Boned up: differential decomposition of child-sized swine remains to model a forensic context

by

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A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

Major: Anthropology

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Iowa State University

Ames, Iowa

2009

DEDICATION

I am immensely indebted to my husband Eric White,
for being my gentle, supportive and reassuring partner
through all my academic endeavors and much of my research project,
without whom life would be scarcely tolerable.
To our daughters, Audrey, Kassidy and Abigail,
for their never-ending ability to see the brighter side of life.

A heartfelt thanks to Jackie Davenport
for lifting my spirits during our graduate adventures
and for her continued reassurances in my abilities.
May the unicorns always gather for you and the cambears live on in a magical place.

With special dedication to my beloved sister, Heather White.

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ACKNOWLEDGEMENTS

Special thanks given to my thesis committee:

Dr. Jill D. E. Pruetz, Anthropology (ISU)
Dr. Nancy R. Coinman, Anthropology (ISU)
Dr. Kenneth H. Holscher, Entomology (ISU)
Dr. Tyler O'Brien, Anthropology (UNI)

Particularly, I would like to thank my major advisor Dr. Jill Pruetz, for her invaluable support and guidance throughout the years, and Dr. Nancy Coinman for her continued encouragement and confidence in me. Much appreciation is owed to the Anthropology Department at Iowa State University for their continued support and patience. Also, special recognition to Al Christian of the ISU Swine Teaching Farm, and to the Chemistry Department at ISU for receipt of the Calvin Rayburn Forensic Research Award both of which helped make this research possible.

ABSTRACT

Forensic anthropology is often connected with the identification of human skeletal remains using various skeletal analyses. However in a medico-legal context, forensic anthropologists aid investigators by collecting information on the condition of skeletal remains. Little research has been conducted on the differences in decomposition rate between subjects in outdoor and insect restricted environments in central Iowa. Limited accessibility to appropriate facilities in the Midwest for a comparison between indoor and outdoor decomposition rates has prevented comprehensive research with human or swine remains from being conducted. A study on the impact insect restriction has on the decomposition process and how subject condition interacts with other variables is needed to determine the degree of differential decomposition.

The research described in this thesis models a forensic context and serves as an introductory study of decomposition and skeletonization of insect restricted remains. The study was conducted in a rural field in central Iowa between July and October 2008. The primary variables examined for the study were insect restriction, duration of containment and temperature differences between conditions. Documented through daily notes and photographs, five male juvenile swine were placed in predetermined conditions, one as a control outside while the remaining four were sealed in plastic totes to be opened on set days until study conclusion after 100 days.

During daily observations or at container opening, each subject was given a predetermined numeric score based on the degree of decomposition exhibited. These scores served as dependent variables during analyses, with independent variables being time since

death, temperature, relative humidity, accumulated degree-days and insect restriction. Temperature and humidity levels at the site were recorded using HOBO data loggers.

Comparisons between subjects allow for statements to be made concerning insect restriction. Results show between conditions that containment in plastic totes significantly slows the rate of decomposition of remains. The greater difference in decomposition is observed between the control subject 5 and subjects 2 and 1, opened at day 40 and 80 respectively. Also notable is that the containment of subject 4 produced only a slightly slower rate of decay than the control, whereas the sealed subjects decay rates were significantly affected. It appears that the sealed containment conditions produced an increase in temperature and relative humidity as well as restricted insect access to the remains, therefore slowing the decomposition process. Further research is necessary to determine the precise sources of the differential decomposition rates.

CHAPTER 1

INTRODUCTION

> "Physical anthropology, with its rich tradition of productive research in human growth and development, physiological adaptation, genetics, anthropometry, and biomechanics, is certainly no less a science of the living than of the dead." (Snow 1982: 128)

This statement by Clyde Snow is an accurate description of the complexity and depth of physical anthropology. Although early studies by physical anthropologists were strongly focused on osteology, with human skeletal identification the principal area of investigation, in time the focus of physical anthropology changed (Stewart, 1979). The study of skeletonized human remains was revealed in the early twentieth century as a new branch of physical anthropology, now referred to as forensic anthropology (Mann et al., 1990). The ability to obtain a biological profile from the analyses of human remains has played an important role in the advancement of forensic anthropology and its use in medico-legal investigations (Komar and Buikstra, 2008).

Over the years, forensic anthropology has broadened its scope beyond the examination of human bones to include studies on decomposition, trauma analysis, and entomology, among other topics (Gruner, 2004; Vass, 1991; Walker, 2000). To carry out decomposition studies, the use of various remains, including swine and humans, is necessary. Studies of the decomposition processes have been carried out through observation of natural

sequences or experimental observations (Mann et al., 1990; Payne and King, 1965; Rodriguez and Bass, 1983;; Voss, 2008). Because pigs are similar to humans in some physical respects and the use of human remains for decomposition research is difficult both ethically and logistically, the use of swine or animals for decay research is suitable. The decomposition processes in central Iowa using pig carrion as a model for humans is the focus of this study.

1.1 Review of Literature: Forensic Anthropology

Since the inception of forensic anthropology, techniques related to analyses used in skeletal biology and taphonomy have been applied to identify human remains and obtain necessary information on sex, age, stature, ancestry, trauma, and pathologies (Bass, 2006; Haglund and Sorg, 1997a). The first biological anthropologists working on forensic cases asked questions about whether remains were human or non-human, determined minimum number of individuals (MNI), and provided estimations on identification (Stewart, 1979). Because of the knowledge of human osteology, taphonomic changes and archaeological techniques gained via research through the years, forensic anthropologists have been able to focus further attention on positive identification, interpretation of trauma, search and recovery of remains, and time since death (Ubelaker, 2009).

Historically, forensic anthropologists have analyzed human remains in a laboratory setting but because they are becoming increasingly involved in the recovery of remains, they see more cases of early to advanced decomposition prior to processing remains. Studies in forensic anthropology allows researchers to discover which specifics to consider surrounding the circumstances of death and alterations to body after death, including observations on soft

tissue changes, insect and animal alterations, trauma and modifications to bone (Dirkmaat et al., 2008).

What must be kept in mind is that no matter how much information is known of the decomposition process, not one model will be sufficient due to the complexity of nature. The accuracy and predictive power of a decomposition model will depend on the processes under investigation; therefore, the more information that is known about stages of decomposition and accumulated degree-days (ADD), the better the model will be that is produced (Madrigal, 1998). Assessing decay rates of child-sized remains in an insect restricted environment in the Midwestern United States, in combination with ADD, will help set a baseline for future researchers and investigators to follow. Research to gain information on decomposition stages for child-sized swine remains will ultimately provide helpful measures for interpreting time since death with human remains in medico-legal death investigations.

The abundance of research using swine as a model for humans in forensic situations has led to a better understanding of the postmortem interval, forensic anthropology, and arthropod succession on carrion (Dix, 2000; Gill, 2005; Komar and Buikstra, 2008). With this, in addition to decomposition, it can be of importance for the anthropologist to look to the environment for indications of time since death or deposition with climatological, entomological or botanical data (Cattaneo, 2007). Postmortem interval has been employed to determine time since death under various circumstances and frequently, a multidisciplinary approach applying anthropological and entomological expertise is used to solve forensically related cases (Walker, 2000). By connecting entomological methods to forensic anthropology, evidence collected can be effectively used in the determination of time since death. As more is learned from anthropological research, models may be created that could

provide future investigators an opportunity to study more specific processes or even further specify time since death.

The decision to study the impacts closed containers have on the decomposition rate was due to an awareness of homicide cases involving the bodies of small children, which have been concealed in containers. According to the April 2008 National Vital Statistics Report (NVSR) put out by the Center for Disease Control (CDC), during the year 2005, children between one and four years of age had a higher homicide rate than children less than one year and over five years (Kung et al., 2008). Although a variety of factors are examined during the estimation of time since death, precisely determining this can be difficult (DiMaio and DiMaio, 1993).

This study is an attempt to quantify the degree to which the rate of decomposition is affected by an enclosed environment. Other studies have suggested that control and limitation of variables such as insect access, humidity and temperature will have a significant effect on the rate of human decomposition (Galloway et al., 1989; Mann et al., 1990; Rodriguez and Bass, 1983). The small amount of research that has been conducted on child-sized swine remains has studied the effects of temperature and rainfall on decomposition (Archer, 2004), as well as arthropod succession (Payne, 1965). Determining the significance that placement of a closed container has on remains in the Midwest may produce results that differ from studies performed in other regions. Understanding how containers affect the rate of decomposition in central Iowa can aid in the advancement of research or future investigations.

1.2 Background: Studies of Forensic Decomposition

A considerable amount of research has been conducted at the Anthropological Research Facility (ARF) in Knoxville, Tennessee to examine human and swine remains under specific circumstances (Mann et al., 1990; Payne and King, 1968; Rodriguez and Bass, 1985). Dr. William Bass from the University of Tennessee was among the first to investigate above ground human decomposition rates (Rodriguez and Bass, 1983). Since the establishment of the ARF, studies have been carried out with bodies placed in numerous situations, including water, indoor and outdoor environments (O'Brien and Kuehner, 2007; Ritchie, 2005; Srnka, 2003), providing insight into how the determinations of decay rates can help identify victims and rule out suspects. Other major studies have been performed further north in Canada to elucidate the relationship between decomposition and arthropod succession (Gill, 2005).

A review of the available literature reveals that environmental temperatures play a vital role in the decomposition of human cadavers (Micozzi, 1991). Because various climatological conditions affect the postmortem interval of remains differently, there is a need for studies on decomposition in various regions across the globe. Unfortunately, very little research has been performed in the Midwestern United States to identify how local temperatures, humidity, scavengers or soil composition affect soft tissue decay and the postmortem period.

Table 1: Studies of decomposition using human and swine corpses according to location and context.

Location	Decay only	Insect Restriction	Insect Activity
Iowa	Decomposition of swine remains placed outside inflicted with trauma (Walker, 2000).	Present study: Differential decomposition of child-sized swine cadavers.	Arthropod succession associated with swine decomposition (Walker, 2000).
Tennessee	Studies of decomposition rates of human corpses placed in water, indoors, and outside (Bass, 1997; Rodriguez and Bass, 1983; O'Brien and Kuehner, 2007; Ritchie, 2005; Srnka, 2003).	Decay rates of human corpses buried underground (Rodriguez and Bass, 1985). Human corpses submerged in water (Rodriguez, 1997).	Examination of differential decomposition between seasons and insect succession on human remains (Mann et al, 1990).
Canada	Decomposition rates of pig remains in underwater and outdoor environments (Anderson and Hobischak, 2004).		Arthropod succession associated with swine placed outside above ground, clothed and stabbed (Gill, 2005).
American Southwest	Examination of decomposition rates using case studies of human corpses (Galloway, 1997).	Differential decomposition rates of small swine placed outdoors in closed containers (Hyder, 2007).	
Other	Deceased mammals placed outside for study of decomposition rates (Micozzi, 1997).	South Carolina: Pig remains placed inside insect restricted containers to examine decay rates (Payne 1965).	

Aside from the need for identification of unknown human remains and cause of death, another vital piece of information investigators are concerned with at a potential crime scene is the time since death (Steadman, 2003). Time since death and postmortem interval refer to the period following when the death occurs and when the body is found. A multi-disciplinary approach incorporating forensic anthropology with entomology has been used to collect information for determining postmortem interval (Platt, 2003). While body temperature and an understanding of postmortem processes is most useful to estimate time since death during the initial days postmortem, determining insect life stages and knowledge of which arthropods are feeding on a corpse can allow for the postmortem interval to be calculated up to several weeks after death (Amendt et al., 2004). Therefore, information gained from additional studies on the decomposition process under a variety of conditions can help improve our understanding of postmortem processes and enhance medico-legal investigations of death.

1.3 Taphonomy

The study of phenomena that affects remains at the time of and after death, or perimortem and postmortem processes, was initially applicable to the areas of paleontology, bioarchaeology and paleoanthropology (Nawrocki, 2009). However, as taphonomy involves the formation of major aspects of the archaeological record and provides insight to behaviors, studies of preservation processes and how they affect information contained in the archaeological record are necessary. Because the fossil record is a result of taphonomic processes, researchers are able to explain the effects of taphonomic processes on remains

(Lyman, 1994), and research in this area helps clarify possible causes of preservation or alteration to remains.

Although rooted in archaeological tradition and originally stemming from a need to understand the processes that affect fossil remains, the same concepts used for taphonomic analyses can be applied to historic and forensic situations (Haglund and Sorg, 1997b). One historic situation at African Plio-Pleistocene hominid sites focused on biasing factors and paleoecological data that could be derived from taphonomic analysis (Behrensmeyer, 1978). Extracting dynamics of human behavior from the archaeological record has led to the discovery recovered data is not a perfect reflection of human behavior (Lyman, 1994).

Due to its broad scope, more recently taphonomy has been utilized in forensic anthropology, as well as the emerging fields of forensic taphonomy and forensic archaeology (Haglund and Sorg, 1997a). Ultimately, providing insight into the forces that alter remains from the living condition can lead experts to a more accurate interpretation of the resulting changes. Aside from environmental, individual and behavioral factors, dozens of other variables also need to be taken into consideration when analyzing remains to understand circumstances surrounding a death (Nawrocki, 2009). The original goal of data collection and analysis in taphonomy has resulted in the application of taphonomic techniques to forensic scene processing (Haglund and Sorg, 1997b).

Research areas within taphonomy that have particular relevance to forensic anthropology include reconstructing the scene, studies of transport and dispersal, and diagenesis. Information gained in forensic anthropology studies, such as soft tissue and flesh or bone modifications, can be applied to taphonomy (Haglund and Sorg, 1997a). Relevant information collected aid in reconstructing events that occurred at or around the time of

death, disposal of remains, and their placement at a scene (Bass, 2006). Research conducted to further understand taphonomic processes would facilitate the interpretation of data collected, past and present. However, it has been noted that current cultural treatments of human death commonly inhibits the use of modern human cadavers for research due to religious, ethical, and emotional reasons (Smith, 1986), therefore creating an obstacle in taphonomy related research.

1.4 Child Homicide

Most cases of child murders on record have been committed by a parent on a male child and are considered filicide (DiMaio and DiMaio, 1993). However in 2001, an increase in child homicide was noted in the United States, involving approximately equal numbers of boys and girls (Finkelhor and Ormrod, 2001). The most common motivators for killing offspring in the cases perpetrated by parents were retaliation of parental duties, an unplanned pregnancy, discipline, acts of secondary altruism where one parent suffers from acute depression, psychotic illness, or jealousy of the child favoring the other parent (Wilczynski, 1995). A recent case of infanticide occurred during October of 2007 in Galveston, Texas where a plastic container was used to conceal the remains of a female child (Williams, 2007).

Throughout the years cases similar to this have taken place across the United States. Sadly, searches of the news for children who have been murdered and concealed produce many upsetting results (Kridel and Demirjian, 2008; Associated Press, 2007). Because of these cases, observations of the decomposition process using child-sized pig remains should be investigated to a greater extent. Determining the significance that placement of a closed container has on remains in the Midwest may produce results that differ from studies

performed in other regions. Understanding how containers affect the rate of decomposition in central Iowa may aid in the advancement of research or future criminal investigations.

1.5 Study Design: Swine as a Model for Humans

Understanding similarities, differences, and common health problems and diseases between humans and pigs has been important in recognizing the significance of using pigs, *Sus scrofa* Linnaeus, as models for humans in biological research. Essentially it has been found that the heart, kidney, liver, pancreas, skin, digestive system and other organs function similarly in both humans and swine, which has led to utilizing swine organs for medical procedures on humans (McGlone and Pond, 2003). In addition, the ratio of skin surface area to body weight in swine is comparable to humans (Pond and Mersmann, 2001).

Because data obtained from animal research is largely anecdotal, the use of humans in forensic research is ideal but difficult logistically. Pigs, however, have played a critical role as models in the study of taphonomic processes because of their morphological similarities to humans' skin and organ placement (Pond and Houpt, 1978). Past anthropological research projects have utilized pig carrion to identify stages of decomposition (Payne, 1965), while more recent research conducted placed pig carrion inside vehicles to determine decomposition rates and arthropod succession (Voss et al., 2008). Few facilities worldwide are able to utilize human remains to simulate a forensic context due to ethical reasons; therefore swine are regularly used as substitutes in related research.

The University of Tennessee's Anthropological Research Facility (ARF) regularly has both human and swine bodies decomposing on their two-acre property for research and skeletal processing (Adams, 2007). However, many researchers around the globe have found

pig carrion to be valuable in this area of study. For instance, at Iowa State University in 2000 a graduate student in Anthropology used swine to examine corpse decay and determine postmortem intervals as part of master's thesis research (Walker, 2000). More recently, a study that took place at Texas State University studied carrion decomposition rates in closed containers (Hyder, 2007). Across the northern border of the United States, the decomposition of pig carcasses in a marine environment around British Columbia, Canada has been examined (Anderson and Hobischak, 2004). Even further away in the Buenos Aires Province of Argentina, pig carrion were used to examine seasonal patterns in arthropod succession (Centeno et al., 2002). Experiments on decomposition and taphonomic processes have been found useful and the research process beneficial to investigators because decomposition is not altered during collection of samples from remains (Adlam and Simmons, 2007).

1.6 Goals and Objectives

The goal of this study is to investigate the impact an insect restricted environment, which models a forensic context of child homicide, has on the decomposition rate of child-sized swine remains in the Midwestern United States. A sample of swine remains averaging 45 pounds are studied regarding outdoor decomposition under varying conditions, such as within and outside of containers, in full, direct, summer sunlight. The information gathered can help determine whether accumulated degree-days (ADD) and decomposition scoring is useful in establishing time since death in central Iowa for remains found in similar situations.

To determine the standard decomposition rate for child-sized swine remains in a rural outdoor central Iowa environment, one control was used in addition to the four experimental

conditions. Four plastic Sterilite® totes were used to simulate a forensic context of child-sized corpses sealed inside an insect restricted environment. Two of four HOBO® temperature loggers were installed to record temperature and humidity fluctuations inside two of the sealed containers. In addition to the temperature loggers enclosed inside the totes, two were placed outside, one in association with the control subject. Each of the five subjects were also placed inside a cage for protection from scavengers. The purpose of the study was to determine if the decomposition rate of child-sized swine remains placed in direct sunlight would have a faster decomposition rate than the remains enclosed in containers.

Data gathered were examined to accept or reject the following hypotheses. Null hypothesis one (H_0: 1) states that subjects in the sealed containers decompose at the same rate as the control, an underlying assumption being that insect restriction has no affect on the condition. Null hypothesis two (H_0: 2) states that the duration of containment does not produce a significant difference in the rate of decomposition. Null hypothesis three (H_0: 3) states the difference in condition temperatures does not produce significant differences in decay rates. Null hypothesis four (H_0: 4) states that the interaction of the factors of time, temperature, and insect restriction does not significantly affect the rate of decay.

CHAPTER 2

METHODS

2.1 Significance for Anthropology

> "For future development of the field, forensic anthropology must follow the lead of paleoanthropology in more ways than just the incorporation of taphonomy. Given the complexity of outdoor scenes and the variety of factors that can impinge upon, and modify remains, a concerted multidisciplinary effort is required." (Dirkmaat et al., 2008: 48)

The specialized sub-discipline forensic anthropology uses methods developed in biological anthropology during investigations of medico-legal significance to identify individuals and establish cause and manner of death (Roberts, 1996). Thus, the anthropological four-field approach generates a holistic understanding which allows a forensic anthropologist to ascertain the details surrounding unidentified human remains, using medical science to provide insight on legal matters (Steadman, 2003).

Forensic anthropologists use the same methods in medico-legal investigations as biological anthropologists during an analysis of human remains from archaeological sites, methods which have proven valuable for identification of skeletonized human remains and understanding the manner surrounding their death (Roberts, 1996). Some of the similarities between medico-legal investigation and archaeology include constructing a hypothesis from

partial evidence, placing events on time lines and a basic understanding of principles of evidential identification, deterioration and change (Cheetham and Hanson, 2009). Because of the multi-disciplinary nature of the field, forensic anthropologists are also involved in work with unidentified remains from victims of war and ethnic cleansing, in addition to medico-legal investigations (Simmons and Haglund, 2005).

In the United States a forensic anthropologist draws upon the holistic perspective to provide information about human remains under examination, which can aid in identification or provide details on the manner or time since death (Steadman, 2003). However, the extensive amount of information potentially retrievable from human remains is heavily dependent on the condition of the body, deposition, burial, excavation, and processing techniques. Examination of human remains within the environment of deposition is essential to the interpretation of the site (Roberts, 1996). Regardless of the undertaking, all work requires an ethical responsibility for those involved. Due to the multiple agencies, a forensic anthropologist has many responsibilities that include maintaining scientific integrity, conforming to legal conventions of the investigation, and fulfilling a responsibility to the affected community (Simmons and Haglund, 2005). In all cases, the anthropologist is part of a multi-disciplinary investigatory team that views cases holistically.

2.2 Location

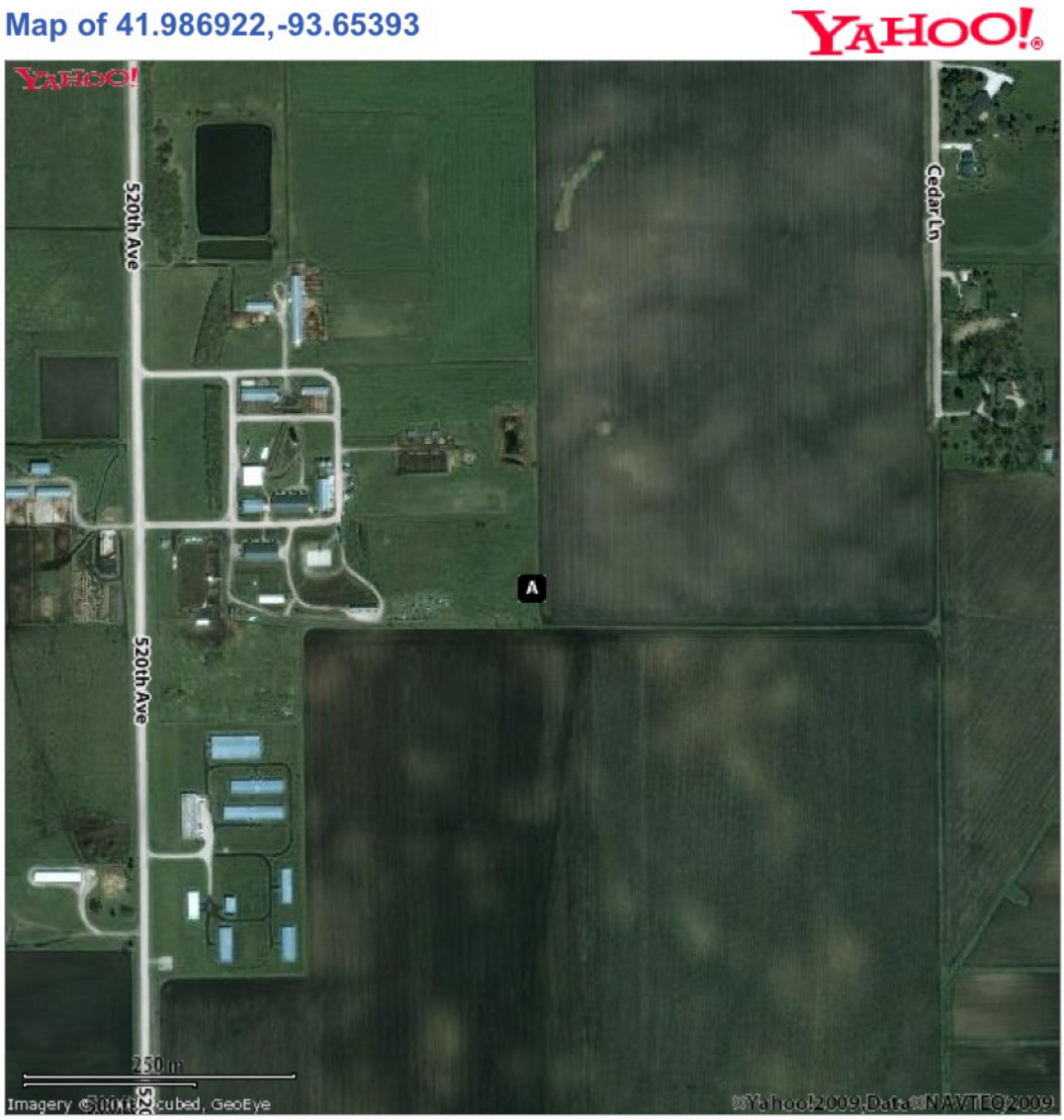
My research was carried out in a rural area of central Iowa south of Ames (41.986922, -93.65393) during the warmest summer months, starting July 1, 2008 and continuing for 100 days, until October 8, 2008. According to the Iowa Environmental Mesonet (IEM) Climodat report accessed December 2008 for the months of June through

October of 2007, the average monthly temperatures in Ames ranged from 57 to 76 degrees Fahrenheit[1].

I conducted this research at a location a few miles south of the Iowa State University campus, in a grassy field near the Iowa State University Swine Teaching Farm. This particular site was selected because of its central location within the state of Iowa, on the outskirts of the city, and in close proximity to the swine seller (Figure 1). The research site has very few shade trees because it is an open field that has been used for sheep grazing during previous months and years. All of the subjects and their cages were placed in full, direct sunlight throughout the duration of the study.

[1] Iowa Environmental Mesonet (IEM). Accessed December 2008. Climodat reports. http://mesonet.agron.iastate.edu/climodat/index.phtml.

Figure 1: Research site contiguous to the Iowa State University Swine Teaching Farm.



2.3 Subjects

In place of human cadavers, for the purpose of this study, pigs (*Sus scrofa* Linnaeus) were used as a model to mimic the decomposition of human remains. The application for approval of swine use was submitted to the Institutional Animal Care and Use Committee (IACUC) in February 2008 and approved on March 11, 2008. The selected pigs were

purchased through the ISU Swine Teaching facility to ensure they were in good condition. A total of five Yorkshire crossbred swine were used because of the similarity of pigs to humans in fat distribution, internal anatomy, and their lack of heavy fur (McGlone and Pond, 2003).

Only male pigs were used to control for possible sex differences. Additionally, the chosen subjects were immature, with their weight averaging 45 lbs to more accurately model the decomposition of child-sized remains. Although the weights of the pigs used are comparable to small children, the skeletal anatomy of young children includes more cartilaginous material than swine of the same weight; therefore the decomposition rate of the small swine may not be directly comparable to that of human child remains (Baker et al., 2005; McGlone and Pond, 2003). It is possible this difference may produce decomposition rates slightly dissimilar to that of young children. However, after a thorough search of the literature on decay rates, no information could be found on direct comparisons between child and swine decomposition.

Because of the need for each of the subjects to have died at approximately the same time, a licensed ISU veterinarian, Dr. Bruce Leuschen, with the aid of Al Christian, euthanized the subjects sequentially at the nursery using a two-step electrocution process approved by IACUC and recommended by the American Medical Association (AMA) on Euthanasia and the American Association of Swine Veterinarians. During the first step, an electrical current ran across the head to render the subject unconscious, after which electrodes were placed on the subjects and death resulted (Figure 2). After euthanization, all of the pigs were transported in the back of a truck to the site, approximately 500 yards from the nursery located near the Swine Teaching Farm. Electrocution was chosen as opposed to gas because the manner of death can affect the decomposition rate, along with the growth of

beetles and flies feeding on the carrion, due to changes in the blood hemoglobin. Poison gas in the blood deters arthropod succession and inhibits the organisms that enhance decomposition, whereas death by electrocution does not affect organisms or arthropod activity (Smith, 1986).

Figure 2: Euthanization via electrocution of Subject 1 on July 1, 2008.

2.4 Materials and Equipment

The five swine subjects were enclosed in pre-fabricated wire rectangular Life Stages® cages of varying measurements, ranging from (36”L x 24”W x 27”H) to (30”L x 21”W x 24”H) and were staggered approximately seven feet apart in a larger wire enclosure (Figure 3). Subjects 1 through 4 were placed separately into plastic Sterilite® 18-gallon totes, after which each tote was placed into a protective Life Stages® cage. The fifth subject was placed on the ground in a single small Life Stages® cage but was not contained inside a

plastic tote. In addition, each cage was separately staked to the ground to prevent movement and destruction of the remains from scavengers. The Life Stages® cages were chosen due to availability, size, structure, and durability.

The cages were identified with orange flags numbered 1 through 5 according to the corresponding subjects within. The plastic Sterilite® containers were labeled from 1 to 4 with permanent marker. As stated previously, four of the cages enclosed plastic Sterilite® 18-gallon totes that four of the deceased pigs were placed in after euthanization. One control subject, enclosed only in a cage, was used to illustrate the rate at which child-sized remains decay in full, direct sunlight during the summer without being contained or restricted from insect predation.

Table 2: 2008 Schedule

Subject	Date out	Container Condition	Examined
1	July 1	Lid sealed shut with duct tape	Sept 19*
2	July 1	Lid sealed shut with duct tape	Aug 10*
3	July 1	Lid sealed shut with duct tape	July 21*
4	July 1	Screen sealed to tub with duct tape, lid cover unsealed	Daily
5	July 1	No container used, open air in cage	Daily

*Containers were examined daily after opening until day 100.

Each of plastic totes 1 through 3 contained a pig carcass and was placed in the corresponding cage with the lids sealed to the totes with duct tape. After the fourth subject was placed in its corresponding 18-gallon plastic Sterilite® tote, a fiberglass window screen (18 X 16 mesh) was sealed onto the container with duct tape before the lid was placed on top as an attempt to prevent arthropod succession during daily observations. The lid for subject 4

was not sealed, thus providing observer access and less insect restriction. Observations were carried out for a period of 100 days, with subjects 3, 2 and 1 opened on days 20, 40 and 80, respectively. As indicated in Table 2 below, subject 1 was enclosed in a plastic tote for the longest duration with subject 5 being a control with no containment.

Figure 3: Site layout with subjects in place, photo orientation North.

2.5 Data Collection

Data recorded during each observation included date, time, current weather conditions, container and cage appearance, along with other possible variables that may influence the decay rate such as scavenging or insects. In addition, the decomposition stages

were indicated using set scoring criteria. The scoring system utilized, adapted from Micozzi (1991) and Galloway (1997), consisted of:

Stage		Description
0	*Fresh*	Algor mortis (body cools to ambient temperature), livor mortis (blood pools creating discoloration due to circulatory stasis), rigor mortis (muscle stiffening).
1	*Bloat*	Bloated appearance of the body: a distended abdomen as the result of gas accumulation. Characterized by gray to green discoloration or marbling of the skin, strong odor, extruded anus. Stage terminates with development of maggot mass.
2	*Early Decomposition*	Post-bloating with discoloration turning darker from green. Stage characterized by the presence of sizable maggot masses, strong odor, and greasy leathery appearance of the soft tissues. Stage terminates with appearance of skeletal elements.
3	*Advanced Decomposition*	This stage includes the disappearance of the maggot masses and a collapse of the abdominal cavity. Soft tissue changes are extensive involving sagging flesh, moist decomposition with bone exposure, and possible adipocere development. Stage terminates with mummification of soft tissues or one half of skeleton exposure.
4	*Skeletonization*	Only bone, cartilage, and desiccated soft tissue remain covering less than one half of the skeleton. Bones may also be characterized by greasy substances and decomposed tissue; body fluids may still be present if mummified. Stage terminates with the disappearance of beetles and all non-desiccated soft tissues.
5	*Extreme Skeletonization*	There is no odor or insect activity. Skeletonization characterized by bleaching, exfoliation, and metaphyseal loss with long bones and cancellous exposure of the vertebrae.

In addition to the written notes and decomposition scoring, a digital camera was used to provide a visual record of the recorded data. Observations of cages 1, 2 and 3 were limited

to the exterior of the containers until opening, while the remaining subjects (4 and 5) were monitored and photographed daily.

To log the daily temperature and humidity outside as well as inside the containers, four HOBO® Temperature Loggers were used. Two loggers were placed outside the containers while two were sealed inside two plastic totes in order to provide comparison of temperatures. The loggers were programmed to record temperature and humidity data every 10 minutes beginning on July 1, 2008 at 11:59 a.m. before the subjects were in place. Data was logged in Fahrenheit and Celsius by the HOBO® temp loggers, to allow for comparison between the temperatures obtained on site and those acquired through the IEM Mesonet Climodat report. It is to be noted, however, due to battery malfunctions, some of the HOBO® loggers did not record data for the entire study. The temp loggers placed inside the container with subject 1 and outside with subject 5 were the only loggers to record data from July 1 through October 8, 2008. The remaining two loggers placed inside with subject 4 and outside the subject 1 container recorded partial data, therefore were not useful for data analysis.

Insect sampling with a sweep net was carried out to determine which species of carrion-related insects appeared on and near the corpses. The collection and preservation of flies and beetles followed forensic entomology guidelines set forth by Amendt and colleagues (2007) and Micozzi (1991). Upon collection of an insect and placement into a four or six dram size glass container, the insect was killed with ethyl acetate then preserved in 70% ethyl alcohol. Vials were then labeled and stored for identification. The various arthropod species were identified with the aid of Forensic Insect Identification Cards produced by James L. Castner and Jason H. Byrd (2000).

CHAPTER 3

RESULTS AND ANALYSIS

3.1 Overview

All containers were opened, and analysis of the collected data began 100 days from the onset of the study. Information on each subject was compiled into observation logs and, from this, decay rates were organized into a table. Average daily temperatures (Celsius) and relative humidity (percent) were graphed using Excel and Boxcar® software. In addition, insect data was compiled according to arthropod succession and to decomposition score. Statistical analyses using SPSS 15.0 were run to determine if any variables significantly affect decomposition or if a correlation exists between them.

3.2 Temperature Data

Recorded temperatures were downloaded from the HOBO® temperature loggers for the months of July, August, September and October 2008. The average daily temperatures recorded by the HOBO® temperature loggers placed outside containers can be used as a baseline for central Iowa temperatures in direct sunlight during this time period. For the purpose of this study, 0° Celsius was used as the base temperature, treating temperatures that fell below as 0° Celsius, because freezing temperatures severely inhibit biological processes such as bacterial growth (Megyesi et al., 2005). Accumulated degree-days were calculated for HOBO® loggers 1 and 5 by adding together all average daily temperatures above 0°C for all days from euthanization and placement of subjects until the termination of the study.

Table 3 provides the ADD for select days beginning with day one, with a complete table provided in Appendix A.

Table 3: Accumulated degree-days using temperatures (°Celsius) collected with the HOBO® loggers 1 (inside) and 5 (outside) corresponding to select study days.

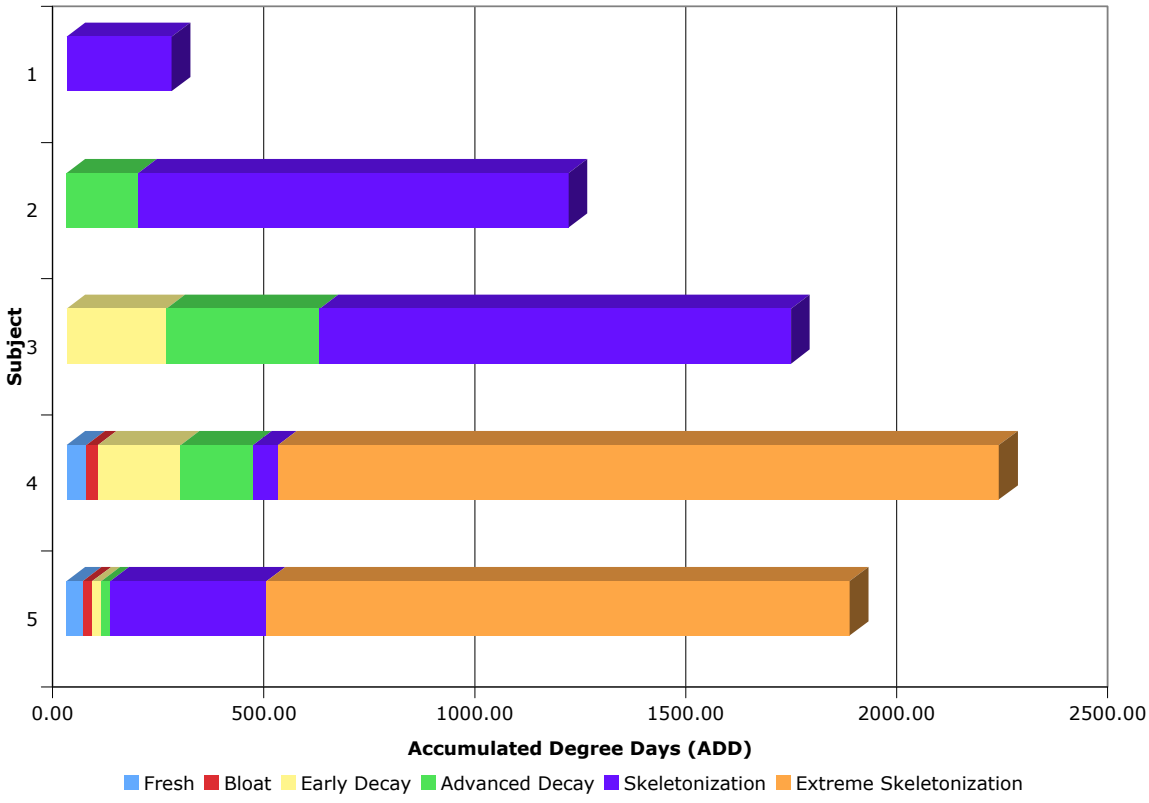
Day	Accumulated Degree: Celsius (logger 1: inside)	Accumulated Degree: Celsius (logger 5: outside)
0	0	0
1	17.92	14.52
2	47.13	39.01
3	74.62	61.29
4	101.42	82.67
5	127.69	103.65
6	157.11	129.78
7	187.16	156.41
8	215.37	182.74
9	239.48	203.89
10	266.72	228.34
11	297.35	255.68
12	325.47	282.34
13	349.60	301.50
14	377.14	322.75
15	408.96	348.81
16	441.72	376.84
17	469.46	401.33
18	496.86	426.15
19	522.89	449.28
20	550.88	474.34
21	581.44	500.33
22	606.91	522.31
40	1101.80	940.53
80	1938.12	1638.17
100	2315.70	1903.37

Throughout the study, temperatures recorded outside containers remained lower than temperatures recorded inside containers, with consistent increases in ADD for both conditions, which total 1903.37 and 2315.70 respectively. Because subjects in the outside control condition reached extreme skeletonization by day 22, the ADD for control subject 5 and subject 4 can be assessed at 606.91°C for outside containers and 522.31°C for inside

containers, while the ADD inside containers for subjects 3, 2 and 1 is 2315.70°C because they did not reach extreme skeletonization by day 100 (Figure 4).

Average temperature recorded by the HOBO® logger inside plastic container 1 was compared to average temperatures taken outside by the logger located in cage 5 in direct sunlight, with temperatures graphed using Boxcar® software (Figure 5). The average monthly temperatures for July, August, September and October 2008 recorded by the outside logger are 23.58°C (74.44°F), 20.61°C (69.11°F), 15.97°C (60.74°F), and 5.68°C (42.23°F) respectively. The average monthly temperatures recorded by the inside logger were 27.3°C (81.14°F), 25.24°C (77.42°F), 18.87°C (65.96°F), and 15.13°C (59.23°F). The overall average outside temperature was 5.18° Celsius lower than the inside temperatures.

Figure 4: Accumulated degree-days and decomposition stage for each subject.



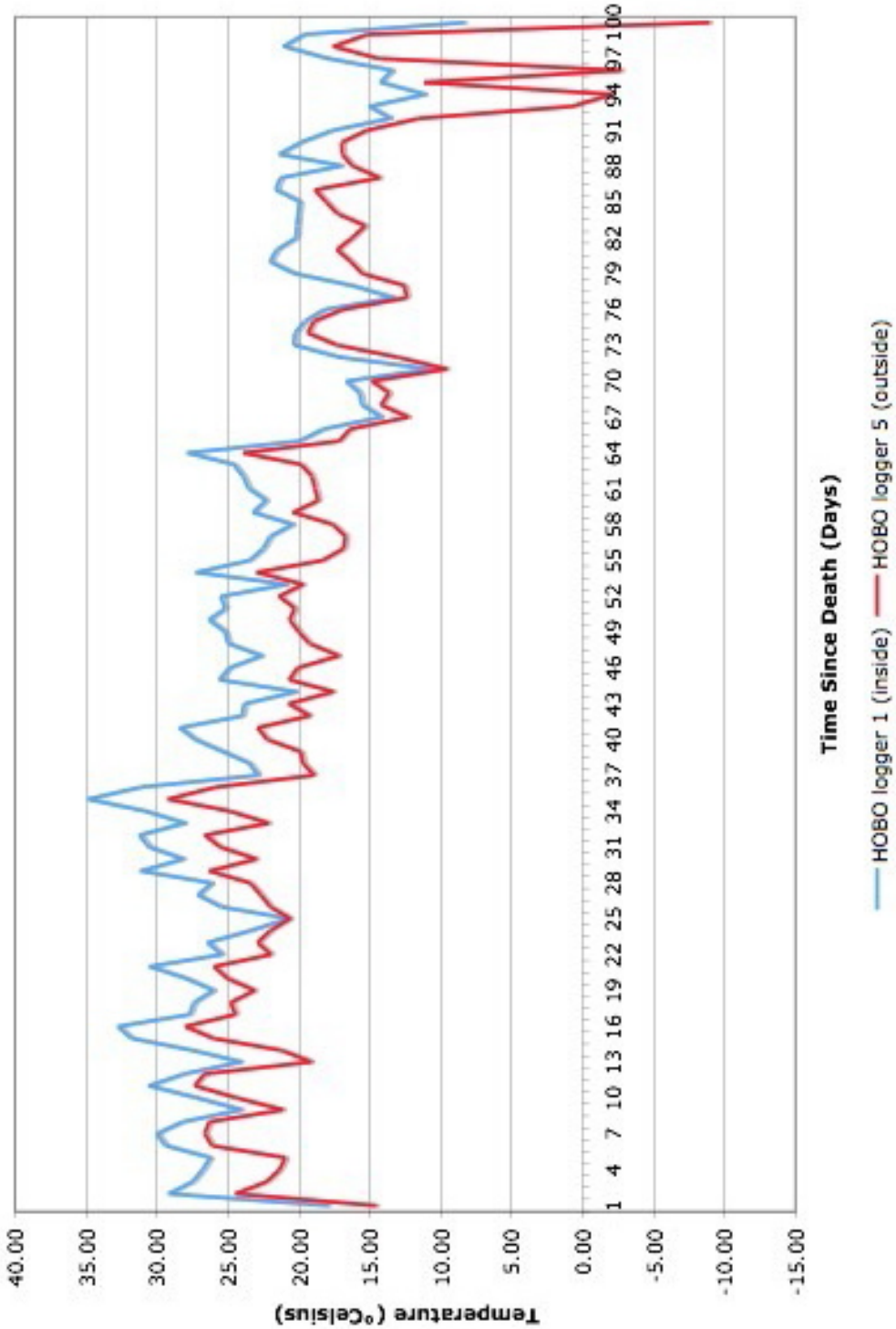


Figure 5: Comparison of inside and outside average daily temperatures (°Celsius) collected with HOBO® temperature loggers 1 and 5. The baseline for central Iowa is established with HOBO® logger 5, associated with the control subject 5.

The percentage relative humidity values recorded by the HOBO® loggers placed inside and outside the plastic containers were graphed and compared (Figure 6). The monthly average outside percentage relative humidity for months July, August, September and October 2008 were 88.07, 95.6, 100.31, and 96.72, whereas the monthly average percentage relative humidity for the inside condition was 101.4, 93.97, 91.4, and 81.84, respectively. The overall average percentage relative humidity for logger 5 outside was 95.18 while the overall inside logger 1 average was 92.15, a difference of 3.03. During the warmest month, July, the percentage relative humidity was higher in the containers than outside, whereas during the months following, which were cooler, the percentage relative humidity was lower inside the containers than outside.

When monthly average temperatures and percentage relative humidity are examined in accordance with active decay stages, excluding data for months August, September and October for the control but including all months for the inside condition because extreme skeletonization was reached during July for the control, the overall average temperature (Celsius) was 23.58 and 21.64, respectively. Following this, the overall average percentage relative humidity was 88.07 outside and 92.15 inside, giving the insect restricted condition a higher percentage relative humidity during active decomposition. The two-degree difference in temperature for the conditions pertaining to decomposition is not sizeable.

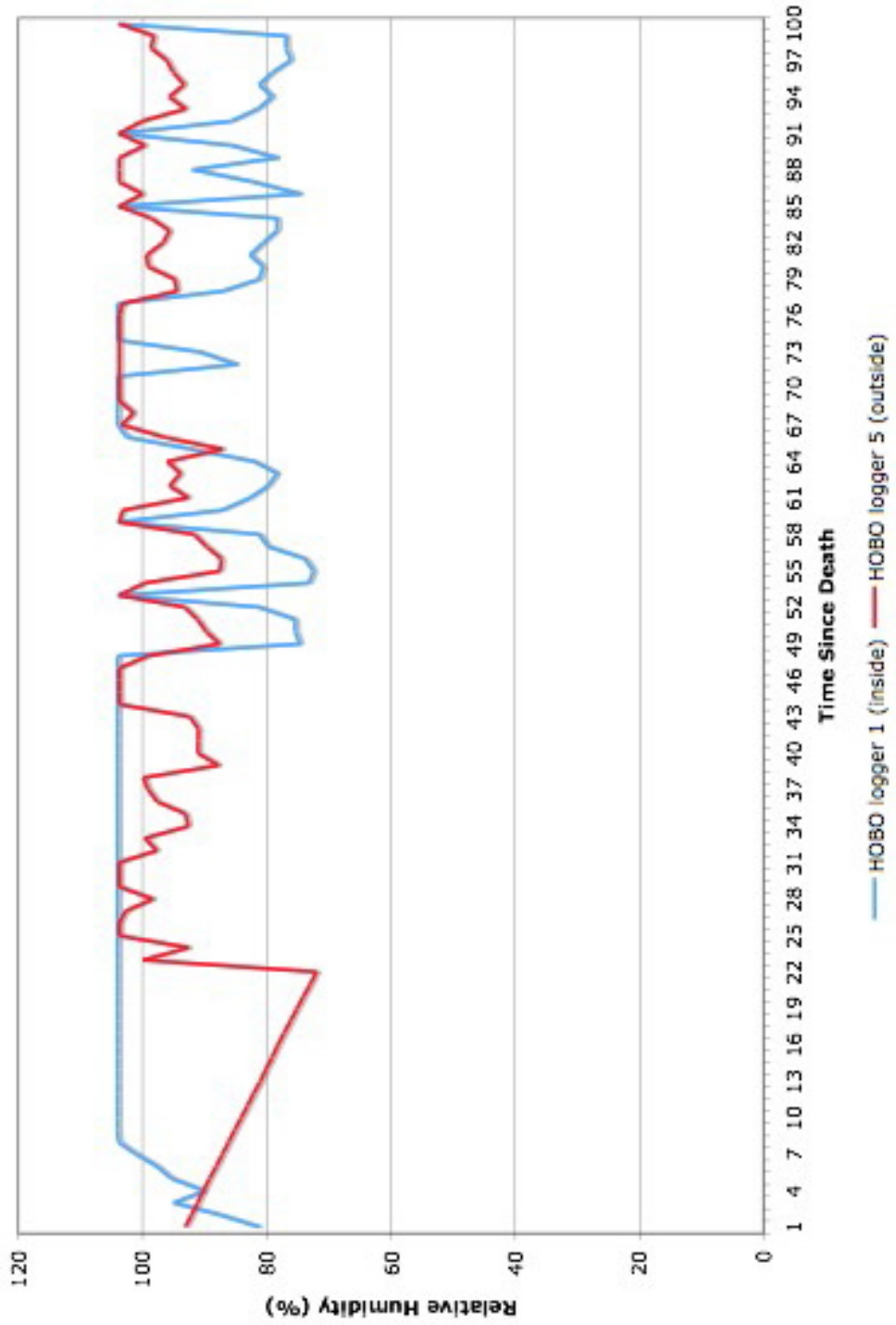


Figure 6: Comparison of inside and outside Relative Humidity percentage collected with HOBO® loggers associated with subjects 1 and 5 for study duration. The baseline for central Iowa is established with HOBO® logger 5. associated with control subject 5.

3.3 Decomposition

In order to conduct statistical analyses of decomposition rate, a quantitative approach was used, where visual assessment of the condition of the pigs was translated into a point-based system for each subject throughout the study. The method for determining stage of decomposition was established using a score system. The stages and scores were fresh (0), bloat (1), early decay (2), advanced decay (3), skeletonization (4), and extreme skeletonization (5) with the scores applied to each pig in its entirety. Figure 8 provides a graph of all the subjects' decay stages by day.

Temperatures were also taken into account when analyzing the stages of decomposition for each subject because decomposition is dependent on accumulated temperature and time passed. The state of decomposition is important when estimating time since death; therefore each stage was plotted against time since death to detect differences between conditions. It was expected the data analysis would show that the remains placed in an insect restricted environment would decompose at a significantly slower rate than the exposed control remains. Comparisons were made between sealed containers regarding the rates of decay (Table 4).

Table 4: Decomposition stages of subjects by days and total decomposition scores. Subject 5 is the control for this study.

Stage (Score)	**5**	**4**	**3**	**2**	**1**
Fresh (0)	0-2	0-2	-	-	-
Bloat (1)	3	3	-	-	-
Early Decay (2)	4	4-11	20-29	-	-
Advanced Decay (3)	5	12-18	30-43	40-47	-
Skeletonization (4)	6-21	19-21	44-100	48-100	80-100
Extreme Skeletonization (5)	22-100	22-100			
Total Decomposition Score	**460**	**441**	**286**	**232**	**80**

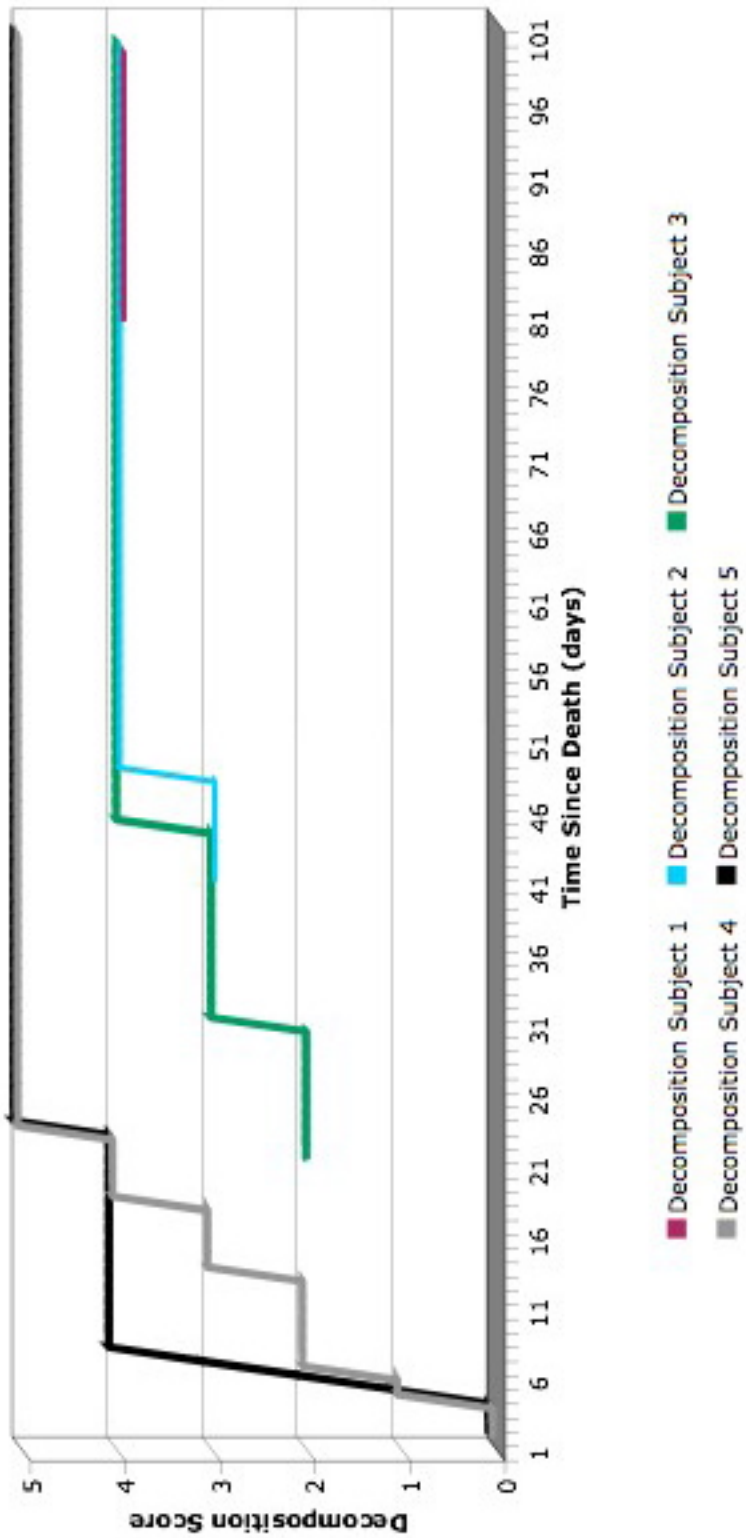


Figure 7: Decomposition score of subjects 1 through 5 with time since death (days).

Figure 8: Decomposition stages (fresh, bloat, early decay, advanced decay, skeletonization, extreme skeletonization) as exemplified by control subject 5 during the course of the study.

As stated in previous research and as has been demonstrated here, an inverse relationship exists concerning the interval between death and discovery, or in this situation the opening of containers, and the accuracy in estimating that interval (Love and Marks, 2003). Therefore, the more time that exists between death and discovery the more difficult and less accurate are the calculations for time since death. Subjects 4 and 5 reached extreme skeletonization at the same time; however, the stages of decomposition were spread out more evenly across time for subject 4, while subject 5 rapidly went from fresh remains through advanced decomposition during the first five days. Examining the decomposition data, subjects 2 and 1 appear to have decomposed at a slightly slower rate and neither reached extreme skeletonization. Subject 3 also did not reach extreme skeletonization, but the remains appear to have reached skeletonization at a faster rate than subjects 2 and 1. One could conclude that opening the container lids had an affect on decay rate, possibly hastened it. However, the longer a lid remained on a container the slower the rate of decomposition. Notable observations of each subject are compiled in the following tables.

Table 5: Notable observations of control subject 5 by day with ADD (outside).

Subject 5 (Control) Day	ADD (out)	Observations
0	0	Score: 0. Pig euthanized, time of death 1:47 p.m. Flies immediately attracted to remains at nursery. Placed on right side in cage approximately 2:00 p.m. Rigor mortis.
1	14.52	Livor mortis. Blood pooled on right side. Flies present. Fly egg deposits around eye. Maggots in mouth at 5:30 p.m. observation. Rigor mortis.
2	39.01	Purple-green discoloration of face. Autolysis: purple-green discoloration on abdomen. Strong odor. Flies present. Maggots on face, in mouth, eye. Fly egg deposits on anus.
3	61.29	Score: 1. Bloat increases throughout day. Flies abundant. Maggots on face, ears. Maggot mass in anus and in mouth during morning then gone by 2:30 p.m. Fly egg deposits on snout, anus.
4	82.67	Score: 2. Bloat less pronounced in afternoon. Strong odor in afternoon/evening. Marbling more pronounced: green, grey, orange. Skin sloughage, right side along ground, replaced by maggot mass by 3:30 p.m. Left eye gone. Flies present. Maggot mass in mouth, ears, anus, under head. Mass moved toward abdomen by 12:30 p.m. Large maggot mass outside cage near head at 6:30 p.m. American carrion beetle observed on back.
5	103.65	Score: 3. Strong odor in morning. Skull exposed, some hide on ground by rostral bone. Left scapula exposed on ground. Left humerus 90% exposed. Right front leg bones 50% exposed. 14 Left ribs exposed in morning, 75% exposed by 12:30 p.m. Some vertebra exposed. Skin detaches from stomach, slips to ground. Front feet intact. Rear right leg being consumed by maggot mass. Flies present. Maggot mass on torso and neck, in stomach, around anus. Mass moves toward rear-end larger in evening, leaving hair scattered around upper portion on ground and belly. American carrion beetle and Hairy rove beetle observed on body.
6	129.78	Score: 4. Little odor. Entire left ribcage exposed. Right tibia exposed. Desiccated soft tissue. Skin is black, except on lower legs where pink; the skin of feet intact. Flies present. Maggots consumed 50% of remains, mass is gone. American carrion, Sexton, and Hairy rove beetles present.
7	156.41	Feet intact. Some desiccated soft tissue. Maggot mass covering soft tissue remains and bones in stomach area, moved to feet. Approximately 90% skeletonized by 7:30 p.m. Flies present. Maggot mass trailing away from cage extending from cage North, toward cage 3 approximately six feet, at 9:30 a.m.. Mass trailed south out of large enclosure by 2:30 p.m. Hairy rove beetles found on body and maggot trail. By 7:30 p.m. maggot trails gone. Field next to large enclosure cut down between observations.
8	182.74	Little to no odor. 95% skeletonized, only feet left with tissue. Nearly all maggots gone from area. Lapland carrion beetle observed in close proximity to remains.
9	203.89	95% skeletonized. Feet intact. Some desiccated soft tissue on cage bottom and skeletal remains. Flies present. No maggot masses, few remain under feet. Red-legged ham beetle.
10	228.34	95% skeletonized. Remains in same condition as previous day. No maggots observed. Flies present.

Table 5 (continued)

11	255.68	95% skeletonized. Feet intact. Flies present. No maggots observed.
12 – 13	322.75	No changes to remains or insect activity.
14 – 16	376.84	95% skeletonized. Feet intact. No changes to condition of remains from previous days. No flies present.
17	401.33	Remains in same condition. Odor. Flies abundant on tissue and bones.
18 – 21	500.33	No odor or significant changes, feet intact however less hair and tissue. Flies present.
22	522.31	Score: 5. > 95% skeletonization. Desiccated soft tissue between ribs and on feet is less. Few flies. Unidentified beetle present.
23 – 68	1473.83	Decreasing amount of soft tissue on front feet and remains. Little to no insect activity.
69 – 100	1903.37	Desiccated soft tissue remains on feet. Bones settling to ground. Steady rate of disarticulation. Little or no insect activity.

Table 6: Notable observations of subject 4 by day with ADD (inside).

Subject 4 Day	**ADD (in)**	**Observations**
0	0	Score: 0. Pig euthanized, time of death 1:45 p.m. Flies immediately attracted to remains at nursery. Placed on right side in container 4 at approximately 2:00 p.m. then a screen fitted and sealed on with duct tape and the lid placed on top of the container. Rigor mortis.
1	17.92	No odor. Foam on snout, dried later in day. Livor mortis visible on right limbs. Flies on/around container.
2	47.13	Slight odor, stronger later in day. Belly has slight green tint. Flies on/around container.
3	74.62	Score: 1. Bloat. Strong odor. Moisture on screen and lid inside in morning. Light green abdomen gets darker throughout day. Bulge on chest by 2:30 p.m. Discoloration on snout. Dark fluid on bottom of tub, possibly from stomach. Flies on tub.
4	101.42	Score: 2. Early Decay. Strong odor. Moisture on screen and lid inside in morning. Head/body sinking down in tub. Dark fluid on bottom of tub depth increases throughout day to 2 inches. Strong grey-green marbling on body, left arm swollen and green. Stomach bulging and dark-brown organs in view, falling into fluid. Flies on/around container. Fly eggs along duct tape/screen edge inside and out.
5	127.69	Strong odor. Fluid approximately 3.5 inches deep. Body more than halfway submerged by fluid, turning dark grey-green throughout day. Front left limb swollen. Remains look as if a pile of skin, bone structure gone. Internal organs still visible in fluid. Flies on/around container. Fly egg deposits on duct tape and screen. Maggots on inside tub walls by 3:50 p.m., on body and in fluid by 6:25 p.m.
6	157.11	Strong odor. Fluid approximately 4 inches deep. Remains >50% submerged. Skin bubbling/sloughing. Left front leg puffy. Still 'bag of bones.' Fluid on screen, white foam on fluid surface. Flies present. Maggots on outside tub and inside on body, organs, fluid, sides of container. Red legged ham beetle.

Table 6 (continued)

7	187.16	Fluid same depth, tan foam still observed. Internal organs visible in fluid, head barely distinguishable. Flies present. Maggot mass on head and neck, which has sunken further into fluid. Maggots scattered on body. Maggots from cage 5 trailing by cages 4 and 3.
8	215.37	Pig no longer discernable, skin piled, remains have broken down and mixed with brown decomp fluid. Flies present. Maggots in fluid/remains.
9	239.48	Thick grey-brown fluid with maggots on what used to be body, still skin pile, and on sides of tub. Fluid same level.
10	266.72	Fluid leaking down outside container. Decomp fluid thick, dark brown-tan. Black skin pile visible. Moisture on screen and lid. Flies present on /around tub. Large maggot mass in container. Maggots also on screen.
11	297.35	Fluid same level. Remains difficult to see due to maggot mass covering all. Flies on/around container. Maggots on screen. Large maggot mass in tub.
12	325.47	Score: 3. Fluid nearly 5 inches deep, very thick and lighter in color, foam on top. Scapula and 8 ribs observed. Flies present on and around tub. Maggots on screen. Large maggot mass in container.
13	349.60	Fluid level back down to 4 inches. Little to no foam. Decomp mud-like. Skull visible in addition to scapula and ribs. Flies present on and around tub. Fewer maggots visible on fluid surface.
14	377.14	Fluid same depth as previous day. Bones shifted plus more than six vertebrae now visible. Flies present outside/on tub. Maggots inside but no longer a large mass. Red legged ham beetle observed on outside tub.
15	408.96	Fluid level 4 inches. Fluid not as thick but bubbling with maggot activity. Bones not visible. Flies present outside tub. Hairy rove beetles and Red legged ham beetles present outside tub.
16	441.72	Bones visible again: skull, ribs. Fluid is brown with white speckles on top. Flies on tub. Maggots in fluid, no mass visible on surface.
17-18	496.86	Fluid is brown and 4 inches. Only skull top visible. Flies present outside. Fluid bubbling with maggot activity.
19	522.89	Score: 4. Fluid same level, dark brown. Skull top, scapula, vertebral column, ribs, and long bone ends visible. Flies present. No maggot activity in fluid observed.
20	550.88	Odor. Only skull observed through fluid.
21	581.44	Crust forming on top of decomp fluid. No bones observed. Liquid is same depth.
22	606.91	Score: 5. Odor. Skull top barely visible through fluid, which is now dark brown. Crust layer still forming on fluid surface. Flies present outside. No maggot activity observed. American carrion beetle and Red legged ham beetle observed outside tub.
100	2315.70	Score: 5. Fluid has thin yellow-white film on top. No flesh on skeletal remains or in fluid. No flies, maggots, or beetles.

Table 7: Notable observations of subject 3 by day with ADD (inside).

Subject 3 Day	ADD (in)	Observations
0	0	Score: 0. Pig euthanized, time of death 1:43 p.m. Flies immediately attracted to remains at nursery. Placed on right side in container 3 at approximately 2:00 p.m. then the lid sealed on with duct tape.
30	815.75	Score: 3. Odor. Skull, scapula, humerus, ribs, and vertebrae visible. Some desiccated soft tissue observed in fluid, which has slight foam on top. Flies present. Hairy rove beetle on ground under tub inside cage.
44	1198.35	Score: 4. Decomp fluid is brown. Soft tissue observed is yellow-tan in color. Bones visible, hair on vertebrae. Flies present. Maggots in fluid.
80	1916.18	Score: 4. Firm crust on fluid surface is light tan. Some bone portions observed jutting through fluid surface. Flies, Hairy rove and Ham beetles present.
100	2315.70	Score: 4. Slight odor. Fluid is thick (similar consistency as wet cement) and dark tan in color. Some pink flesh observed on long bones when removed. No flies, maggots, or beetles present.

Table 8: Notable observations of subject 2 by day with ADD (inside).

Subject 2 Day	ADD (in)	Observations
0	0	Score: 0. Pig euthanized, time of death 1:41 p.m. Flies immediately attracted to remains at nursery. Placed on right side in container 2 at approximately 2:00 p.m. then the lid sealed on with duct tape.
40	1101.80	Score: 3. Primarily brown decomp fluid. Soft tissue observed is yellow and red. Some skeletal remains visible. Flies present. Maggot activity in fluid and on remains.
48	1296.53	Score: 4. Strong odor. Decomp fluid is thin. Small lump of tissue and vertebrae are visible. Reddish color dissipating in fluid. Flies present. No maggot activity observed.
80	1916.18	Score: 4. Decomp fluid is brown. Remains under fluid and unobservable. Flies and Red ham beetles present. Maggot activity in fluid.
100	2315.70	Score: 4. Slight odor. Fluid thick and brown. Some pink flesh observed on long bones when removed. No flies or maggots observed. Red ham beetles and dead Hairy rove beetles observed.

Table 9: Notable observations of subject 1 by day with ADD (inside).

Subject 1 Day	ADD (in)	Observations
0	0	Score: 0. Pig euthanized, time of death 1:40 p.m. Flies immediately attracted to remains at nursery. Placed on left side in container 1 at approximately 2:00 p.m. then the lid sealed on with duct tape.
30	815.75	Foam coming out from under lid sides and tape is loosened. Brown liquid on outside of container. Maggots trailing West from container and cage. Maggot masses on ground on East and South side of container. Hairy rove beetles present.
80	1916.18	Score: 4. Strong odor. Tape still sealed to tub in spots. Light tan firm crust on portions of brown decomp fluid surface. Bone portions visible appear greasy. Flies present. No maggot activity observed. Dead beetle larvae on fluid surface.
100	2315.70	Score: 4. Slight odor. Fluid is consistency of runny mud and orange-tan in color. No flesh on bones, greasy. No flies present prior to removing remains. No maggots found in fluid. Living beetles not present. Many dead beetles and beetle larvae in fluid.

3.4 Arthropod Activity

Carrion related insect activity was documented and representative specimens collected from subjects 5 (control) and 4. The samples were labeled and stored in glass vials with 70% ethyl alcohol for preservation. Arthropod succession was compared between all conditions, which were useful in determining if insect restriction can impact decomposition rate. The control data may be useful as a baseline for comparisons to other studies.

The records for each subject show no fly egg deposits once the subjects entered into the advanced decomposition stage. Fly eggs were found on the outside of all containers during the initial weeks following death. Containment of the remains appears to have inhibited the appearance of fly larvae on the remains held in the insect restricted environments. However, the containers did not fully prevent insects from accessing the remains until the planned dates for opening. Flies were present throughout the duration of the study, regardless of decay stage. Beetles were not observed prior to early decay for all subjects, and they continued visiting the remains sporadically until the end of the study. The

final subject opened (1) contained many deceased Hairy rove beetles (*Creophilus maxillosus*) and their larvae in the fluid, which were not observed inside any of the other containers. This may have been due to the duct tape adhesive failing during the study. Following are tables of arthropod activity and decay stage according to subject. A complete list of flies and beetles identified during the study are included in Appendix B, in addition to succession.

Table 10: Arthropod succession of control subject 5 by decomposition stage.

Subject 5	Fresh (0)	Bloat (1)	Early Decay (2)	Advanced Decay (3)	Skeletonization (4)	Extreme Skeletonization (5)
Fly egg deposits	X	X	X			
Fly larvae	X	X	X	X	X	
Adult fly	X	X	X	X	X	X
Beetle			X	X	X	X

Table 11: Arthropod succession of subject 4 by decomposition stage.

Subject 4	Fresh (0)	Bloat (1)	Early Decay (2)	Advanced Decay (3)	Skeletonization (4)	Extreme Skeletonization (5)
Fly egg deposits		X	X			
Fly larvae			X	X	X	X
Adult fly	X	X	X	X	X	X
Beetle			X	X	X	X

Table 12: Arthropod succession of subject 3 by decomposition stage.

Subject 3	Fresh (0)	Bloat (1)	Early Decay (2)	Advanced Decay (3)	Skeletonization (4)	Extreme Skeletonization (5)
Fly egg deposits			X			
Fly larvae			X	X	X	
Adult fly			X	X	X	
Beetle			X	X	X	

Table 13: Arthropod succession of subject 2 by decomposition stage.

Subject 2	Fresh (0)	Bloat (1)	Early Decay (2)	Advanced Decay (3)	Skeletonization (4)	Extreme Skeletonization (5)
Fly egg deposits						
Fly larvae				X	X	
Adult fly				X	X	
Beetle				X	X	

Table 14: Arthropod succession of subject 1 by decomposition stage.

Subject 1	Fresh (0)	Bloat (1)	Early Decay (2)	Advanced Decay (3)	Skeletonization (4)	Extreme Skeletonization (5)
Fly egg deposits						
Fly larvae						
Adult fly					X	
Beetle					X	

Table 15: Location comparison of insect succession and stages of decomposition. See Appendix B for species identified during this study.

Decay Stage	Present Study	Tennessee (Hall, 2001)	Iowa (Walker, 2000)	Indiana (Johnson, 1975)	Italy (2004)
Fresh	Blow flies Muscid flies Bottle flies	Blow flies Muscid flies Carrion beetles Clown beetles	Blow flies Muscid flies	Blow flies	Blow flies Flesh flies
Bloat	Blow flies Muscid flies Flesh flies Bottle flies Black Scavenger flies Cheese Skipper flies	Blow flies Muscid flies Flesh flies Carrion beetles Clown beetles Rove beetles	Blow flies Muscid flies Ground beetles	Blow flies Minute Scavenger flies Scuttle flies	Blow flies Muscid flies Flesh flies Scuttle flies Black Scavenger flies Skipper flies Carrion beetles Clown beetles Rove beetles Checkered beetles
Decay	Blow flies Bottle flies Flesh flies Muscid flies Black Scavenger flies Cheese Skipper flies American Carrion beetles Hairy Rove beetles Red-legged Ham beetles	Blow flies Muscid flies Flesh flies Carrion beetles Clown beetles Rove beetles Checkered beetles Dermestid beetles Sap beetles Lamellicorn beetles	Blow flies Muscid flies Rove beetles Carrion beetles Ground beetles	Blow flies Muscid flies Scuttle flies Black Scavenger flies Minute Scavenger flies Skipper flies Carrion beetles Clown beetles Rove beetles Sap beetles Hide beetles	Blow flies Muscid flies Flesh flies Scuttle flies Black Scavenger flies Skipper flies Carrion beetles Clown beetles Rove beetles Checkered beetles Dermestid beetles

3.5 Quantitative Assessment

The small sample size may restrict this research from making substantial statements on the decomposition rate of immature swine. For research results to be statistically robust, most statistical tests require a sample size of 30 or more (Madrigal, 1998). However, because this is not feasible in decomposition studies, generally smaller sample sizes are used (Rodriguez and Bass, 1985). During statistical analysis, decomposition was treated as a dependent variable in analyses using SPSS 15.0 software. The relevant independent variables for quantitative assessment of the study were identified as time since death, temperature, relative humidity and accumulated degree-days (ADD). To determine if any significant correlations exist, Pearson's product-moment correlation coefficient and the nonparametric Spearman's rho analyses were run. Nonparametric tests on scores are more desirable to use on small sample sizes because of possible difficulties with normality (Bryman and Cramer, 2009). A comparison of the parametric and nonparametric results showed differences between tests and subjects. The test results can be observed in Tables 15 and 16 following.

Results of the Pearson's *r* show that subject 1 produced the only strong and significant positive correlation between decomposition score and temperature ($r = 0.710$, two-tailed, $p = 0.000$, $N = 22$). The relationship between decay score and temperature for subject 3 was a significant negative correlation ($r = -.237$, two-tailed, $p = 0.032$). Temperature did not show any significant correlations using Pearson's *r* with decay score for subjects 2, 4, or 5. Time since death and decomposition score showed a strong positive correlation ($p < 0.01$) for all subjects, as did results for ADD and decay score for each ($p < 0.01$). Relative humidity and decay score showed a strong significant positive correlation (*p*

< 0.01) for subjects 1, 2 and 5. The parametric correlations conducted regarding the dependent variable (decomposition score) and independent variables (time since death, ADD, relative humidity) for the control subject 5 were strong, significant and positive at the 0.01 level.

The nonparametric Spearman's rho showed strong and significant positive correlations between the dependent variable of control subject 5 (decomposition score) and the independent variables (ADD, time since death, relative humidity) and a strong significant negative correlation with temperature at the $p < 0.01$ level (Table 15). However, using this test, no significant correlations could be found between decay score or any of the independent variables for subject 1. Subject 2 had strong positive significant correlations with time since death and ADD at the $p < 0.01$ level, but weaker significant negative correlations between the dependent variable with temperature and relative humidity were found at the $p < 0.05$ level (Table 16). Nonparametric tests for subject 3 show strong and significant positive correlations ($p < 0.01$) of decay score with time since death and ADD, while strong significant negative correlations at the same level were identified between decay score with relative humidity and temperature. No correlation was found with subject 4 regarding decomposition and relative humidity; however, there was a strong significant negative correlation for temperature. Time since death and ADD of subject 4 were also strong significant positive correlations at the $p < 0.01$ level.

Table 16: Parametric Correlations: Pearson's product-moment.

		Accumulated Degree-days (out)	Temperature Celsius (out)	Relative Humidity (out)	Time Since Death (days)
Decomposition Score Subject 5	Pearson Correlation	.627(**)	-.055	.558(**)	.580(**)
	Sig. (2-tailed)	.000	.583	.000	.000
	Sum of Squares and Cross-products	36980.186	-36.687	723.678	1735.000
	Covariance	369.802	-.367	7.237	17.350
	N	101	101	101	101

** Correlation is significant at the p < 0.01 level (2-tailed).

		Decomposition Score Subject 1	Decomposition Score Subject 2	Decomposition Score Subject 3	Decomposition Score Subject 4
Time Since Death (days)	Pearson Correlation	.954(**)	.667(**)	.790(**)	.674(**)
	Sig. (2-tailed)	.000	.000	.000	.000
	Sum of Squares and Cross-products	343.636	478.452	1251.195	2504.000
	Covariance	16.364	7.843	15.447	25.040
	N	22	62	82	101
Accumulated Degree-days (in)	Pearson Correlation	.974(**)	.738(**)	.840(**)	.717(**)
	Sig. (2-tailed)	.000	.000	.000	.000
	Sum of Squares and Cross-products	8210.140	11248.592	30001.408	63073.339
	Covariance	390.959	184.403	370.388	630.733
	N	22	62	82	101
Relative Humidity (in)	Pearson Correlation	.893(**)	.379(**)	-.032	.132
	Sig. (2-tailed)	.000	.002	.772	.188
	Sum of Squares and Cross-products	320.287	228.241	-33.554	249.203
	Covariance	15.252	3.742	-.414	2.492
	N	22	62	82	101
Temperature Celsius (in)	Pearson Correlation	.710(**)	.232	-.237(*)	-.158
	Sig. (2-tailed)	.000	.070	.032	.115
	Sum of Squares and Cross-products	68.649	43.168	-89.090	-116.346
	Covariance	3.269	.708	-1.100	-1.163
	N	22	62	82	101

** Correlation is significant at the p < 0.01 level (2-tailed).
* Correlation is significant at the p < 0.05 level (2-tailed).

Table 17: Nonparametric Correlations: Spearman’s rho.

			Accumulated Degree-days (out)	Temperature Celsius (out)	Relative Humidity (out)	Time Since Death (days)
Spearman's rho	Decomposition Score Subject 5	Correlation Coefficient	.719(**)	-.424(**)	.638(**)	.719(**)
		Sig. (2-tailed)	.000	.000	.000	.000
		N	101	101	101	101

** Correlation is significant at the p < 0.01 level (2-tailed).

			Decomposition Score Subject 1	Decomposition Score Subject 2	Decomposition Score Subject 3	Decomposition Score Subject 4
Spearman's rho	Time Since Death (days)	Correlation Coefficient	.361	.611(**)	.811(**)	.722(**)
		Sig. (2-tailed)	.099	.000	.000	.000
		N	22	62	82	101
	Accumulated Degree-days (in)	Correlation Coefficient	.361	.611(**)	.811(**)	.719(**)
		Sig. (2-tailed)	.099	.000	.000	.000
		N	22	62	82	101
	Relative Humidity (in)	Correlation Coefficient	.362	-.312(*)	-.488(**)	-.106
		Sig. (2-tailed)	.097	.013	.000	.293
		N	22	62	82	101
	Temperature Celsius (in)	Correlation Coefficient	.361	-.289(*)	-.573(**)	-.405(**)
		Sig. (2-tailed)	.099	.023	.000	.000
		N	22	62	82	101

** Correlation is significant at the p < 0.01 level (2-tailed).

* Correlation is significant at the p < 0.05 level (2-tailed).

CHAPTER 4

CONCLUSIONS

The ideal situation for experimental work to be carried out is at the site where an animal is known to have died and the remains undisturbed, with the exact time of death known (Smith 1986). Although the rearrangement of a corpse or the use of special equipment to facilitate study disturbs the natural sequence of events, for this study euthanization was performed a short distance off-site to enable quick transportation of the remains and rearrangement of them into the cages. The use of a device that alters exposure to elements not only changes the ambient temperature and moisture but also potentially excludes certain insect species behaviorally; in this case plastic containers were used. In addition, to protect the carcasses from vertebrate predators a cage was utilized and anchored. All of these factors have been noted to disturb the natural sequence of decomposition and were examined here.

In this chapter I will provide a general summary of the results, placing them in context with relevant information on previous studies. Lastly, the limitations associated with the study and recommendations for future research will be discussed.

4.1 Summary of Results

My observations and statistical analyses enabled a rejection of three of the four null hypotheses presented in chapter 1. Insect restriction was found to affect the rate of decomposition in a significant manner resulting in differential decomposition, rejecting null

hypothesis one ($H_0$1). Decomposition scores of subjects 4, 3, 2 and 1 indicates containment duration produces a considerable difference in decay rate, thus rejecting null hypothesis two ($H_0$2). Although a difference was found between outside and inside temperatures, due to the additional variables and insect restriction, I am unable to determine if temperature produce differential decomposition rates and therefore cannot reject null hypothesis three ($H_0$3). The null hypothesis four ($H_0$4) can be rejected because analyses provide that time, temperature, and insect restriction significantly affect rate of decay.

Based on the variables and decomposition stages, the rate was slower for the subjects contained within plastic totes. A number of factors likely contributed to the slower rate of decay. First, containment delayed insect access to the remains whereas the control subject 5 and subject 4, which were not as restricted, decomposed more rapidly. Second, insect presence, desiccation, and advanced decomposition stage lasted longer in all the contained subjects than the control subject. The restricted access of maggots to the remains retarded the breaking down of carrion soft tissues.

The data collected associated with control subject 5, placed outside in full direct sunlight, provides a baseline for summers in central Iowa in respect to daily temperature, accumulated degree-days, percentage relative humidity and decomposition stage in the control subject's remains. When necessary, variables were correlated with the time interval since death, rather than date, in order to standardize comparisons. The baseline may be used as a comparison in future investigations in order to estimate decay rate or postmortem interval of comparable sized human remains. It is important to note that this study only accounts for accumulated time, temperature, relative humidity, and containment condition to

explain the variation in decomposition. Other climatic and contextual factors that could affect decomposition rate are not accounted for but will be discussed later in this chapter.

4.2 Decomposition Studies

Immediately after death, the body temperature falls to the ambient temperature of its surroundings (Spitz, 2006). The first major observable change is a stiffening of the muscle fibers related to the breakdown of glycogen and the accumulation of lactic acid, known as rigor mortis, which can take five to seven hours and last between 48 and 72 hours. The next significant stage observed subsequent to rigor mortis is autolysis, which is biochemical fermentation with the release of gases (ammonia, hydrogen sulphide, carbon dioxide, and nitrogen). This stage is characterized by green marbling discoloration of the body and abdominal bloating. Microorganisms remaining in and feeding on the body stimulate the next stage, putrefaction, where the abdomen collapses, sagging flesh is observed, and soft body parts rapidly disappear (Spitz, 2006).

In this study, subjects 4 and 5 remained in the fresh stage during the first two days following death after which were in the bloat stage for day three. Subject 4 and control subject 5 reached early decay by day four of the study, however the length of time spent in this early decay stage varied, with subject 4 not attaining advanced decay until the twelfth day whereas subject 5 was in advanced decay by day five and skeletonization by day six. Subjects 3, 2, and 1 did not reach advanced decay until they were beyond day 30. The delayed decomposition of the contained remains, as well as the control reaching skeletonization within one week, appear to be typical results and comparable to results of other studies (Hyder, 2007; Payne, 1965).

The appearance of necrophagous insects usually occurs with the onset of autolysis and putrefaction, depending on the time of year and situation of the corpse, accelerating putrefaction and disintegration of the remains (Smith, 1986). Skeletonization occurs after advanced decomposition, leaving behind primarily skeletal elements and possibly some desiccated soft tissue. However, because bones of children are small and may just be starting to ossify, not being as mineralized as the adult skeletal elements, they therefore may suffer greater postmortem degradation due to the decomposition process (Baker et al., 2005).

Some of the initial studies of human decomposition at the University of Tennessee's Anthropological Research Facility (ARF) focused on the impacts of insect activity on decomposition (Rodriguez and Bass, 1983) as well as the decay rates of buried and surface remains (Rodriguez and Bass, 1985). Mann et al. (1990) summarize some of the more important decomposition variables based on collective research at the ARF noting most destruction of soft tissue is due to insect larvae feeding. This study corroborates the results observed that fresh remains could be skeletonized in one week during hot, humid periods in eastern Tennessee (Steadman, 2003). In my study, it is clear more rapid decomposition occurred with control subject 5 in the outdoor environment, in contrast to the insect restriction conditions, which is consistent with previous studies conducted on remains placed outside (Rodriguez and Bass, 1985; Bass, 1997; Voss, 2008). As anticipated, the decay rate was greatly reduced for subjects 1, 2 and 3, those contained in the insect restricted environment. The restriction appears to have effectively decreased the access and therefore the decomposition rate. Decomposition of the enclosed subject 4 was not considerably affected because of insect exposure due to the lid being removed daily. Similarly, Galloway et al. (1989) found remains progressed through the early stages of decay more slowly in

enclosed structures, although plastic containers were not used as in this study. However, research carried out in Texas, which examined the impacts of insect restriction using plastic containers, found insect restriction as the key variable to slowing decay rate (Hyder, 2007).

The contained (inside) environment overall had higher percentage relative humidity levels during the first half of the study and lower humidity for the last half. Whereas the humidity levels in the control condition (outside) during the first 22 days was in a consistent decline and remained lower than the contained environments. Due to the insect restriction, no definitive statements can be made toward others conclusions that lower humidity has been found to reduce insect activity (Mann et al., 1990) because the sealed containers prohibited insect access. Skeletonization was observed on all remains, although a small amount of soft tissue remained on subjects 5, 3 and 2 at the study conclusion.

4.3 Possible Limitations and Future Research

Limitations in this research include, first, the use of pigs as a substitute for human cadavers. Swine carrion use limits the conclusions that can be drawn from the results with inferences that can be made against human remains. However, the unavailability and ethical use of deceased human subjects in addition to the open, unsecured research location necessitated the use of swine in place of human remains. Second, the use of five subjects for the research makes it difficult to formulate definitive conclusions about the variables involved. Increasing the sample size would produce more robust and statistically significant results while providing more accurate comparisons between conditions.

Third, size and sex of carrion could be manipulated. This research was conducted using male 45-pound swine corpse, it is unknown if size of subject or if using female carrion

would produce different results in decomposition. Fourth, for this research containers were sealed in a manner that would model a forensic context. A stronger seal, allowing for complete insect restriction, would prohibit access of any arthropods providing more conclusive statements to be made on differential decomposition and insect restriction. Fifth, similar research carried out during different months in central Iowa, or differing conditions, would likely produce varied results.

Sixth, chemical analyses and comparisons of the decomposition liquid from the containers and control were not performed. It is unknown if any differences between conditions would be found using various chemistry or molecular biology techniques. In addition, more in depth entomological analysis would provide detailed information about arthropod activity and insect succession. Lastly, decomposition scoring was determined for the remains overall. Using scores that would account for differential decomposition on individual remains, such as total body scoring through combined scoring of various anatomical regions, could allow further conclusions to be made about differential decomposition rates.

4.4 Research Significance

Using child-sized swine cadavers, this research presented a unique contribution to Forensic Anthropology with the simulation of an instance of child homicide and concealment within sealed plastic containers. The data obtained provides a starting point and an initial baseline for small body decomposition in a specific forensic context, with the application relating to the criminal mindset of child murderers. Modifications to the current research design could lead to a compilation of data on various scenarios. The information gleamed

from such contributions could offer insight to such issues as forensic skeletal consultations, criminal cases, human rights violations, genocide and mass grave investigations, or examination of bioarchaeological information.

APPENDIX A

ACCUMULATED DEGREE-DAYS

CLIMATE DATA: HOBO LOGGERS

Accumulated Degree-days (Celsius)

DAY	Accumulated Degree: Celsius (logger 1: inside)	Accumulated Degree: Celsius (logger 5: outside)
0	0.00	0
1	17.92	14.52
2	47.13	39.01
3	74.62	61.29
4	101.42	82.67
5	127.69	103.65
6	157.11	129.78
7	187.16	156.41
8	215.37	182.74
9	239.48	203.89
10	266.72	228.34
11	297.35	255.68
12	325.47	282.34
13	349.60	301.50
14	377.14	322.75
15	408.96	348.81
16	441.72	376.84
17	469.46	401.33
18	496.86	426.15
19	522.89	449.28
20	550.88	474.34
21	581.44	500.33
22	606.91	522.31
23	633.38	545.25
24	656.82	567.25
25	677.58	587.87
26	703.07	609.87
27	730.21	632.57
28	756.36	656.00
29	787.57	682.33
30	815.75	705.37
31	846.34	730.92
32	877.58	757.54
33	905.69	779.68
34	936.58	804.61
35	971.48	833.83
36	1002.68	859.73
37	1025.59	878.68
38	1049.11	898.42
39	1074.51	918.30
40	1101.80	940.53
41	1130.22	963.44
42	1154.23	982.70
43	1178.09	1003.44
44	1198.35	1021.04
45	1223.99	1041.75
46	1248.90	1061.85
47	1271.56	1079.02
48	1296.53	1098.28

49	1321.75	1118.30
50	1348.11	1138.98
51	1373.30	1159.28
52	1398.84	1180.69
53	1419.76	1200.42
54	1447.05	1223.40
55	1470.55	1241.73
56	1493.07	1258.60
57	1515.12	1275.31
58	1535.57	1292.94
59	1558.83	1313.38
60	1581.16	1332.04
61	1604.71	1350.91
62	1628.65	1369.98
63	1653.26	1389.82
64	1681.14	1413.75
65	1701.13	1430.90
66	1719.42	1447.30
67	1733.65	1459.62
68	1749.21	1473.83
69	1764.95	1487.48
70	1781.62	1502.34
71	1792.39	1511.94
72	1809.62	1525.05
73	1829.99	1542.38
74	1850.29	1561.78
75	1869.87	1580.72
76	1888.11	1597.66
77	1901.49	1610.05
78	1917.78	1622.64
79	1938.12	1638.17
80	1960.18	1654.50
81	1981.74	1671.82
82	2001.94	1688.06
83	2022.11	1703.40
84	2042.17	1720.70
85	2062.14	1738.78
86	2083.78	1757.65
87	2105.09	1771.95
88	2122.13	1788.19
89	2143.54	1805.14
90	2163.44	1822.14
91	2181.10	1837.39
92	2194.67	1848.95
93	2209.72	1849.70
94	2220.86	1849.70
95	2235.14	1858.80
96	2248.57	1858.80
97	2266.62	1870.58
98	2287.74	1888.16
99	2307.39	1903.37
100	2315.70	545.25

HOBO logger 5: outside (control-baseline)

DATE	AVG TEMP C	AVG TEMP F	AVG RH %
07/1/08	14.52	58.14	93.11
07/2/08	24.49	76.08	92.13
07/3/08	22.28	72.11	91.13
07/4/08	21.38	70.48	90.21
07/5/08	20.98	69.77	89.19
07/6/08	26.13	79.03	88.18
07/7/08	26.63	79.93	87.18
07/8/08	26.33	79.40	86.18
07/9/08	21.15	70.07	85.15
07/10/08	24.45	76.01	84.11
07/11/08	27.34	81.21	83.08
07/12/08	26.66	79.99	82.07
07/13/08	19.16	66.49	81.04
07/14/08	21.25	70.24	80.07
07/15/08	26.06	78.91	79.11
07/16/08	28.03	82.45	78.17
07/17/08	24.49	76.09	77.16
07/18/08	24.82	76.68	76.14
07/19/08	23.13	73.64	75.12
07/20/08	25.06	77.10	74.07
07/21/08	25.98	78.77	73.01
07/22/08	21.99	71.58	72.00
07/23/08	22.93	73.28	99.90
07/24/08	22.00	71.60	92.56
07/25/08	20.62	69.12	103.80
07/26/08	22.00	71.60	103.80
07/27/08	22.70	72.86	102.71
07/28/08	23.43	74.17	98.29
07/29/08	26.33	79.40	103.80
07/30/08	23.04	73.47	103.80
07/31/08	25.56	78.00	103.80
08/1/08	26.62	79.92	97.72
08/2/08	22.14	71.85	99.65
08/3/08	24.93	76.87	92.67
08/4/08	29.22	84.60	93.03
08/5/08	25.90	78.62	97.55
08/6/08	18.95	66.11	99.08
08/7/08	19.73	67.52	99.88
08/8/08	19.88	67.79	87.76
08/9/08	22.23	72.01	91.07
08/10/08	22.92	73.25	91.17
08/11/08	19.26	66.67	91.01
08/12/08	20.73	69.32	92.38
08/13/08	17.61	63.69	103.80
08/14/08	20.71	69.27	103.80
08/15/08	20.10	68.18	103.80
08/16/08	17.17	62.91	103.80
08/17/08	19.26	66.66	99.11
08/18/08	20.01	68.03	87.63
08/19/08	20.68	69.22	89.72

08/20/08	20.30	68.55	91.10
08/21/08	21.41	70.54	93.22
08/22/08	19.73	67.51	103.80
08/23/08	22.98	73.36	99.66
08/24/08	18.33	65.00	87.53
08/25/08	16.87	62.36	87.29
08/26/08	16.71	62.08	89.69
08/27/08	17.63	63.73	91.69
08/28/08	20.44	68.79	103.80
08/29/08	18.66	65.58	103.15
08/30/08	18.87	65.97	92.67
08/31/08	19.07	66.33	95.68
09/1/08	19.84	67.71	93.87
09/2/08	23.93	75.08	96.06
09/3/08	17.14	62.85	87.17
09/4/08	16.41	61.54	96.52
09/5/08	12.31	54.16	103.35
09/6/08	14.21	57.58	101.41
09/7/08	13.65	56.58	103.80
09/8/08	14.86	58.75	103.80
09/9/08	9.60	49.27	103.80
09/10/08	13.11	55.60	103.80
09/11/08	17.33	63.20	103.80
09/12/08	19.39	66.91	103.80
09/13/08	18.94	66.09	103.80
09/14/08	16.94	62.50	103.80
09/15/08	12.40	54.31	103.23
09/16/08	12.58	54.65	94.42
09/17/08	15.53	59.95	94.77
09/18/08	16.34	61.41	99.12
09/19/08	17.32	63.18	99.32
09/20/08	16.24	61.23	96.65
09/21/08	15.34	59.62	95.64
09/22/08	17.29	63.13	98.63
09/23/08	18.09	64.56	103.80
09/24/08	18.86	65.95	100.03
09/25/08	14.31	57.75	103.80
09/26/08	16.24	61.23	103.80
09/27/08	16.95	62.50	103.80
09/28/08	17.00	62.60	99.61
09/29/08	15.25	59.45	103.80
09/30/08	11.56	52.81	100.12
10/1/08	0.75	33.36	93.04
10/2/08	-2.08	28.26	95.70
10/3/08	11.17	52.11	93.26
10/4/08	-2.68	27.18	95.01
10/5/08	14.46	58.02	96.13
10/6/08	17.59	63.65	98.63
10/7/08	15.21	59.37	98.18
10/8/08	-8.96	15.88	103.80

HOBO logger 1: inside container

DATE	AVG TEMP C	AVG TEMP F	AVG RH %
07/1/08	17.92	64.25	81.20
07/2/08	29.21	84.58	87.40
07/3/08	27.50	81.50	95.06
07/4/08	26.80	80.24	90.06
07/5/08	26.27	79.29	95.36
07/6/08	29.41	84.94	97.63
07/7/08	30.05	86.10	101.03
07/8/08	28.21	82.78	103.87
07/9/08	24.10	75.39	104.00
07/10/08	27.25	81.04	104.00
07/11/08	30.63	87.13	104.00
07/12/08	28.12	82.61	104.00
07/13/08	24.13	75.43	104.00
07/14/08	27.54	81.57	104.00
07/15/08	31.82	89.28	104.00
07/16/08	32.76	90.98	104.00
07/17/08	27.73	81.92	104.00
07/18/08	27.40	81.32	104.00
07/19/08	26.03	78.86	104.00
07/20/08	27.99	82.38	104.00
07/21/08	30.57	87.02	104.00
07/22/08	25.46	77.84	104.00
07/23/08	26.48	79.66	104.00
07/24/08	23.44	74.19	104.00
07/25/08	20.76	69.37	104.00
07/26/08	25.49	77.88	104.00
07/27/08	27.13	80.84	104.00
07/28/08	26.16	79.08	104.00
07/29/08	31.21	88.17	104.00
07/30/08	28.18	82.72	104.00
07/31/08	30.59	87.06	104.00
08/1/08	31.25	88.25	104.00
08/2/08	28.10	82.59	104.00
08/3/08	30.89	87.61	104.00
08/4/08	34.90	94.82	104.00
08/5/08	31.20	88.16	104.00
08/6/08	22.90	73.23	104.00
08/7/08	23.53	74.35	104.00
08/8/08	25.39	77.71	104.00
08/9/08	27.30	81.14	104.00
08/10/08	28.42	83.15	104.00
08/11/08	24.01	75.22	104.00
08/12/08	23.86	74.95	104.00
08/13/08	20.26	68.47	104.00
08/14/08	25.63	78.14	104.00
08/15/08	24.91	76.84	104.00
08/16/08	22.67	72.80	104.00
08/17/08	24.97	76.95	104.00
08/18/08	25.22	77.40	74.67
08/19/08	26.35	79.44	75.40

08/20/08	25.19	77.34	75.40
08/21/08	25.54	77.97	81.27
08/22/08	20.92	69.66	104.00
08/23/08	27.29	81.12	73.20
08/24/08	23.50	74.30	72.47
08/25/08	22.52	72.53	73.93
08/26/08	22.05	71.68	79.80
08/27/08	20.45	68.81	81.27
08/28/08	23.27	73.88	104.00
08/29/08	22.32	72.18	87.13
08/30/08	23.56	74.40	82.73
08/31/08	23.93	75.08	79.80
09/1/08	24.61	76.31	78.33
09/2/08	27.87	82.17	82.00
09/3/08	19.99	67.99	92.27
09/4/08	18.29	64.93	102.53
09/5/08	14.23	57.61	104.00
09/6/08	15.56	60.01	104.00
09/7/08	15.74	60.33	104.00
09/8/08	16.67	62.01	104.00
09/9/08	10.77	51.39	104.00
09/10/08	17.23	63.01	84.93
09/11/08	20.38	68.68	90.80
09/12/08	20.30	68.53	104.00
09/13/08	19.58	67.24	104.00
09/14/08	18.24	64.83	104.00
09/15/08	13.38	56.09	104.00
09/16/08	16.29	61.32	87.13
09/17/08	20.34	68.61	81.27
09/18/08	22.06	71.70	80.53
09/19/08	21.56	70.81	82.73
09/20/08	20.20	68.36	80.53
09/21/08	20.17	68.31	78.33
09/22/08	20.06	68.11	78.33
09/23/08	19.97	67.94	104.00
09/24/08	21.64	70.95	74.67
09/25/08	21.31	70.36	82.15
09/26/08	17.04	62.67	91.96
09/27/08	21.41	70.54	78.33
09/28/08	19.90	67.82	85.67
09/29/08	17.66	63.79	104.00
09/30/08	13.57	56.43	85.67
10/1/08	15.05	59.09	81.40
10/2/08	11.14	52.05	79.07
10/3/08	14.28	57.70	81.27
10/4/08	13.43	56.18	79.07
10/5/08	18.05	64.49	76.13
10/6/08	21.11	70.00	76.87
10/7/08	19.66	67.39	76.87
10/8/08	8.30	46.94	104.00

APPENDIX B

INSECT IDENTIFICATION & SUCCESSION

INSECT IDENTIFICATION

	Species
Blow flies	*Chrysomya rufifacies, Phormia regina,*
Muscid flies	*Synthesiomyia nudiseta*
Bottle flies	*Phaenicia coeruleiviridis, Phaenicia cuprina, Chryomyopsis cadaverina*
Flesh flies	*Sarcophaga haemorrhoidalis*
Scavenger flies	*Sepsis* sp.
Cheese skippers	*Piophilia casei*
Red-legged ham beetle	*Necrobia rufipes*
American carrion beetle	*Necrophila Americana*
Sexton beetle	*Nicrophorus orbicollis*
Hairy rove beetle	*Creophilus maxillosus*

INSECT ACTIVITY: SUBJECT 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Fly Egg							X	X	X	X										
Fly Larvae						X			X	X			X	X	X	X	X	X		
Adult Fly		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Beetle									X	X		X						X		

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Fly Egg	X	X	X		X															
Fly Larvae						X	X	X		X	X		X							
Adult Fly	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Beetle	X									X										

	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Fly Egg																				
Fly Larvae																				
Adult Fly	X	X	X	X	X	X	X	X	X					X			X	X		
Beetle																				

	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Fly Egg																				
Fly Larvae																				
Adult Fly							X	X				X								X
Beetle																				

	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Fly Egg																				
Fly Larvae															X	X	X	X	X	X
Adult Fly	X				X	X		X						X	X	X	X			X
Beetle	X						X													

INSECT ACTIVITY: SUBJECT 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Fly Egg						X		X	X				X							
Fly Larvae							X	X	X		X		X	X	X					
Adult Fly		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Beetle									X								X			

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Fly Egg																				
Fly Larvae																				X
Adult Fly	X	X	X	X	X	X		X	X	X	X	X	X	X	X		X	X	X	X
Beetle														X						

	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Fly Egg																				
Fly Larvae	X	X	X	X	X	X	X		X		X				X	X	X	X	X	X
Adult Fly	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X
Beetle			X												X		X	X		

	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Fly Egg																				
Fly Larvae	X	X	X	X	X	X	X		X					X	X				X	X
Adult Fly	X	X	X	X		X	X			X	X	X		X	X	X	X	X	X	X
Beetle	X	X		X		X				X	X			X		X	X	X	X	X

	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Fly Egg																				
Fly Larvae	X	X		X	X	X	X		X								X			
Adult Fly	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X			X
Beetle	X	X		X			X	X		X	X			X	X	X	X		X	

INSECT ACTIVITY: SUBJECT 3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Fly Egg							X	X	X	X									X	X
Fly Larvae						X	X		X	X	X	X	X	X	X					X
Adult Fly	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Beetle																X	X			

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Fly Egg	X	X	X																	
Fly Larvae	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Adult Fly	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Beetle			X							X				X	X		X			

	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Fly Egg																				
Fly Larvae	X	X	X	X		X				X				X	X	X	X	X		X
Adult Fly	X	X	X	X	X	X	X	X	X	X						X	X	X	X	X
Beetle							X		X					X	X		X			

	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Fly Egg																				
Fly Larvae		X	X	X	X	X	X	X	X											
Adult Fly	X	X	X		X		X			X	X	X			X	X		X	X	X
Beetle			X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X

	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Fly Egg																				
Fly Larvae																				
Adult Fly	X		X	X		X	X	X	X		X			X	X	X	X			X
Beetle	X	X		X	X	X	X	X	X	X				X	X	X	X	X		

INSECT ACTIVITY: SUBJECT 4

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Fly Egg				X	X	X	X	X	X	X										
Fly Larvae					X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Adult Fly	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Beetle						X							X	X	X		X			

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Fly Egg																				
Fly Larvae					X		X		X	X	X	X		X						
Adult Fly	X	X	X		X				X	X		X	X	X	X		X	X	X	X
Beetle		X																		

	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Fly Egg																				
Fly Larvae															X					
Adult Fly	X	X	X	X	X	X	X	X	X								X		X	X
Beetle								X										X		

	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Fly Egg																				
Fly Larvae																				
Adult Fly			X	X				X	X		X	X	X							X
Beetle					X															X

	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Fly Egg																				
Fly Larvae																				
Adult Fly	X		X		X	X	X	X	X			X			X	X	X	X		X
Beetle					X							X								

INSECT ACTIVITY: SUBJECT 5

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Fly Egg	X	X	X	X																
Fly Larvae	X	X	X	X	X	X	X	X	X											
Adult Fly	X	X	X			X	X	X	X	X	X	X	X				X	X	X	X
Beetle				X	X	X	X	X	X											

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Fly Egg																				
Fly Larvae																				
Adult Fly	X	X					X	X	X	X	X	X						X		
Beetle	X	X																X		

	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Fly Egg																				
Fly Larvae																				
Adult Fly																				
Beetle																				

	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Fly Egg																				
Fly Larvae																				
Adult Fly							X							X						
Beetle																				

	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Fly Egg																				
Fly Larvae																				
Adult Fly																X				
Beetle																				

APPENDIX C

DAILY DECOMPOSITION SCORES

BY SUBJECT

	SUBJECT				
DAY	**5 (Control)**	**4**	**3**	**2**	**1**
0	0	0	0	0	0
1	0	0			
2	0	0			
3	1	1			
4	2	1			
5	3	2			
6	4	2			
7	4	2			
8	4	2			
9	4	2			
10	4	2			
11	4	2			
12	4	3			
13	4	3			
14	4	3			
15	4	3			
16	4	3			
17	4	4			
18	4	4			
19	4	4			
20	4	4	2		
21	4	4	2		
22	5	5	2		
23	5	5	2		
24	5	5	2		
25	5	5	2		
26	5	5	2		
27	5	5	2		
28	5	5	2		
29	5	5	2		
30	5	5	3		
31	5	5	3		
32	5	5	3		
33	5	5	3		
34	5	5	3		
35	5	5	3		
36	5	5	3		
37	5	5	3		
38	5	5	3		
39	5	5	3		
40	5	5	3	3	
41	5	5	3	3	
42	5	5	3	3	
43	5	5	3	3	
44	5	5	4	3	
45	5	5	4	3	
46	5	5	4	3	
47	5	5	4	3	
48	5	5	4	4	
49	5	5	4	4	

50	5	5	4	4	
51	5	5	4	4	
52	5	5	4	4	
53	5	5	4	4	
54	5	5	4	4	
55	5	5	4	4	
56	5	5	4	4	
57	5	5	4	4	
58	5	5	4	4	
59	5	5	4	4	
60	5	5	4	4	
61	5	5	4	4	
62	5	5	4	4	
63	5	5	4	4	
64	5	5	4	4	
65	5	5	4	4	
66	5	5	4	4	
67	5	5	4	4	
68	5	5	4	4	
69	5	5	4	4	
70	5	5	4	4	
71	5	5	4	4	
72	5	5	4	4	
73	5	5	4	4	
74	5	5	4	4	
75	5	5	4	4	
76	5	5	4	4	
77	5	5	4	4	
78	5	5	4	4	
79	5	5	4	4	
80	5	5	4	4	4
81	5	5	4	4	4
82	5	5	4	4	4
83	5	5	4	4	4
84	5	5	4	4	4
85	5	5	4	4	4
86	5	5	4	4	4
87	5	5	4	4	4
88	5	5	4	4	4
89	5	5	4	4	4
90	5	5	4	4	4
91	5	5	4	4	4
92	5	5	4	4	4
93	5	5	4	4	4
94	5	5	4	4	4
95	5	5	4	4	4
96	5	5	4	4	4
97	5	5	4	4	4
98	5	5	4	4	4
99	5	5	4	4	4
100	5	5	4	4	4
TOTAL	460	441	286	232	80

REFERENCES

Adams, Bradley J. 2007. *Forensic Anthropology*. New York, NY: Chelsea House, An imprint of Infobase Publishing.

Adlam, Rachel E. and Tal Simmons. 2007. The effects of repeated physical disturbance on soft tissue decomposition: Are taphonomic studies an accurate reflection of decomposition? *Journal of Forensic Sciences* 52 (5): 1007-1014.

Amendt, Jens, Krettek, Roman, and Richard Zehner. 2004. Forensic Entomology. *Naturwissenschaften* 91: 51-65.

Anderson, Gail S. and Valerie J. Cervenka. 2002. Insects associated with the body: Their use and analyses. In: William D. Haglund and Marcella H. Sorg, eds. *Advances in forensic taphonomy: Method, theory, and archaeological perspectives*. Boca Raton, FL: CRC Press LLC. pp 173-200.

Anderson, Gail S. and NR. Hobischak. 2004. Decomposition of carrion in the marine environment in British Columbia, Canada. *Int J Legal Med* 118: 206-209.

Archer, Melanie S. 2004. Rainfall and temperature effects on the decomposition rate of exposed neonatal remains. *Science & Justice* 44(1): 35-41.

Associated Press. July 31, 2007. *4 Infants' remains found; mom charged*. Chicago Tribune (IL) page 3.

Baker, Brenda J., Dupras, Tosha L. and Mathew W. Tocheri. 2005. *The osteology of infants and children*. College Station, TX: Texas A&M University Press.

Bass, William M. 1997. Outdoor decomposition rates in Tennessee. In: William D. Haglund and Marcell H. Sorg, eds. *Forensic taphonomy: The postmortem fate of human remains*. Boca Raton, FL: CRC Press LLC. pp 181-186.

Bass, William M. 2006. Forensic anthropology. In: Werner U. Spitz. *Spitz and Fisher's medicolegal investigation of death*. Springfield, IL: Charles C. Thomas, Publisher LTD. pp 240-254.

Behrensmeyer, Anna K. 1978. Taphonomic and ecological information from bone weathering. *Paleobiology* 4(2): 150-162.

Binford, Lewis R. 1962. Archaeology as Anthropology. *American Antiquity* 28(2): 217-225.

Blau, Soren and Douglas H. Ubelaker. 2009. *Handbook of forensic anthropology and archaeology*. Walnut Creek, CA: Left Coast Press, Inc.

Brickley, Megan B. and Roxana Ferllini. 2007. *Forensic anthropology: Case studies from Europe*. Springfield, IL: Charles C. Thomas, Publisher LTD.

Bryman, Alan and Duncan Cramer. 2009. *Quantitative data analysis with SPSS 14, 15 & 16: A guide for social scientists.* London: Routledge.

Calcagno, James M. 2003. Keeping biological anthropology in anthropology, and anthropology in biology. *American Anthropologist* 105(1): 6-15.

Cattaneo, Cristina. 2007. The skeletal remains of a child, victim of organized crime: the study of postmortem interval, personal identification and cause and manner of death. In: Megan B. Brickley and Roxana Ferllini, eds. *Forensic anthropology: Case studies from Europe*. Springfield, IL: Charles C. Thomas, Publisher LTD. pp 137-150.

Centeno, N., Maldonado, M. and A. Oliva. 2002. Seasonal patterns of arthropods occurring on sheltered and unsheltered pig carcasses in Buenos Aires Province (Argentina). *Forensic Science International* 126: 63-70.

Cheetham, Paul N. and Ian Hanson. 2009. Excavation and recovery in forensic archaeological investigations. In: Soren Blau and Douglas H. Ubelaker, eds. *Handbook of forensic anthropology and archaeology*. Walnut Creek, CA: Left Coast Pres, Inc. pp 141-149.

DiMaio, Dominick J. and Vincent J. M. DiMaio. 2003. *Forensic pathology*. Boca Raton, FL: CRC Press LLC.

Dirkmaat, Dennis C., Cabo, Luis L., Ousley, Stephen D. and Steven A. Symes. 2008. New perspectives in forensic anthropology. *Yearbook of Physical Anthropology* 51:33-52.

Dix, Jay and Michael Graham. 2000. *Time of death, decomposition and identification: at atlas*. Boca Raton, FL: CRC Press LLC.

England, David B. 2006. *Post mortem interval and decomposition rates: biological observations and mathematical analyses.* Masters thesis: Oregon State University, Corvalis.

Finkelhor, David and Richard Ormrod. October 2001. Homicides of children and youth. *Juvenile Justice Bulletin* NCJ 187239. U.S. Department of Justice.

Galloway, Alison. 1997. The process of decomposition: A model from the Arizona-Sonoran Desert. In: William D. Haglund and Marcella H. Sorg, eds. *Forensic Taphonomy: The postmortem fate of human remains*. Boca Raton, FL: CRC Press LLC. pp 151-164.

Galloway, Alison, Birkby, WH., Jones, AM., Henry, TE. and BO. Parks. 1989. Decay rates of human remains in an arid environment. *Journal of Forensic Sciences* 34: 607-616.

Gill, Ginger J. 2005. *Decomposition and arthropod succession on above ground pig carrion in rural Manitoba.* Manitoba: Canadian Police Research Centre.

Gruner, Susan V. 2004. *The forensically important Calliphoridae (Insecta : Diptera) of pig carrion in rural North Central Florida.* Masters thesis: University of Florida, Gainesville.

Haglund, William D. and Marcella H. Sorg. 1997a. Introduction to forensic taphonomy. In: William D. Haglund and Marcella H. Sorg, eds. *Forensic taphonomy: The postmortem fate of human remains*. Boca Raton, FL: CRC Press LLC. pp 1-9.

Haglund, William D. and Marcella H. Sorg. 1997b. Method and theory of forensic taphonomic research. In: William D. Haglund and Marcella H. Sorg, eds. *Forensic taphonomy: The postmortem fate of human remains*. Boca Raton, FL: CRC Press LLC. pp 13-26.

Haglund, William D. and Marcella H. Sorg. 2002. *Advances in forensic taphonomy: Method, theory, and archaeological perspectives*. Boca Raton, FL: CRC Press LLC.

Hammersley, Martyn and Paul Atkinson. 2007. *Ethnography: Principles in practice.* New York, NY: Routledge.

Heron, Carl. 1996. Archaeological science as forensic science. In: John Hunter, Charlotte Roberts and Anthony Martin, eds. *Studies in crime: An introduction to forensic archaeology*. London: B T Batsford Ltd. pp 156-170.

Hewadikaram, Kamani A. and M. Lee Goff. 1991. Effect of carcass size on rate of decomposition and arthropod succession patterns. *Am. J. of Forensic Med. and Pathol.* 12(3): 235-240.

Hunter, John R. 1996. A background to forensic archaeology. In: John Hunter, Charlotte Roberts and Anthony Martin, eds. *Studies in crime: An introduction to forensic archaeology*. London: B T Batsford Ltd. pp 7-23.

Hunter, John R. and Margaret Cox. 2005. *Forensic archaeology: Advances in theory and practice.* New York, NY: Routledge.

Hunter, John, Roberts, Charlotte and Anthony Martin. 1996. *Studies in crime: An introduction to forensic archaeology*. London: B T Batsford Ltd.

Hyder, Margaret A. 2007. *A study on the rate of decomposition of carrion in closed containers placed in a shaded area outdoors in Central Texas.* Masters thesis: Texas State University, San Marcos.

Janaway, Robert C. 1996. The decay of buried human remains and their associated materials. In: John Hunter, Charlotte Roberts and Anthony Martin, eds. *Studies in crime: An introduction to forensic archaeology*. London: B T Batsford Ltd. pp 58-85.

Komar, Debra A. and Jane E. Buikstra. 2008. *Forensic anthropology: Contemporary theory and practice*. New York: Oxford University Press.

Kridel, Kristen and Karoun Demirjian. February 13, 2008. *Relative beat boy, 4, to death, charges say – Suspect made her kids help in beating, they tell police*. Chicago Tribune (IL) page 1 Metro section.

Kung, Hslang-Ching, Hoyert, Donna L., Xu, Jiaquan and Sherry L. Murphy. 2008. Deaths: final data for 2005. *National Vital Statistics Reports* 56(10). Hyattsville, MD: National Center for Health Statistics.

Love, Jennifer C. and Murray K. Marks. 2003. Taphonomy and time: Estimating the postmortem interval. In: Dawnie Wolfe Steadman, ed. *Hard evidence: Case studies in forensic anthropology*. Upper Saddle River, NJ: Pearson Education, Inc. pp 160-175.

Lyman, R. Lee. 1994. *Vertebrate taphonomy*. Cambridge, United Kingdom: Cambridge University Press.

Madrigal, Lorena. 1998. *Statistics for anthropology*. Cambridge, United Kingdom: Cambridge University Press.

Manhein, Mary H. 1999. Decomposition rates of deliberate burials: a case study of preservation. In: W.D. Haglund, M.H. Sorg. *Forensic Taphonomy: The postmortem fate of human remains*. Boca Raton, FL: CRC Press LLC. pp 469-481.

Mann, Robert W., Bass, William M. and Lee Meadows. 1990. Time since death and decomposition of the human body: Variables and observation in case and experimental field studies. *Journal of Forensic Sciences* 35: 103-111.

McGlone, John. and Wilson Pond. 2003. *Pig production: biological principles and applications.* New York: Delmar Learning.

Megyesi, Mary S., Nawrocki, Steven P. and Neal H. Haskell. 2005. Using accumulated degree-days to estimate the postmortem interval from decomposed human remains. *Journal of Forensic Sciences* 50 (3): 1-9.

Micozzi, Marc S. 1991. *Postmortem change in human and animal remains: A systematic approach*. Springfield, IL: Charles C Thomas.

Morton, Robert J. and Wayne D. Lord. 2002. Detection and recovery of abducted and murdered children: Behavioral and taphonomic influences. In: William D. Haglund and Marcella H. Sorg, eds. *Advances in forensic taphonomy: Method, theory, and archaeological perspectives*. Boca Raton, FL: CRC Press LLC. pp 151-171.

Nawrocki, Stephen P. 2009. Forensic taphonomy. In: Soren Blau and Douglas H. Ubelaker, eds. *Handbook of forensic anthropology and archaeology*. Walnut Creek, CA: Left Coast Pres, Inc. pp 284-294.

O'Brien, Tyler G. and Amy Kuehner. 2007. Waxing grave about adipocere: soft tissue change in an aquatic context. *Journal of Forensic Sciences* 52(2): 294-301.

Ortner, Sherry B. 1984. Theory in Anthropology since the sixties. *Comparative Studies in Society and History* 26(1): 126-166.

Payne, Jerry A. 1965. A summer carrion study of the baby pig *Sus scrofa* Linnaeus. *Ecology* 46: 592-602.

Payne, Jerry A. and Edwin W. King. 1968. Arthropod succession and decomposition of buried pigs. *Nature* 219: 1180-1181.

Payne, Jerry A. and Edwin W. King. 1969. Lepidoptera associated with pig carrion. *Journal of Lepidopterists' Society* 23(3): 191-195.

Platt, Richard. 2003. *Crime Scene: the ultimate guide to forensic science*. New York: Dorling Kindersley Publishing. pp 52-53.

Pond, Wilson G. and Katherine A. Houpt. 1978. *The biology of the pig.* New York: Cornell University Press.

Pond, Wilson G. and Harry J. Mersmann. 2001. *Biology of the pig.* New York: Cornell University Press.

Ritchie, Genevieve. 2005. *A comparison of human decomposition in an indoor and an outdoor environment*. Masters thesis: University of Tennessee, Knoxville.

Roberts, CA. 1996. Forensic anthropology 1: The contribution of biological anthropology to forensic contexts. In: John Hunter, Charlotte Roberts and Anthony Martin, eds. *Studies in crime: An introduction to forensic archaeology*. London: B T Batsford Ltd. pp 101-121.

Rodriguez, William C. III and William M. Bass. 1983. Insect activity and its relationship dot decay rates of human cadavers in East Tennessee. *Journal of Forensic Sciences* 28: 423-432.

Rodriguez , William C. III and William M. Bass. 1985. Decomposition of buried bodies and methods that may aid in their location. *Journal of Forensic Sciences* 30(3): 836-852.

Schoenly, Kenneth J., Haskell, Neal H., Mills, David K., Bieme-Ndi, Carine., Larsen, Kristie., and Yer Lee. 2006. Recreating death's acre in the school yard: Using pig carcasses as model corpses to teach concepts of forensic entomology & ecological succession. *The American Biology Teacher* 68 (7): 402-410.

Simmons, Tal and William D. Haglund. 2005. Anthropology in a forensic context. In: John Hunter and Margaret Cox, eds. *Forensic archaeology: Advances in theory and practice*. New York, NY: Routledge. pp 159-176.

Smith, Kenneth G. V. 1986. *A manual of forensic entomology*. London: The Trustees of the British Museum (Natural History).

Snow, Clyde C. 1982. Forensic anthropology. *Ann. Rev. Anthropol.* 11: 97-131.

Sorg, Marcella H. and William D. Haglund. 2002. Advancing forensic taphonomy: Purpose, theory, and process. In: William D. Haglund and Marcella H. Sorg, eds. *Advances in forensic taphonomy: Method, theory, and archaeological perspectives*. Boca Raton, FL: CRC Press LLC. pp 3-29.

Spitz, Werner U. 2006. *Spitz and Fisher's medicolegal investigation of death*. Springfield, IL: Charles C. Thomas, Publisher LTD.

Srnka, Carrie F. 2003. *The effects of sun and shade on the early stages of human decomposition*. Masters thesis: University of Tennessee, Knoxville.

Steadman, Dawnie. 2003. *Hard Evidence: case studies in forensic anthropology*. New Jersey: Prentice Hall.

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

Ubelaker, Douglas H. 2009. Historical development of forensic anthropology: Perspective from the United States. In: Soren Blau and Douglas H. Ubelaker, eds. *Handbook of forensic anthropology and archaeology*. Walnut Creek, CA: Left Coast Pres, Inc. pp 76-86.

Vass, Arpad A. 1991. *Time Since Death Determinations of Human Cadavers Utilizing Soil Solution*. PhD dissertation: University of Tennessee, Knoxville.

Voss, Sasha C., Forbes, Shari L. and Ian R. Dadour. 2008. Decomposition and insect succession on cadavers inside a vehicle environment. *Forensic Sci. Med. Pathol.* 4:22-32.

Walker, Cameron M. 2000. *A multidisciplinary approach to determining postmortem intervals in central Iowa.* Thesis: Iowa State University, Ames.

Wilczynski Ania. 1995. Child killing by parents: a motivational model. *Child Abuse Review* 4: 365-370.

Williams, Scott E. 2007. *Child's remains wash up in West Bay*. The Daily News.