig #1 also showed less variation in the decomposition rates observed when compared with pigs #2 and #3, the non-clothed group, than the variation observed with pig #4.

The decomposition rate of pig #1 varied more than the decomposition rate of pig #4 within the clothed group than it varied from the decomposition rate of the non-clothed group, pigs #2 and #3. Pig #1 was in an environment that was similar to pigs #2 and #3, whereas pig #4 was in a more shaded environment. Pigs #1, #2 and #3 reached the early, advanced and skeletonization stages of decomposition on approximately the same days for the same stages. All three pigs also remained in each stage of decomposition for roughly the same lengths of time (Table 5.1). Pig #1 varied from pigs #2 and #3 in that it showed an increased amount of adipocere on day 121. The final decomposition stages were the same for all three pigs however, the clothing on pig #1 may have retained more moisture on this carcass causing the increase in adipocere formation. The minimal variation observed between pig #1, clothed, and pigs #2 and #3, non-clothed, suggests that clothing may not affect the decomposition rate. As pig #4 had traits that were not present in pigs #1, #2 and #3, it is reasonable to compare the decomposition processes of pigs #1, #2 and #3 separately. Further research needs to be conducted to address the effects clothing may have on decomposition rates.

Table 5.1: Pigs #1, #2 and #3: Time frame and progression of decompositional stages for the head, trunk and limbs.

Days in which each section of each pig was in each specified state of decomposition				
Section	*Decomp. Stage*	***Pig 1***	***Pig 2***	***Pig 3***
Head	**Fresh**	1 – 3	1 – 3	1 – 3
	Early Decomp	4 – 14	4 – 13	4 – 13
	Advanced Decomp	15 – 29	14 – 29	14 – 34
	Skeletonized	30 – 121	30 – 121	35 – 121
Trunk	**Fresh**	1 – 3	1 – 3	1 – 3
	Early Decomp	4 – 23	4 – 25	4 – 27
	Advanced Decomp	24 – 63	26 – 63	28 – 63
	Skeletonized	64 – 121	64 – 121	64 – 121
Limbs	**Fresh**	1 – 4	1 – 4	1 – 4
	Early Decomp	5 – 27	5 – 27	5 – 28
	Advanced Decomp	28 – 42	28 – 34	29 – 39
	Skeletonized	43 – 121	35 – 121	40 – 121

5.3 Taphonomic Variation of Pig #4

Pig #4 had two traits that were not present in the other three pigs. Firstly, pig #4 had dark skin. Secondly, the microenvironment of pig #4 was more shaded than the locations of the other pigs. The increased shade was not known prior to the study due to limits place on site access. Site set up was conducted during full sun in the early afternoon and all four placement locations had the same amount of sun during his time. Thus, the variation in the sun exposure was not known until after the study began. The set up was conducted in the early afternoon due to the limitations of when the pigs could be killed and transported to the site and when the researcher could gain access to the site.

The variation in decomposition rates observed with pig #4 in relation to pigs #1, #2 and #3 could be explained by the increased shade. Past research has shown that shade decreases the decomposition rates of carcasses in an outdoor environment (Komar, 1998; Shean et al., 1993). In contrast, Sharanowski et al. (2008) found that shade only affected the rate of decomposition in the spring and during the first two stages of decomposition in the fall. The conclusions drawn by Sharanowski et al. (2008) were based on recorded variations in temperatures between the sun exposed and shaded locations during each season in Saskatchewan, Canada. Shade may provide an environment with more moisture and cooler temperatures. The microenvironment of pig #4 may have been cooler than the other three pigs due to the shorter period of direct sunlight. Cooler temperatures are also known to slow decomposition rates however, the degree of temperature difference needed to affect the rate of decomposition has not yet been established. Due to the variation present in the microenvironment of pig #4, the results obtained from this study may not be representative of the effect of cotton clothing on decomposition rates in an outdoor environment. The variations in the decomposition rates observed could be from natural variation alone. Further research needs to be conducted regarding the effect of clothing and amount of shade present in the environment in which cadaveric remains are located on decomposition rates.

The black skin pigment of pig #4 may have been a factor that influenced decomposition rates. Past research has noted similar change in skin pigmentation colour as seen with pig #4 (Bass, 1997). Currently, there is no literature that addresses whether skin pigmentation has any affect on the rate of decomposition. Further research needs to be conducted to address the possible effect of skin pigment on decomposition rates.

The decomposition rate of pig #4 was slower than that present in pigs #1, #2 and #3, with the exception of the head of pig #4. The head of pig #4 remained in the fresh stage for a longer time period than the other pigs; however, the darkly pigmented skin made the observation of the discolouration step of the early decomposition stage difficult. Therefore, pig #4 may not have remained in the fresh stage as long as it appeared to due to the difficulty in making this observation. The head of pig #4 decomposed at the same rate as the heads of the other three pigs once the purge step of early decomposition was reached. The trunk and limbs showed more variation. The final stages of decomposition achieved by pig #4 at the end of the study were one step lower for the trunk and limbs in comparison to the trunk and limbs of pigs #1, #2 and #3.

The trunk of pig #4 remained in the advanced decomposition stage for 16 days longer than the other three pigs. The final step of decomposition reached for the trunk of pig #4 was the first step of the skeletonization stage. Pigs #1, #2 and #3 increased to the second step of the skeletonization stage, therefore completing the study at a further step of decomposition. The variation observed in pig #4 may have been caused by the clothing. Clothing was present on pig #1, yet, pig #1 did not show any variation in decomposition rates from pigs #2 and #3; therefore, the variation experienced by pig #4 cannot be ruled out as natural variation. Further research needs to be conducted to determine the effects of clothing on decomposition rates.

The decomposition of the limbs, of pig #4, also showed more variation in decomposition rates than the limbs of pigs #1, #2 and #3. The final stage of decomposition, that the limbs of pig #4 reached, was the first step of the skeletonization stage. This step was achieved on day 43 and remained at the same step until the end of the study. The limbs of pigs #1, #2 and #3 increased to the second step of the skeletonization stage between days 57 and 64. The lower final stage of decomposition, found with the limbs of pig #4, could be a result of the increased shade exposure.

5.4 Mathematical Trends

Due to the limited sample size, i.e. four pigs, statistical analyses were not conducted. Graphical analyses were conducted to determine trends in the decomposition patterns and timeframes. Decomposition rate follows a logarithmic curve. Decomposition rates for each section of the pig (head, trunk and limbs), the total body scores (TBS), and within the separate groupings (clothed and non-clothed) follow this same pattern. Our results support the use of a logarithmic model to predict decomposition rates.

Graphical analyses of the average TBS of the clothed group and the non-clothed group produce very similar trends (Figure 5.1). The logarithmic trendlines show small differences between the slopes and the R^2 values. The equation of the average TBS for the clothed grouping is y=7.5301ln(x) – 4.0453 with an R^2 value of 0.9564. The non-clothed grouping average TBS equation is y=7.758ln(x) – 4.3345 with an R^2 value of 0.9569. The R^2 values indicate that 95.64% and 95.69% of the decomposition data for the clothed and non-clothing groups, respectively, is accurately represented by the logarithmic trendlines. The variation in the slopes, measure of decay, 7.5301 and 7.758, clothed and non-clothed respectively, suggests a variation in decay rates between the two groupings. This variation may not be significant demonstrable due to the low sample size. The variation in the clothed grouping is likely due to the variation present in pig #4 and not the presence of clothing. It is not possible to distinguish which factor, clothing or traits associated with pig #4 only, affected the decay rates. The differences observed may be natural variation. Future research needs to be conducted to determine the experimental effect clothing has on decomposition rates.

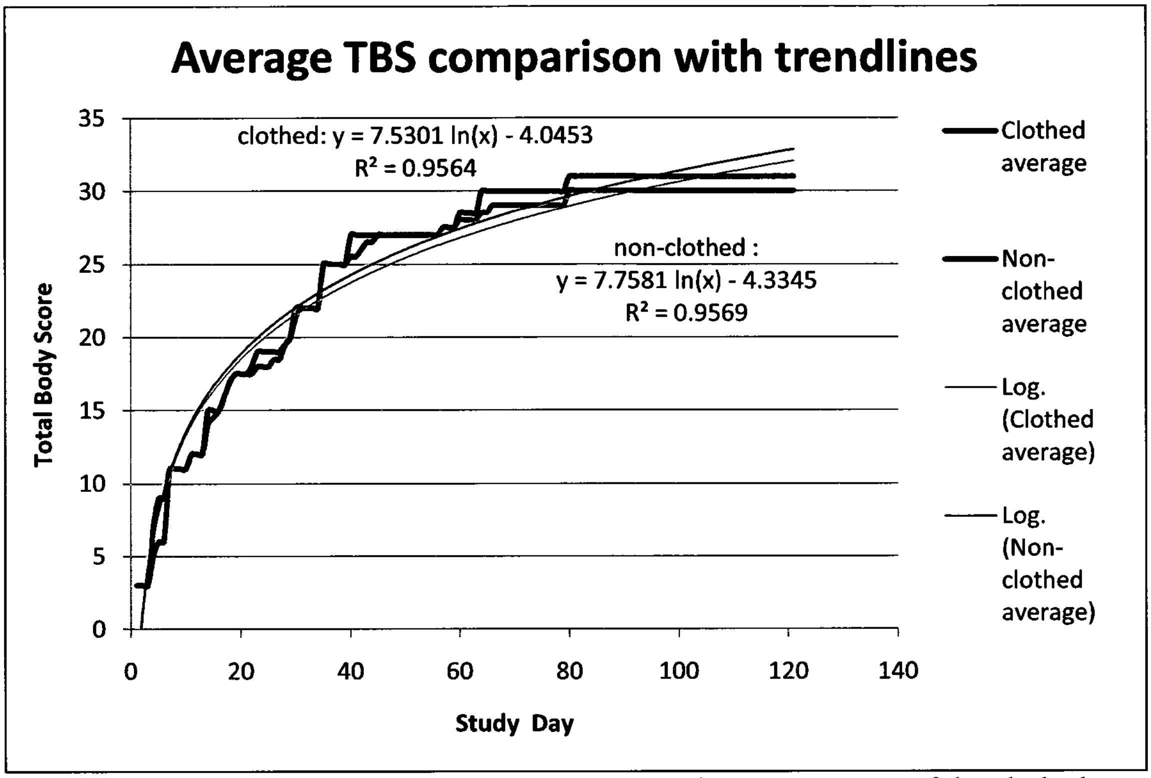

Figure 5.1: Graph showing the relationship between the average TBS of the clothed group (pigs #1 and #4) and the non-clothed group (pigs #2 and #3). Graph displays mathematical decay trendlines.

Graphical analyses of the average TBS for the sample as a whole, pigs #1, #2, #3 and #4, and the average TBS for the grouping of only pigs #1, #2 and #3 also shows slight variation between the two sample groupings (Figures 5.2 and 5.3). Similar to the averages of the clothed and non-clothed groupings, there was minimal variation between the slopes and R^2 values for the entire sample TBS average and the TBS average for the sample with the removal of pig #4. The equation for the entire sample is $y=7.644\ln(x) - 4.1899$ with an R^2 value of 0.9584, indicating that 95.84% of the data is accurately predicted by the logarithmic trend. The slope of the line falls between the values for the clothed and non-clothed grouping. This is expected as it is the average of the entire sample including pig #4 which is the one pig that showed variation for the decomposition rates. The equation for the sample with pig #4 removed was $y=7.759\ln(x) - 4.2916$ with an R^2 value of 0.9569, indicating 95.69% of the data is accurately predicted by the logarithmic model. This equation is very close to the equation from the non-clothed group TBS average. The close relationship between the clothed group and the sample group of pigs #1, #2, and #3 shows that pig #1 decomposed at the same rate as pigs #2 and #3 (non-clothed group). The similarity in the decomposition rate of pig #1 with pigs #2 and #3 (non-clothed group) may indicate that the variation in the decomposition rate of pig #4 may not have been due to the clothing. The variation found in the decomposition rate of pig #4 could be due to the increase in shade exposure and/or its dark skin pigmentation.

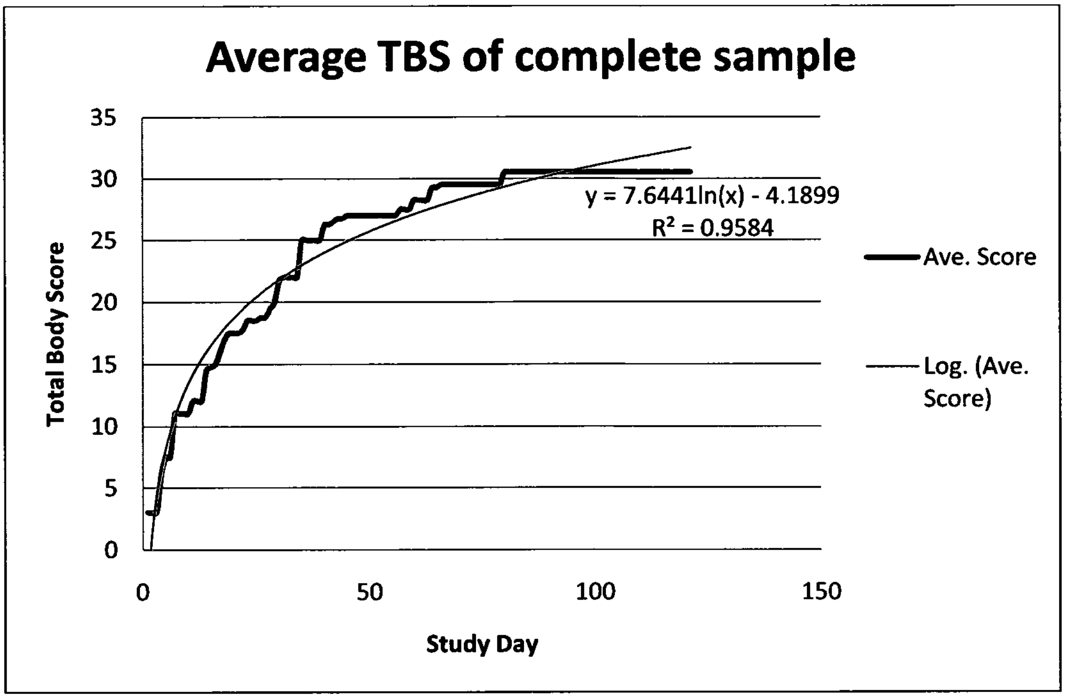

Figure 5.2: Graph showing the average TBS for the entire sample, pigs #1, #2, #3 and #4. Mathematical trendline shown.

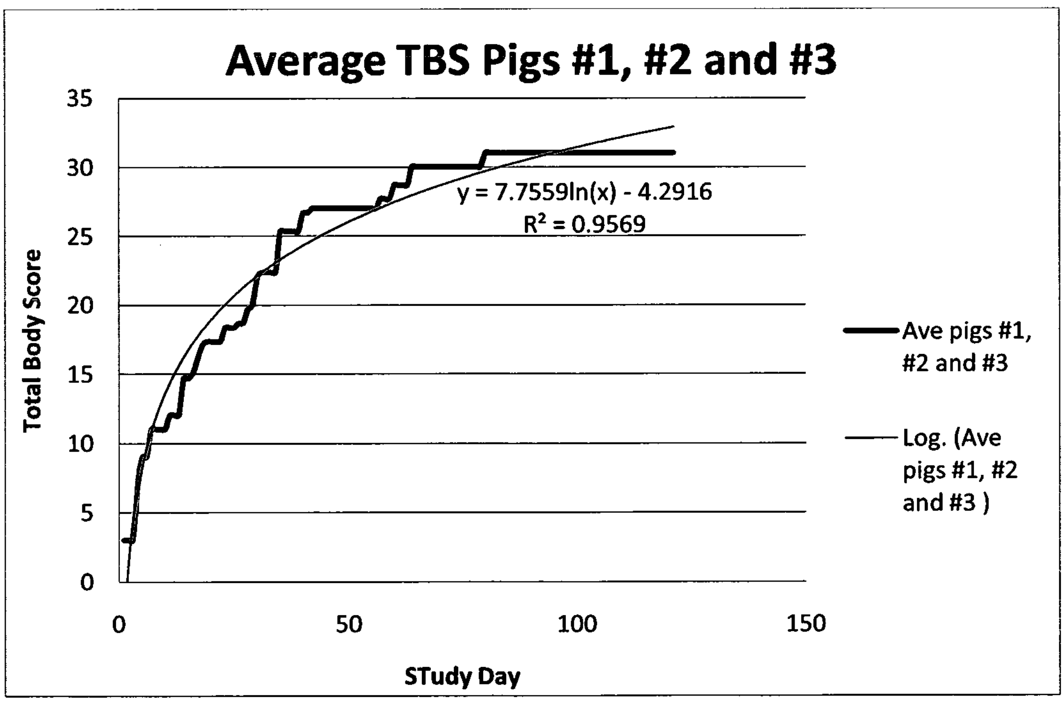

Figure 5.3: Graph showing the average TBS for pigs #1, #2 and #3 only. Mathematical trendline shows close relationship to the non-clothed group.

5.5 Decomposition Rate Comparison with Past Research

Comparison of decomposition rates from this study with those of other studies can only be carried out in a qualitative way. A statistical comparison cannot be conducted due to differences in the types of past studies, the research subjects utilized, and the lack of availability of full datasets. The studies by Galloway et al. (1997), Komar (1998), Megyesi (2005) and Prieto et al. (2004) were all retrospective reviews. The time since death intervals in these studies were based on an estimation from when the decedent went missing to when the body was recovered, therefore the timeframes provided may overestimate the time necessary to reach a given decomposition stage. These studies were also unable to track the progression of changes from the fresh stage to the skeletonization stage of decomposition.

The studies by Mann et al. (1990) and Bass (1997) are experimental studies. However, raw datasets are not obtainable. Statistical comparative tests were thus not possible. Bunch (2009) used pig carcasses, however, they were child-sized and exsanguinated – neither condition was true in the current study.

Previous studies have established that size of a pig affects the decomposition rates (Hewadikaram and Goff, 1991; Komar, 1998). The absence of blood in the pigs probably affected the decomposition rates reported by Bunch (2009) as it has been noted that parts of the body with a high volume of blood decompose faster (Clark et al., 1997).

Research conducted in Tennessee, by Mann et al. (1990:105), found that during the summer months an adult body becomes fully skeletonized in 2 to 4 weeks. During the first week in Tennessee, discolouration of the body and bloating occurred, skin slippage began and fluids were purging from the mouth, nose, and rectum. From the second to fourth week, bloating was completed and bones were exposed. After the first month, and during the first year, the skeleton bleached, algae had grown on some bones, and rodents had also gnawed on some of the bones (Bass, 1997:183-185). The changes documented by Bass (1997) and Mann et al. (1990) all occurred sooner than observed during this study. Skin slippage began on some heads on day 11 and did not progress to the rest of the bodies until day 18 or later. Bloating was not completed until days 30 to 32. Skeletonization was not found to begin until between days 64 and 80 which was much later than recorded for the summer in Tennessee.

Decomposition rates reported from Southern Arizona are also faster than rates found with the current study (Galloway et al., 1989). Early decompositional changes were found between days 1 and 5 however, some changes remained until the end of the first month (Galloway et al., 1989:610). Advanced decompositional changes occurred between days 4 and 10 with some bodies remaining in this stage for 2 months (Galloway et al., 1989:611). The skeletonization stage occurred from 3 weeks to 1 month after death; however, due to the hot dry weather, causing mummification, some individuals were not skeletonized until 2 months to 1 year after death (Galloway et al., 1989:611). Exfoliation of the cortical bone surface began in the fourth month (Galloway et al., 1989:611).

Results from the current study found all decomposition stages occurring at a later time than what was documented by Galloway et al. (1989). Early decomposition spanned days 5 to 28 and advanced decomposition remaining until days 64 to 79. At the end of this study, day 121, all exposed bones still retained grease. None of the exposed bones showed any signs of exfoliation, a changed documented as beginning at this length of time in Arizona.

Tennessee and Arizona have hotter climates than Nova Scotia. Tennessee is more humid and Arizona is drier than Nova Scotia. The differences in the climates of Tennessee and Arizona are likely the cause of the faster decomposition rates in comparison to the decomposition rates of the summer in Nova Scotia.

Decomposition studies conducted in Edmonton, Alberta, by Komar (1998) and central New York State by Bunch (2009), presented decomposition rates in cold climate environments. Komar (1998) addressed the advanced decomposition stage, assessing the length of time it took for a body to reach partial or complete skeletonization. Komar found that, in an Edmonton summer, complete skeletonization could occur in 6 weeks (1998:59). In the winter it could take 4 months or less for an individual to reach skeletonization (1998:61). Preliminary results, reported by Bunch (2009:40), found significant variation in skeletonization rates. Skeletonization was achieved at two of the three geographic sites in 30 weeks, whereas, the third pig carcass reached skeletonization in 44 days. The study conducted by Bunch (2009) began in October, therefore, the decompositions rates presented were based on fall temperatures rather than those of the summer.

Similar to Tennessee and Arizona, Edmonton also showed an increased rate of skeletonization in the summer. Skeletonization occurred between 2 and 4 weeks earlier in Edmonton than rates found in the current study. The winter rates described in the Edmonton study over a four month time period appear to be more reflective of the rates found for Nova Scotia during the 2009 summer. The study conducted by Bunch (2009) was difficult to use as a comparison as the research began in late October and utilized exsanguinated child-sized pigs.

Decomposition rates in Spain were determined based on a study of human forensic cases spanning a 10 year period (Prieto et al., 2004). Phase 1, putrefaction, occurred between 1 week and 1 month (Prieto et al., 2004:3). Phase 2, initial skeletonization, occurred in 2 months for bodies that decomposed on the surface of the ground (Prieto et al., 2004:3). Phase 3, advanced skeletonization, occurred from 6 months to 1 year for bodies on the ground surface (Prieto et al., 2004:3). The putrefaction stage, defined by Prieto et al. (2004), is comparable to the early decomposition stage described in this study. Early decomposition occurred between days 7 and 28 in this study. The initial skeletonization stage, in Prieto et al. (2004), is reflective of the advanced decomposition stage in this study, which occurred between days 29 and 63 to 79. The skeletonization stage that occurred after days 64 to 80, in this study, reflects the stage defined as "advanced skeletonization" by Prieto et al. (2004). The decomposition rates described in this study are comparable to the rates documented by Prieto et al. (2004) from Spain. The rates established by Prieto et al. (2004) encompass all seasons. Because of this, it is not possible to compare decomposition rates in a Nova Scotia summer and decomposition rates in the summer in Spain. The rates reported in the Spanish study are also based on the estimated time from a person going missing to the body being recovered. Thus, it does not reflect the minimum length of time it takes to reach the specified stages of decomposition. The length of time required to reach the comparable decomposition stages in Spain may be significantly less than the timeframes reported by Prieto et al. (2004).

Decomposition rates were recorded in two entomological studies conducted in

Western Canada. Anderson and VanLaerhoven (1996) carried out the first study in British Columbia tracking insect succession. Sharanowski et al. (2008) investigated insect succession on sunlit and shaded carrion in Saskatchewan. Both studies utilized pigs. Anderson and VanLaerhoven (1996:618-620) began their study in June and report more rapid decomposition rates than found in this study. Their defined bloated stage, representative of the early decomposition stage in this study, occurred between days 2 and 10. The active decay stage, representative of advanced decomposition, in the current research, was present during days 11 to 16. In contrast, early decomposition occurred between days 5 and 28, the advanced decomposition stage spanned days 29 to 79 in this study. Advanced decay reported by Anderson and VanLaerhoven (1996), consistent with the skeletonization stage in this study, occurred between days 17 and 42.

Sharanowski et al. (2008:230) reported decomposition rates using the same definition of decomposition stages as Anderson and VanLaerhoven (1996), however, found more rapid decomposition rates during the summer season. The bloated (early decomposition) stage occurred between days 1 and 4, active decay (advanced decomposition) occurred between days 5 and 11 and advanced decay (skeletonization stage) occurred between days 12 and 25 (Sharanowski et al., 2008:230). Decomposition rates found by Sharanowski et al. (2008) were significantly faster than rates found in this study.

The study conducted by Anderson and VanLaerhoven (1996) used pigs that weighed only 22 kilograms which is smaller than the pigs used in this study. Sharanowski et al. (2008) utilized pigs that weighed between 49 and 79 kilograms, a size representative of human adults. This size similarity makes these results more comparable to this research. The slower decompositions rates found in this study reinforce the necessity for regional decomposition data as the rates found during the summer in Saskatchewan are considerably faster than what was found during the summer in Nova Scotia. The higher summer temperatures in Saskatchewan likely explain the difference in decomposition rates.

Entomological research, conducted in Nova Scotia, reports different timeframes than this study. Leblanc and Strongman (2002) investigated insects associated with the decomposition of small pig carcasses during the fall, in Nova Scotia. Simpson and Strongman (2002) compared the insects associated with decomposition in rural and urban sites. Leblanc and Strongman (2002:148) found significantly faster decomposition rates than this study; the fresh stage occurring between days 0 to 5, bloating (early decomposition) between days 6 and 12, active decay (advanced decomposition) between days 13 and 26, and advanced decay (skeletonization) after day 26. These increased rates could be due to the small carcass size (0.75-1.70 kg) and the study beginning in September which is a hotter month than June. The results reported by Simpson and Strongman (2002:136) indicate that skeletonization occurred between 10 and 12 days. The study also reported maggot masses covering the entire pig bodies which was not observed in this study. Simpson and Strongman (2002) began their study in July, which has higher temperatures than June, when the current study began. Insects have a significant influence on decomposition rates (Bass, 1997 and Mann et al., 1990). The insect activity and higher temperatures could account for the much faster decomposition rates reported by Simpson and Strongman (2002).

Comparisons were also carried out with a study in which all pig carcasses were buried (Weitzel, 2005). Decomposition rates reported by Weitzel (2005) were also more rapid than the rates found in this study. The decompositional changes observed with the buried pigs were more representative of the changes documented in this study, i.e. adipocere formation. Weitzel (2005:5) found skeletonization to occur in 3 to 5 weeks when carcasses were buried at approximately 40 cm, during June. When carcasses were buried in May, or deeper than 40 cm, skeletonization took between 5 weeks and 3 months to occur. The rate of skeletonization for May, or a depth of deeper than 40 cm, was more reflective of the length of time it took to achieve the same stage in this study. Research into the length of time it takes for buried remains to decompose has found it can take up to eight times longer for buried remains to decompose compared to surface remains (Maples and Browning, 1994). Clark et al. (1997) notes that a buried body, in a warm environment, may become skeletonized as rapidly as an exposed body in a mild or cool climate. This could explain the closer relationship of the decomposition rates found by Weitzel (2005) to the decomposition rates found in this study. Adipocere in the thoracic region was often reported with the burials (Weitzel, 2005), a finding consistent with the current research in Nova Scotia.

The insect activity observed in this study was not comparable to any previous research, in that beetle larvae were the dominant feature of the fauna. Both entomological studies previously conducted within Nova Scotia reported that the carcasses were completely covered by maggot masses (Leblanc and Strongman, 2002; Simpson and Strongman, 2002). Maggot masses never covered the entire pig carcass, for any of the specimens, during this study period. The heads were completely covered but never the entire body. Similarly, Galloway et al. (1989) found the same coverage of maggot masses, as did the previous studies in Nova Scotia, with the exception of a few instances in which maggot masses did not cover the entire carcass. Minimal maggot masses occurred in cases where the body was in an enclosed environment that restricted insect access. Anderson and VanLaerhoven (1996), Bass (1997), Mann et al. (1990), and Sharanowski et al. (2008) all reported individuals becoming completely covered with maggots very early in the decomposition process. One possible reason for the observed lack of maggot masses during this study was the cooler temperatures during June when the research began. Approximately one-half of June had temperatures below +10°C. Insects are affected by temperature; therefore, the cooler temperatures may have caused the decrease in their activity. The small size of the maggot masses would have also caused the pig carcasses to remain cooler. Maggot masses generate high temperatures which accelerate the decomposition rate.

The other variation in insect activity, when comparing this study to previously documented research, was the concentration of beetle larvae and beetles. The largest swarms of insects, on all pigs, were comprised of beetle larvae rather than maggots. Beetles are typically found when remains become mummified or are very desiccated. The slower decomposition could be related to the higher concentration of beetle larvae and the way in which they feed. Beetles have articulated jaws, therefore they bite and chew the remains, whereas maggots have non-articulated jaws and do not bite and chew. Maggot mandibles are hooked and sharp so they feed by raking the flesh, shredding it and at the same time inoculating the flesh with bacteria. Thus, maggots feed on a slurry of bacteria, the products of bacterial metabolism, and the end products of autolysis and putrefaction.

The minimal maggot activity and increased beetle activity may also have played a role in the increased adipocere formation. Since the temperature of the pig carcasses did not increase due to maggot activity, the environment was more favourable for adipocere formation. The cooler temperatures, presence of cotton clothing, and increased moisture all provided a favourable environment for adipocere formation.

CHAPTER 6

CONCLUSIONS

Decomposition rates for an urban environment in the Halifax Regional Municipality appear slower than decomposition rates reported from past research in other regions. The decomposition rates found during this study are summarized in Table 6.1. The heads were the first body section to skeletonize and the trunks were the last section to reach the skeletonization stage. The differences in decomposition rates observed between the four pigs as a single group may be due to normal variation, as could be the variation observed between the clothed and non-clothed groups. The differences in decomposition between pig #4 and the other three pigs may be attributed to its darker skin pigmentation or presence of clothing, rather than its placement in a shaded environment. Use of these rates for the estimation of time since death should be carried out with caution due to the limited sample size.

	Decomposition Stage	Timeframe
Head	Fresh	1 – 6
	Early Decomposition	4 – 14
	Advanced Decomposition	14 – 34
	Skeletonization	30 – 121
Trunk	Fresh	1 – 6
	Early Decomposition	4 – 27
	Advanced Decomposition	24 – 79
	Skeletonization	64 – 121
Limbs	Fresh	1 – 6
	Early Decomposition	5 – 28
	Advanced Decomposition	28 – 42
	Skeletonization	35 – 121
Total Body	Fresh	1 – 6
	Early Decomposition	5 – 29
	Advanced Decomposition	14 – 79
	Skeletonization	64 – 121

Table 6.1: Decomposition rates found for an urban environment in the Halifax Regional Municipality, Nova Scotia.

Decomposition rates were found to follow a logarithmic trend. All body sections, head, trunk and limbs, as well as the total body scores, followed the logarithmic model. Due to the small sample size statistical analyses were not possible; however, graphical analyses showed that all pigs followed the logarithmic model with over 95% accuracy.

Further research needs to be conducted to verify the decomposition rates found by this preliminary study. The small sample size limited the ability to determine if the variation observed across the sample was due to the presence of clothing on pigs #1 and #4, the increased shade experienced by pig #4, the dark skin pigmentation of pig #4 or natural variation. Future research needs to be conducted to determine the effects of clothing and skin pigmentation on decomposition rates, as well as the effect of shade within the region studied.

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APPENDIX A

DECOMPOSITION SCORING TABLES

Table A1: Head and neck decomposition scoring table.

HEAD & NECK		
Score	**F.**	**Fresh**
1		3. Fresh, no discolouration or insect activity
	G.	**Early Decomposition**
2		**7.** Pink-white appearance with skin slippage and some hair loss
3		**8.** Gray to green discoloration; some flesh relatively fresh
4		**9.** Discolouration to brownish shades particularly at edges, nose, and ears; some flesh still relatively fresh
5		**10.** Purging of decompositional fluids out of eyes, ears, nose, mouth, some bloating of face may be present
6		**11.** Brown to black discolouration of flesh.
	H.	**Advanced Decomposition**
7		**7.** Caving in of the flesh and tissues of eyes and throat.
8		**8.** Moist decomposition in which there is bone exposure, less than one half that of the area being scored
9		**9.** Mummification with bone exposure of less than one half that of the area being scored
	I.	**Skeletonization**
10		**5.** Bone exposure of more than half that of the area being scored with greasy substances and decomposed tissue
11		**6.** Bone exposure of more than half the area being scored with desiccated tissue or mummified tissue
12		**7.** Bones are largely dry, but still retaining some grease
13		**8.** Dry bone

(Adapted from Megyesi et al. 2005)

Table A2: Trunk decomposition scoring table.

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

(Adapted from Megyesi et al. 2005)

Table A3: Limb decomposition scoring table.

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

(Adapted from Megyesi et al. 2005)

APPENDIX B

RAW DATA

Table B1: Raw data for pig #1.

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
1	June 2	1	1	1	3	
2	June 3	1	1	1	3	
3	June 4	1	1	1	3	'balloon' of skin out of nostril
4	June 5	3	3	1	7	
5	June 6	3	3	3	9	
6	June 7	3	3	3	9	green discolouration of throat
7	June 8	5	3	3	11	most bloated out of 4 pigs
8	June 9	5	3	3	11	more decomposed but not to level of next stage
9	June 10	5	3	3	11	increase in bloating & green colouration
10	June 11	5	3	3	11	
11	June 12	6	3	3	12	skin slippage on head and beetles present
12	June 13	6	3	3	12	beetles
13	June 14	6	3	3	12	significant fly activity
14	June 15	7	3	4	14	beginning to lose flesh on head
15	June 16	7	3	4	14	some skin drying over abdomen
16	June 17	8	3	4	15	
17	June 18	8	4	4	16	skin and hair on legs changing
18	June 19	8	4	5	17	hair appears longer due to decomp
19	June 20	8	4	5	17	bloating is slowing decreasing, heads more caved

Pig #1 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
20	June 21	8	4	5	17	blister like appearance on abdomen
21	June 22	8	4	5	17	overall deflation of head & neck
22	June 23	8	4	5	17	almost nothing but some skin left on head; some intestines projecting from bellybutton
23	June 24	8	6	5	19	increase in insect activity; neck fully caved in; abdomen ruptured at bellybutton
24	June 25	8	6	5	19	large deflation; large amount of intestines out now; yellow/orange colouration change in skin
25	June 26	8	6	5	19	Significant increase in intestines, no longer looks defined; increase in drying and colour of skin
26	June 27	8	6	5	19	Increase in sagging/abdominal rupture
27	June 28	8	6	5	19	significant liquified head and shoulders
28	June 29	8	6	6	20	no structure left, all sagged, less black colouration
29	June 30	8	6	6	20	front quarters more sagged, more oozing from abdomen
30	July 1	10	7	6	23	abdomen more flattened; skeletonization of body beginning
31	July 2	10	7	6	23	increase in amount skeletonized
32	July 3	10	7	6	23	very moist decomp, jello-like appearance
33	July 4	10	7	6	23	skin covered in what looks like slime
34	July 5	10	7	6	23	increase in skeletonization
35	July 6	11	7	8	26	lots of skeletonization now
36	July 7	11	7	8	26	more drying of skin, colour changing from lighter grey to dark brown black
37	July 8	11	7	8	26	increase in darkening of skin colour
38	July 9	11	7	8	26	increase in drying
39	July 10	11	7	8	26	skin still darkening

Pig #1 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
40	July 11	11	7	8	26	lost 'width' or breadth of chest
41	July 12	11	7	8	26	white mold growth
42	July 13	11	8	8	27	no major changes in skeletonization still <50%
43	July 14	11	8	8	27	starting to dry out again after rain
44	July 15	11	8	8	27	mold growth overall
45	July 16	11	8	8	27	increase in skeletonization, pools of brown water on body
46	July 17	11	8	8	27	noticeable increase in decomp, looks less mummified
47	July 18	11	8	8	27	looks less leathery (rain)
48	July 19	11	8	8	27	increase in tissue loss
49	July 20	11	8	8	27	limited changes
50	July 21	11	8	8	27	increase in skeletonization and mold
51	July 22	11	8	8	27	liquefied tissue present over body
52	July 23	11	8	8	27	continual bleaching of exposed bones
53	July 24	11	8	8	27	exposed bones drying out, mold growth
54	July 25	11	8	8	27	abdominal tissue disrupted; bones slightly more bleached; increase in skeletonization
55	July 26	11	8	8	27	mold growth again
56	July 27	11	8	8	27	vertebral bodies longitudinally cracking; cartilage almost all decomposed
57	July 28	11	8	9	28	overall increase in skeletonization
58	July 29	11	8	9	28	abdomen has foamy substance; lots of horse flies
59	July 30	11	8	9	28	increase in skeletonization but not to next stage
60	July 31	12	8	9	29	mold present; liquified tissue

Pig #1 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
61	August 1	12	8	9	29	
62	August 2	12	8	9	29	some new maggot activity
63	August 3	12	8	9	29	oozing tissue & more tissue decomp
64	August 4	12	9	9	30	white mold; past 50% skeletonized but not far enough along abdomen
65	August 5	12	9	9	30	whit mold growth
66	August 6	12	9	9	30	some more drying
67	August 7	12	9	9	30	
68	August 8	12	9	9	30	more drying
69	August 9	12	9	9	30	increase in mummification
70	August 10	12	9	9	30	
71	August 11	12	9	9	30	increase in tissue wetness and liquification
72	August 12	12	9	9	30	
73	August 13	12	9	9	30	
74	August 14	12	9	9	30	
75	August 15	12	9	9	30	white mold growth
76	August 16	12	9	9	30	
77	August 17	12	9	9	30	white mold present
78	August 18	12	9	9	30	
79	August 19	12	9	9	30	abdominal adipocere/tissue more desiccated
80	August 20	12	10	9	31	exposed bones are dried and bleached
81	August 21	12	10	9	31	more desiccation again
82	August 22	12	10	9	31	

Pig #1 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
83	August 23	12	10	9	31	
84	August 24	12	10	9	31	
85	August 25	12	10	9	31	
86	August 26	12	10	9	31	
87	August 27	12	10	9	31	
88	August 28	12	10	9	31	
89	August 29	12	10	9	31	
90	August 30	12	10	9	31	
91	August 31	12	10	9	31	abdominal tissue more desiccated
92	September 1	12	10	9	31	
93	September 2	12	10	9	31	
94	September 3	12	10	9	31	
95	September 4	12	10	9	31	
96	September 5	12	10	9	31	
97	September 6	12	10	9	31	
98	September 7	12	10	9	31	
99	September 8	12	10	9	31	
100	September 9	12	10	9	31	
101	September 10	12	10	9	31	
102	September 11	12	10	9	31	
103	September 12	12	10	9	31	
104	September 13	12	10	9	31	
105	September 14	12	10	9	31	

Pig #1 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
106	September 15	12	10	9	31	
107	September 16	12	10	9	31	
108	September 17	12	10	9	31	
109	September 18	12	10	9	31	
110	September 19	12	10	9	31	
111	September 20	12	10	9	31	
112	September 21	12	10	9	31	
113	September 22	12	10	9	31	
114	September 23	12	10	9	31	
115	September 24	12	10	9	31	
116	September 25	12	10	9	31	
117	September 26	12	10	9	31	
118	September 27	12	10	9	31	
119	September 28	12	10	9	31	wet with adipocere and water around skeletons
120	September 29	12	10	9	31	
121	September 30	12	10	9	31	white mold present again

Table B2: Raw data for pig #2.

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
1	June 2	1	1	1	3	fresh
2	June 3	1	1	1	3	
3	June 4	1	1	1	3	
4	June 5	3	3	1	7	
5	June 6	3	3	3	9	marbling of front legs
6	June 7	3	3	3	9	
7	June 8	5	3	3	11	increase in bug/fly activity
8	June 9	5	3	3	11	Increase in decomp however not to next stage
9	June 10	5	3	3	11	increase in colour on abdomen
10	June 11	5	3	3	11	increase in marbling and bloating
11	June 12	6	3	3	12	skin slippage on head (1st note of skin slippage)
12	June 13	6	3	3	12	significant increase in bloating
13	June 14	6	3	3	12	progression towards black discolouration from green & increase in skin slippage
14	June 15	8	3	4	15	bloating increased; flesh loss on heads, slight bone visibility
15	June 16	8	3	4	15	skin looks like it stretching on abdomen and approaching rupture
16	June 17	8	3	4	15	increase in bloating & skeletonization of head
17	June 18	8	4	4	16	very black abdomen; increase in skin slippage
18	June 19	8	4	5	17	abdominal skin slipping; head & neck caved in
19	June 20	8	4	5	17	neck is more caved in
20	June 21	8	4	5	17	body very grey in colour; head appears detached from body due to caved in flesh
21	June 22	8	4	5	17	
22	June 23	8	4	5	17	

Pig #2 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
23	June 24	8	5	5	18	shoulders caved in and sagging; no neck left
24	June 25	8	5	5	18	very black abdomen
25	June 26	8	5	5	18	very black abdomen with slight tear
26	June 27	8	6	5	19	increase in abdominal rupture
27	June 28	8	6	5	19	significant liquification of head and shoulders
28	June 29	8	6	6	20	legs detached from shoulder; black colouration less intense
29	June 30	8	6	6	20	large insect mass
30	July 1	10	7	6	23	abdomen more flattened out; rear right leg skeletonized ;skeletonization of body beginning
31	July 2	10	7	6	23	greatest skeletonization of all 4 pigs at this point
32	July 3	10	7	6	23	increase in skeletonization
33	July 4	10	7	6	23	
34	July 5	10	7	6	23	
35	July 6	11	7	8	26	
36	July 7	11	7	8	26	skin colour changing from light grey to dark brown/black
37	July 8	11	7	8	26	increase in darkening of skin
38	July 9	11	7	8	26	skin drying out
39	July 10	11	7	8	26	increase in drying and colour
40	July 11	11	8	8	27	breadth of pig has decreased
41	July 12	11	8	8	27	white mold growth
42	July 13	11	8	8	27	
43	July 14	11	8	8	27	drying again since rain
44	July 15	11	8	8	27	leathery appearance of skin where torn
45	July 16	11	8	8	27	more obvious skeletonization at shoulder

Pig #2 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
46	July 17	11	8	8	27	increase skeletonization at shoulder
47	July 18	11	8	8	27	stretched looking holes through skin
48	July 19	11	8	8	27	increase in tissue loss
49	July 20	11	8	8	27	more ribs showing
50	July 21	11	8	8	27	more ribs showing; increased holes in skin
51	July 22	11	8	8	27	
52	July 23	11	8	8	27	almost 50% skeletonized
53	July 24	11	8	8	27	tissue drying; bones are drying; white mold growth
54	July 25	11	8	8	27	more tissue desiccation; bones grey brown in colour
55	July 26	11	8	8	27	mold growth again
56	July 27	11	8	8	27	increase in drying of exposed bones
57	July 28	11	8	9	28	overall increase in skeletonization; mold growth again
58	July 29	11	8	9	28	abdomen looks mummified again
59	July 30	11	8	9	28	increase in skeletonization but not to extent of next stage
60	July 31	12	8	9	29	white mold; liquified tissue around pig
61	August 1	12	8	9	29	
62	August 2	12	8	9	29	bleaching of exposed bones
63	August 3	12	8	9	29	increase in tissue decomp & skeletonization
64	August 4	12	9	9	30	past 50% skeletonized however not to next stage
65	August 5	12	9	9	30	
66	August 6	12	9	9	30	mummified tissue over abdomen
67	August 7	12	9	9	30	increase in drying
68	August 8	12	9	9	30	
69	August 9	12	9	9	30	increase in drying and mummification

Pig #2 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
70	August 10	12	9	9	30	
71	August 11	12	9	9	30	more liquification of tissue
72	August 12	12	9	9	30	appear slimy due to rain
73	August 13	12	9	9	30	
74	August 14	12	9	9	30	
75	August 15	12	9	9	30	white mold growth
76	August 16	12	9	9	30	
77	August 17	12	9	9	30	some white mold
78	August 18	12	9	9	30	
79	August 19	12	9	9	30	increase in drying; mold present
80	August 20	12	10	9	31	exposed bones more dried
81	August 21	12	10	9	31	slightly less tissue
82	August 22	12	10	9	31	
83	August 23	12	10	9	31	
84	August 24	12	10	9	31	
85	August 25	12	10	9	31	
86	August 26	12	10	9	31	
87	August 27	12	10	9	31	
88	August 28	12	10	9	31	
89	August 29	12	10	9	31	
90	August 30	12	10	9	31	
91	August 31	12	10	9	31	pooled water along adipocere of spinal column
92	September 1	12	10	9	31	
93	September 2	12	10	9	31	more desiccated; white mold present

Pig #2 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
94	September 3	12	10	9	31	
95	September 4	12	10	9	31	
96	September 5	12	10	9	31	
97	September 6	12	10	9	31	
98	September 7	12	10	9	31	
99	September 8	12	10	9	31	
100	September 9	12	10	9	31	
101	September 10	12	10	9	31	
102	September 11	12	10	9	31	
103	September 12	12	10	9	31	
104	September 13	12	10	9	31	
105	September 14	12	10	9	31	adipocere along spine is sloppy wet
106	September 15	12	10	9	31	
107	September 16	12	10	9	31	
108	September 17	12	10	9	31	
109	September 18	12	10	9	31	
110	September 19	12	10	9	31	
111	September 20	12	10	9	31	
112	September 21	12	10	9	31	
113	September 22	12	10	9	31	
114	September 23	12	10	9	31	
115	September 24	12	10	9	31	
116	September 25	12	10	9	31	
117	September 26	12	10	9	31	

Pig #2 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
118	September 27	12	10	9	31	
119	September 28	12	10	9	31	pigs soaking wet with pools of water around skeleton/in adipocere
120	September 29	12	10	9	31	lots of water in adipocere around hips
121	September 30	12	10	9	31	white mold present

Table B3: Raw data for pig #3.

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
1	June 2	1	1	1	3	
2	June 3	1	1	1	3	some fluid and froth coming out of nose
3	June 4	1	1	1	3	
4	June 5	3	3	1	7	green/blue discolouration around eye
5	June 6	3	3	3	9	marbling of legs
6	June 7	3	3	3	9	no discolouration around neck all on top of head and nose
7	June 8	5	3	3	11	increase in bug and fly activity
8	June 9	5	3	3	11	increase in bloating and discolouration
9	June 10	5	3	3	11	significant marbling; colouration increasing daily
10	June 11	5	3	3	11	maggot mass on head
11	June 12	6	3	3	12	
12	June 13	6	3	3	12	significant loss of tissue on head around jaw
13	June 14	6	3	3	12	lots of liquified tissue around head
14	June 15	8	3	4	15	increase in bloating & visibility of skull
15	June 16	8	3	4	15	skin of abdomen stretching/looks like close to rupture; some drying of abdominal skin; increase in insect activity of head
16	June 17	8	3	4	15	neck starting to cave in
17	June 18	8	4	4	16	increase in liquification of head
18	June 19	8	4	5	17	head & neck caved in; some beetle activity on legs
19	June 20	8	5	5	18	some release of gases/fluids
20	June 21	8	5	5	18	maggots in pockets under abdominal skin; neck completely caved in
21	June 22	8	5	5	18	
22	June 23	8	5	5	18	skin only left on head and neck
23	June 24	8	5	5	18	abdomen not ruptured deflating at shoulders

Pig #3 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
24	June 25	8	5	5	18	very black abdomen; large increase in fly/insect activity
25	June 26	8	5	5	18	still very bloated; drying of skin; lots of insects
26	June 27	8	5	5	18	very minimal rupture of abdomen (slowest progression at this stage in comparison)
27	June 28	8	5	5	18	very black abdomen
28	June 29	8	6	5	19	abdomen colouration much less intense; increase in deflation
29	June 30	8	6	6	20	rupture of abdomen near ground; front legs skeletonizing
30	July 1	8	6	6	20	abdomen completely sagged no bloating left
31	July 2	9	6	6	21	rear right leg slightly mummified; least skeletonization compared to others
32	July 3	9	6	6	21	major sagging very moist; minimal skeletonization
33	July 4	9	6	6	21	skin appears covered in slime
34	July 5	9	6	6	21	liquified gel like substance around abdomen
35	July 6	11	7	6	24	darkening of abdominal skin appearing slightly mummified
36	July 7	11	7	6	24	skin colour starting to change to dark brown/black from light grey/brown
37	July 8	11	7	6	24	rear/back starting to liquify
38	July 9	11	7	6	24	increase in decomp of back and flank; increase in drying of skin
39	July 10	11	7	6	24	skin colour darkening
40	July 11	11	8	8	27	loss in breadth
41	July 12	11	8	8	27	area of back still decomposing and oozing; white mold growth present
42	July 13	11	8	8	27	still <50% skeletonized
43	July 14	11	8	8	27	increase in liquification at flank
44	July 15	11	8	8	27	oozing at flank

Pig #3 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
45	July 16	11	8	8	27	noticeable increase in skeletonization; pools of greasy looking water on body
46	July 17	11	8	8	27	skin less leathery; flank more decomposed
47	July 18	11	8	8	27	
48	July 19	11	8	8	27	maggots by shoulder
49	July 20	11	8	8	27	2 maggot masses
50	July 21	11	8	8	27	increase in size of maggot mass; look more mummified
51	July 22	11	8	8	27	noticeable increase in skeletonization and maggots
52	July 23	11	8	8	27	starting to reach skeletonization amount of other pigs
53	July 24	11	8	8	27	still lots of maggot activity; lots of liquified tissue; drying of exposed bones
54	July 25	11	8	8	27	ribs and hips now visible
55	July 26	11	8	8	27	increase in skeletonization; liquified tissue green in colour
56	July 27	11	8	8	27	maggot mass smaller but still present; more drying
57	July 28	11	8	8	27	white mold growth
58	July 29	11	8	8	27	liquified tissue all around; >50% skeletonization but not to next stage yet
59	July 30	11	8	8	27	
60	July 31	12	8	8	28	white mold present; some liquified tissue around body
61	August 1	12	8	8	28	
62	August 2	12	8	8	28	
63	August 3	12	8	8	28	oozing tissue and less tissue present
64	August 4	12	9	9	30	
65	August 5	12	9	9	30	white mold
66	August 6	12	9	9	30	still wet and more greasy than others

Pig #3 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
67	August 7	12	9	9	30	increase in tissue liquification
68	August 8	12	9	9	30	slightly more dry
69	August 9	12	9	9	30	increase in mummification
70	August 10	12	9	9	30	
71	August 11	12	9	9	30	increase in tissue wetness and liquification
72	August 12	12	9	9	30	
73	August 13	12	9	9	30	
74	August 14	12	9	9	30	
75	August 15	12	9	9	30	
76	August 16	12	9	9	30	
77	August 17	12	9	9	30	some white mold
78	August 18	12	9	9	30	lots of white mold growth
79	August 19	12	9	9	30	increase in drying of tissue; white mold present
80	August 20	12	10	9	31	exposed bones bleaching and drying
81	August 21	12	10	9	31	shoulder girdle looks disturbed; increase in tissue desiccation
82	August 22	12	10	9	31	
83	August 23	12	10	9	31	
84	August 24	12	10	9	31	
85	August 25	12	10	9	31	
86	August 26	12	10	9	31	
87	August 27	12	10	9	31	
88	August 28	12	10	9	31	
89	August 29	12	10	9	31	
90	August 30	12	10	9	31	

Pig #3 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
91	August 31	12	10	9	31	
92	September 1	12	10	9	31	
93	September 2	12	10	9	31	
94	September 3	12	10	9	31	
95	September 4	12	10	9	31	
96	September 5	12	10	9	31	
97	September 6	12	10	9	31	
98	September 7	12	10	9	31	
99	September 8	12	10	9	31	
100	September 9	12	10	9	31	increase in desiccation of abdominal tissue and adipocere
101	September 10	12	10	9	31	
102	September 11	12	10	9	31	
103	September 12	12	10	9	31	
104	September 13	12	10	9	31	
105	September 14	12	10	9	31	
106	September 15	12	10	9	31	
107	September 16	12	10	9	31	
108	September 17	12	10	9	31	
109	September 18	12	10	9	31	
110	September 19	12	10	9	31	
111	September 20	12	10	9	31	
112	September 21	12	10	9	31	
113	September 22	12	10	9	31	
114	September 23	12	10	9	31	

Pig #3 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
115	September 24	12	10	9	31	
116	September 25	12	10	9	31	
117	September 26	12	10	9	31	
118	September 27	12	10	9	31	
119	September 28	12	10	9	31	wet will pools of water around body
120	September 29	12	10	9	31	
121	September 30	12	10	9	31	

Table B4: Raw data for pig #4.

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
1	June 2	1	1	1	3	fresh
2	June 3	1	1	1	3	
3	June 4	1	1	1	3	
4	June 5	3	3	1	7	
5	June 6	3	3	3	9	marbling of front legs
6	June 7	3	3	3	9	
7	June 8	5	3	3	11	increase in bug/fly activity
8	June 9	5	3	3	11	Increase in decomp however not to next stage
9	June 10	5	3	3	11	increase in colour on abdomen
10	June 11	5	3	3	11	increase in marbling and bloating
11	June 12	6	3	3	12	skin slippage on head (1st note of skin slippage)
12	June 13	6	3	3	12	significant increase in bloating
13	June 14	6	3	3	12	progression towards black discolouration from green & increase in skin slippage
14	June 15	8	3	4	15	bloating increased; flesh loss on heads, slight bone visibility
15	June 16	8	3	4	15	skin looks like it stretching on abdomen and approaching rupture
16	June 17	8	3	4	15	increase in bloating & skeletonization of head
17	June 18	8	4	4	16	very black abdomen; increase in skin slippage
18	June 19	8	4	5	17	abdominal skin slipping; head & neck caved in
19	June 20	8	4	5	17	neck is more caved in
20	June 21	8	4	5	17	body very grey in colour; head appears detached from body due to caved in flesh
21	June 22	8	4	5	17	
22	June 23	8	4	5	17	

Pig #4 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
23	June 24	8	5	5	18	shoulders caved in and sagging; no neck left
24	June 25	8	5	5	18	very black abdomen
25	June 26	8	5	5	18	very black abdomen with slight tear
26	June 27	8	6	5	19	increase in abdominal rupture
27	June 28	8	6	5	19	significant liquification of head and shoulders
28	June 29	8	6	6	20	legs detached from shoulder; black colouration less intense
29	June 30	8	6	6	20	large insect mass
30	July 1	10	7	6	23	abdomen more flattened out; rear right leg skeletonized ;skeletonization of body beginning
31	July 2	10	7	6	23	greatest skeletonization of all 4 pigs at this point
32	July 3	10	7	6	23	increase in skeletonization
33	July 4	10	7	6	23	
34	July 5	10	7	6	23	
35	July 6	11	7	8	26	
36	July 7	11	7	8	26	skin colour changing from light grey to dark brown/black
37	July 8	11	7	8	26	increase in darkening of skin
38	July 9	11	7	8	26	skin drying out
39	July 10	11	7	8	26	increase in drying and colour
40	July 11	11	8	8	27	breadth of pig has decreased
41	July 12	11	8	8	27	white mold growth
42	July 13	11	8	8	27	
43	July 14	11	8	8	27	drying again since rain
44	July 15	11	8	8	27	leathery appearance of skin where torn
45	July 16	11	8	8	27	more obvious skeletonization at shoulder

Pig #4 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
46	July 17	11	8	8	27	increase skeletonization at shoulder
47	July 18	11	8	8	27	stretched looking holes through skin
48	July 19	11	8	8	27	increase in tissue loss
49	July 20	11	8	8	27	more ribs showing
50	July 21	11	8	8	27	more ribs showing; increased holes in skin
51	July 22	11	8	8	27	
52	July 23	11	8	8	27	almost 50% skeletonized
53	July 24	11	8	8	27	tissue drying; bones are drying; white mold growth
54	July 25	11	8	8	27	more tissue desiccation; bones grey brown in colour
55	July 26	11	8	8	27	mold growth again
56	July 27	11	8	8	27	increase in drying of exposed bones
57	July 28	11	8	9	28	overall increase in skeletonization; mold growth again
58	July 29	11	8	9	28	abdomen looks mummified again
59	July 30	11	8	9	28	increase in skeletonization but not to extent of next stage
60	July 31	12	8	9	29	white mold; liquified tissue around pig
61	August 1	12	8	9	29	
62	August 2	12	8	9	29	bleaching of exposed bones
63	August 3	12	8	9	29	increase in tissue decomp & skeletonization
64	August 4	12	9	9	30	past 50% skeletonized however not to next stage
65	August 5	12	9	9	30	
66	August 6	12	9	9	30	mummified tissue over abdomen
67	August 7	12	9	9	30	increase in drying
68	August 8	12	9	9	30	
69	August 9	12	9	9	30	increase in drying and mummification

Pig #4 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
70	August 10	12	9	9	30	
71	August 11	12	9	9	30	more liquification of tissue
72	August 12	12	9	9	30	appear slimy due to rain
73	August 13	12	9	9	30	
74	August 14	12	9	9	30	
75	August 15	12	9	9	30	white mold growth
76	August 16	12	9	9	30	
77	August 17	12	9	9	30	some white mold
78	August 18	12	9	9	30	
79	August 19	12	9	9	30	increase in drying; mold present
80	August 20	12	10	9	31	exposed bones more dried
81	August 21	12	10	9	31	slightly less tissue
82	August 22	12	10	9	31	
83	August 23	12	10	9	31	
84	August 24	12	10	9	31	
85	August 25	12	10	9	31	
86	August 26	12	10	9	31	
87	August 27	12	10	9	31	
88	August 28	12	10	9	31	
89	August 29	12	10	9	31	
90	August 30	12	10	9	31	
91	August 31	12	10	9	31	pooled water along adipocere of spinal column
92	September 1	12	10	9	31	
93	September 2	12	10	9	31	more desiccated; white mold present

Pig #4 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
94	September 3	12	10	9	31	
95	September 4	12	10	9	31	
96	September 5	12	10	9	31	
97	September 6	12	10	9	31	
98	September 7	12	10	9	31	
99	September 8	12	10	9	31	
100	September 9	12	10	9	31	
101	September 10	12	10	9	31	
102	September 11	12	10	9	31	
103	September 12	12	10	9	31	
104	September 13	12	10	9	31	
105	September 14	12	10	9	31	adipocere along spine is sloppy wet
106	September 15	12	10	9	31	
107	September 16	12	10	9	31	
108	September 17	12	10	9	31	
109	September 18	12	10	9	31	
110	September 19	12	10	9	31	
111	September 20	12	10	9	31	
112	September 21	12	10	9	31	
113	September 22	12	10	9	31	
114	September 23	12	10	9	31	
115	September 24	12	10	9	31	
116	September 25	12	10	9	31	
117	September 26	12	10	9	31	

Pig #4 Continued

Day	Calendar day	Head score	Trunk score	Limb score	Total Body score	Comments
118	September 27	12	10	9	31	
119	September 28	12	10	9	31	pigs soaking wet with pools of water around skeleton/in adipocere
120	September 29	12	10	9	31	lots of water in adipocere around hips
121	September 30	12	10	9	31	white mold present

Weather Data

Table B5: Weather data.

Day	Calendar day	Precipitation (mm)	Ave Temp (°C)	Min Temp (°C)	Max Temp (°C)
1	June 2	0.0	13.3	8.5	18.1
2	June 3	0.0	14.9	8.9	20.9
3	June 4	0.0	14.9	8.5	21.3
4	June 5	0.0	13.0	9.6	16.3
5	June 6	5.2	12.6	10.1	15.1
6	June 7	0.2	15.6	10.2	21.0
7	June 8	0.0	14.6	8.8	20.4
8	June 9	0.0	12.6	7.2	18.0
9	June 10	0.0	9.7	8.1	11.3
10	June 11	17.6	11.4	9.5	13.2
11	June 12	12.2	14.0	12.0	15.9
12	June 13	0.0	14.6	9.9	19.3
13	June 14	0.0	13.2	8.8	17.5
14	June 15	0.2	11.7	7.9	15.4
15	June 16	0.0	11.3	6.6	15.9
16	June 17	0.0	10.9	5.8	15.9
17	June 18	0.0	16.7	9.0	24.3
18	June 19	0.0	15.0	11.7	18.3
19	June 20	15.8	16.3	14.0	18.6
20	June 21	7.6	15.0	14.1	15.8
21	June 22	13.8	15.8	14.0	17.6
22	June 23	6.4	16.5	14.8	18.2
23	June 24	1.0	16.8	14.4	19.1
24	June 25	0.2	17.9	14.1	21.6
25	June 26	0.0	16.6	13.5	19.7
26	June 27	0.2	16.3	13.7	18.8
27	June 28	5.4	16.5	14.8	18.1
28	June 29	14.2	16.5	15.1	17.8
29	June 30	0.4	17.3	14.0	20.5
30	July 1	0.6	16.4	14.1	18.7
31	July 2	0.6	15.0	13.5	16.4
32	July 3	0.6	15.6	14.0	18.2
33	July 4	8.2	16.1	13.8	18.3
34	July 5	0.8	16.8	13.8	19.7
35	July 6	0.0	14.6	9.7	19.4
36	July 7	0.0	13.1	9.7	16.5
37	July 8	0.0	12.9	10.3	15.4

Weather Data Continued					
Day	**Calendar day**	**Precipitation (mm)**	**Ave Temp °C**	**Min Temp °C**	**Max Temp °C**
38	July 9	0.0	14.0	9.3	18.7
39	July 10	0.0	14.7	8.4	20.9
40	July 11	0.0	16.5	10.9	22.0
41	July 12	0.0	17.5	14.4	20.5
42	July 13	3.8	18.1	13.8	22.3
43	July 14	0.0	17.9	12.4	23.4
44	July 15	3.2	16.2	9.9	22.5
45	July 16	0.0	17.0	13.4	20.6
46	July 17	2.2	17.9	15.9	19.9
47	July 18	6.8	17.9	16.9	18.8
48	July 19	0.2	21.0	16.3	25.6
49	July 20	0.0	20.7	14.6	26.8
50	July 21	0.0	18.8	16.4	21.2
51	July 22	27.0	19.3	16.7	21.9
52	July 23	0.4	18.1	14.8	21.3
53	July 24	0.0	16.6	14.8	18.3
54	July 25	0.0	17.3	14.5	20.0
55	July 26	0.0	19.2	17.3	23.1
56	July 27	0.2	20.1	15.2	22.9
57	July 28	0.0	21.1	16.9	25.2
58	July 29	0.0	21.8	17.4	26.1
59	July 30	4.0	19.6	17.5	21.6
60	July 31	1.2	20.7	16.8	24.6
61	August 1	0.2	22.0	17.2	26.7
62	August 2	0.2	20.4	15.6	25.2
63	August 3	28.8	19.3	16.0	22.5
64	August 4	0.0	19.0	15.2	22.7
65	August 5	0.0	18.8	15.8	21.8
66	August 6	1.0	20.1	16.1	24.0
67	August 7	2.2	19.9	14.7	25.0
68	August 8	0.0	18.2	13.9	22.4
69	August 9	0.0	19.0	13.1	24.8
70	August 10	6.4	16.1	13.3	18.8
71	August 11	0.6	18.2	15.7	20.6
72	August 12	0.2	17.9	13.7	22.1
73	August 13	0.0	17.1	12.9	21.3
74	August 14	0.0	21.2	15.5	26.9
75	August 15	0.0	23.6	15.5	31.7
76	August 16	0.0	25.5	19.7	31.2
77	August 17	0.0	23.5	18.2	28.8

Weather data Continued					
Day	**Calendar day**	**Precipitation (mm)**	**Ave Temp °C**	**Min Temp °C**	**Max Temp °C**
78	August 18	0.0	22.4	17.5	27.3
79	August 19	0.0	20.7	16.3	25.1
80	August 20	0.0	22.6	15.7	29.4
81	August 21	0.0	19.3	15.3	23.3
82	August 22	0.0	22.7	18.3	27.1
83	August 23	51.6	20.5	16.8	24.1
84	August 24	2.4	17.0	15.2	18.7
85	August 25	0.2	17.8	13.5	22.1
86	August 26	0.0	15.9	13.5	18.3
87	August 27	0.0	15.8	10.6	20.9
88	August 28	0.0	14.3	8.5	20.1
89	August 29	57.8	13.9	8.9	18.8
90	August 30	10.6	19.4	14.8	24.0
91	August 31	1.2	17.6	12.0	23.1
92	September 1	0.0	15.5	9.6	21.3
93	September 2	0.0	15.5	8.7	22.3
94	September 3	0.0	16.6	10.5	22.6
95	September 4	0.0	18.2	12.2	24.1
96	September 5	0.0	18.7	13.2	24.2
97	September 6	0.0	14.3	8.0	20.5
98	September 7	0.0	13.4	7.0	19.7
99	September 8	0.0	16.3	8.6	23.9
100	September 9	0.0	14.0	8.2	19.8
101	September 10	0.0	11.5	5.4	17.6
102	September 11	0.0	12.9	7.4	18.4
103	September 12	0.0	16.6	9.6	23.6
104	September 13	6.2	17.7	15.3	20.1
105	September 14	0.2	15.5	11.7	19.3
106	September 15	15.8	12.4	8.5	16.3
107	September 16	0.2	11.8	8.0	15.5
108	September 17	0.0	10.4	5.8	15.0
109	September 18	0.0	13.8	7.6	20.0
110	September 19	0.0	11.3	7.8	14.7
111	September 20	0.0	12.3	6.9	17.7
112	September 21	0.0	14.7	8.6	20.8
113	September 22	0.0	14.8	10.0	19.6
114	September 23	0.0	18.2	14.4	21.9
115	September 24	0.6	15.9	12.7	19.1
116	September 25	1.6	10.6	7.3	13.9
117	September 26	0.2	10.6	6.1	15.0

Weather data Continued					
Day	**Calendar day**	**Precipitation (mm)**	**Ave Temp °C**	**Min Temp °C**	**Max Temp °C**
118	September 27	2.0	10.9	6.1	15.6
119	September 28	18.2	15.8	13.1	18.5
120	September 29	0.0	15.3	12.1	18.4
121	September 30	2.5	15.5	20.1	10.9