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A MATTER OF TIME: AN ACTUALISTIC STUDY OF THE POSTMORTEM INTERVAL OF PIG DECOMPOSITION IN SOUTHEASTERN IDAHO

by

Michael Duffin

A thesis

submitted in partial fulfillment

of the requirements for the degree of

Master of Science in the Department of Anthropology

Idaho State University

Fall 2022

To the Graduate Faculty

The members of the committee appointed to examine the thesis of MICHAEL DUFFIN find it satisfactory and recommend that it be accepted.

Name,

Major Advisor

Name,

Committee Member

Name,

Graduate Faculty Representative

Idaho State University

September 14, 2022

Michael Duffin

1222 Freeman Lane 27 Pocatello, ID 83201

RE: IBC Inquiry form dated 10 October 2021 regarding study: A Matter of Time: An Actualistic Study of the Postmortem Interval of Pig Decomposition in Southeastern Idaho

Dear Michael Duffin:

The Institutional Biosafety Committee determined that your project did not need biosafety committee approval, so you were free to conduct your study immediately.

Sincerely,

Deb Easterly
Interim Chair of the IBC

Dedication

This thesis is dedicated to my wonderful, better halves, Ralyn and my son Trystan. I love you both so much, thank you for your continued support throughout graduate school. My family and their unwavering support. It is also dedicated to all my friends I’ve made along the way, fellow classmates, and everyone else who had a positive impact on my life.

Acknowledgements

I would like to thank Dr. Michael, Dr. Petersen, Dr. Reedy, Dr. Speer and the rest of the anthropology department for imparting their knowledge of anthropology throughout the years. I'd also like to thank both the Duffin and Casperson families for allowing me to conduct this research on their land for 285 days. I would especially like give a whole-hearted thank you to Dr. Samantha Blatt, my mentor and advisor, for her patience, guidance, and belief in myself throughout all of grad school. I couldn't have done it without your help. Finally, I'd like to give one special thank you to my dad, Chris Duffin, for being there every single day of research and just wanting to be part of my education.

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List of Abbreviations

ADD	Accumulated Degree Days
GPS	Global Positioning System
IBC	Institutional Biosafety Committee
IDFG	Idaho Department of Fish and Game
PMI	Post Mortem Interval
SD	Standard Digital
TBS	Total Body Score
UK	United Kingdom

List of Symbols

$\pm$	Plus, or minus
$>$	Less than
$\geq$	Less than or equal to
°	Degrees
~	Approximately

Abstract

The postmortem interval (PMI), aids forensic investigation of circumstances surrounding death by providing an estimation to narrow the time between the death event and body recovery via assessment of decomposition rate. The universality of decomposition rates remains highly contested, researchers agree that environmental specificity is fundamental to the predictability of PMI. Quantification of decomposition rates in various Intermountain West environments remain untested. Therefore, replication of PMI studies are needed in unique environmental contexts to articulate patterns of decomposition within that environment, while also reducing taphonomic biases that may occur in a given study. This project assessed the decomposition rate of *Sus scrofa* (domestic pig) as a human proxy in two microclimates, differing in elevation, located in Southeastern Idaho and tested accuracy with PMI predictions. Elevation differences and accuracy estimations were noted less than ideal, due to the fact that decomposition had stagnated on specimens.

Keywords: post mortem interval, decomposition, taphonomy, forensic anthropology, accumulated degree days.

Chapter I: Introduction

1.1 Background

At the onset of discovering a body, medio-legal and law enforcement authorities often seek the guidance of forensic anthropologists to help determine how long a body was exposed within an environment based on observations of decomposition. This is done by estimating the postmortem interval or PMI, which is the time between death and discovery of a body (Hachem et al., 2020). The PMI can be a point in time by which to examine alibis of crimes, victim movements/activities, shed light of manner of death, and an overall timeline ante-mortem (happening before before) and perimortem (happening around the time of death) events leading to a death and post-mortem events. Therefore, PMI is fundamental evidence for law enforcement as anthropologists explore new methods in attempts to estimate it (Hachem et al., 2020).

While there are patterns to rates of decomposition of the human body, there are also countless factors which can influence the appearance of those patterns. Factors that can influence decomposition include but are not limited to climate and weather (Behrensmeyer 1970), insect and animal activity, condition of the body, and type of deposition. So, while considerable research (Steadman 2018, Bolton 2014, Megyesi et al., 2005) has focused on estimation of PMI, these have highlighted the need for regional climate and scenario-specific models.

There are many examples in forensic anthropology of cases which highlight this need. A 1977 case of the renowned William Bass, in particular, led to the very first body farm in Tennessee, in which various factors influencing decomposition could be observed and studied. With this case, Bass underestimated the PMI of a Civil War Colonel by 112 years (Montgomery, 1999). In 2019, Dr. Michael and colleagues announced the identity of a homicide victim 103 years after his murder and cave burial in Dubois, Idaho (Michael et al., 2022). Noting that limited data in environmental contexts created difficulty in estimating PMI (Michael et al., 2022). Since the founding of the first body farm, most experimental research regarding decomposition rates have been in its capacity for multi-regional comparative studies (Wescott, 2018). To date, attempts in developing universal PMI estimation methods have found limited in success (Bunch 2009, & Christensen, et al., 2010). Research conducted by Marhoff et al. (2016) notes that data needs to be more regional based. Environmental effects on organic tissue are not uniform throughout the world, Marhoff et al. (2016) argue, different environments will influence decomposition differently; this observation led to the establishment of the first body farm in Australia to understand decomposition within this regional context (Marhoff et al., 2016).

Furthermore, little is understood about how high desert environments, which encompass numerous microenvironments in various elevations with unique terrain and vegetation, affect progression of decomposition and PMI estimation. This leaves law enforcement and victims in such environments, like Idaho, at a disadvantage.

1.2 Aims and Objectives

The primary objective of this proposed research is to help narrow and estimate the PMI, the time since death, of decedents recovered from environments like south east Idaho. Secondary objectives are to determine if distance in the aspect of both horizontal and vertical scales will yield different results on test subjects within different environments.

1.3 Research Questions

Since this research explores the potential effects environmental factors can impact carcasses, it is my assumption that a difference in elevation and distance between sites will possess temperature differences. These differences might be enough to impact the rate at which decomposition occurs at each site. I propose two primary research questions listed below as the driving force of this project:

1. Are Megyesi et al (2005) ADD calculations appropriate to the southeast Idaho environment?
2. Will elevation significantly impact the rate and pattern of decomposition in southeastern Idaho?

1.4 Thesis Outline:

This thesis is a culmination of taphonomy and taphonomic studies to utilize this discipline in a manner to provide data to southeastern Idaho. This chapter introduces the importance of taphonomic research and establishes two research questions for this study. Chapter 2 highlights the background of taphonomy and also delves into relevant studies conducted in the field in relation to the research conducted in this thesis. Chapter 3 is a presentation of the methods and materials employed during research and data collection. Results of the research will be presented in Chapter 4 to observe both qualitative and quantitative analysis. Chapter 5 will be an interpretation of the results section, and will address each research question, limitations of the study, and future suggestions.

Chapter II: Literature Review

Understanding taphonomy and decomposition has been one of many objectives for anthropologists. There is extensive work and research that formulate new methods to more accurately depict how decomposition may occur in a local environment. More so, there are ongoing debates that argue which is the correct species to use for decomposition studies. Since this study uses pigs as a means to understand decomposition within South Eastern Idaho, various studies exploring the effects of weather, environmental factors, and various species will be explored within this chapter. Furthermore, a history of the study alongside key developments will also be useful in this research.

2.1 Taphonomy

Early foundations of taphonomy predate the modern era of anthropology and date back to Leonardo da Vinci. da Vinci, controversially at the time, used samples to infer that local fossils found in nearby mountain ranges were not moved due to the result of biblical nature, but the species had actually existed in the area before passing (Martin, 1991). However, taphonomy was first coined in 1940 by Ivan Efremov as the "study of transition of organic remains from the biosphere into the lithosphere" (Behrensmeyer and Kidwell, 2000: 103). Originally, taphonomy emerged as a new field of paleontology and paleoecology, with aspirations to unite the field with sedimentology (Martin, 1991). These attempts were initially to study modes of transport, fossilization, amongst other processes earlier species went through (Milliken, 2014).

There are several processes that must occur for an organism to be transported into the lithosphere—outer soil layer of the earth—after death (Britannica., 2020). Biological and geological processes transport organic remains into a new context (area) (Ubelaker, 1997). These processes can alter the remains and are influenced various factors including (Ubelaker, 1997: 77):

1. Animals interact with remains by scavenging, gnawing, and digestion of remains; yet they can also trample or fall on them as well, and

2. Physical factors of alteration occur with natural causes of the earth, these include but are not limited to: rockfall, water transport, sand blasting, weathering, burial, volcanic materials, etc.

After these processes occur, bodies are now within a context which can be studied to gain insight of how they got there and what happened to them during their placement.

2.2 Taphonomic Theory

Taphonomic theory within anthropology has been borrowed from other disciplines. One of the foundational pieces in taphonomy is rooted with the geological law of superposition, which states that in the sequence of rock layers, the youngest layers are found on top and the oldest are found at the bottom (Hamblin, 1978). This is supplemental to soil analysis when elements are observed to see if any disturbances have occurred in the soil from where a decedent may be found (Fitzpatrick, 2008). The principle of uniformitarianism is another theory borrowed by taphonomic studies, but with a twist (Pokines, 2010). That is, the application is more concerned with bone-altering processes being similar in contemporary times to past processes (Pokines, 2010). Paleobiologist Ralph Johnson (1960) helped shape early taphonomic theory with his *Models… of Formation of Fossil Assemblages*. Johnson proposed three models of transportation of remains into their contexts; Model I is concerned with the more sudden burial of life assemblage, Model II is a slower process that occurs to organisms living around the site, Model III are assemblages that occur strictly out of transportation—such as water carrying parts of remains away from their original sites (Johnson, 1960: 1078-79).

2.3 Soil Analysis

Soil research in forensic taphonomy dates back to 1856, where analysis was first used to help solve a crime of missing coins replaced by sand. This was done by comparing sand at the scene with other locations until it was discovered where the sand had originated from—and the coins stolen (Fitzpatrick, 2008). Since then, many reliable techniques have been utilized to help discern the origin of collected samples (Fitzpatrick, 2008). This data can be extremely useful in aiding forensic research where very little information is known, like southeast Idaho. Soil analysis is useful because of morphological characteristics (Schoeneberger et al., 2002). Forensic anthropologists will analyze the soil for any external foreign contaminants that do not match the original soil found in a given location (Fitzpatrick, 2008). If there are any inconsistencies in a soil sample surrounding a discovered burial, it can be assumed the location is a potential crime scene (Fitzpatrick, 2008).

2.4 Forensic Taphonomy

Forensic Taphonomy is specifically focused on post mortem changes in human remains and environmental influences of those changes (Pokines and Symes, 2014). This includes factors and patterns of decomposition and how those factors may inform predictions of PMI. In the 1970's, studies using what is known as vertebrate taphonomy, helped with shaping anthropologic understandings of the taphonomic processes (Dirkmaat, et al., 2008). Dirkmaat et al. (2008) cite that the 1970's also yielded two key findings for the field. First, Taphonomy was seen as a transformative method no longer strictly binding it to paleontological studies (Dirkmaat et al., 2008). This is because the study became increasingly accepted in other subdisciplines within anthropology, specifically archaeology and practices within the discipline could benefit greatly from it (Dirkmaat et al., 2008). The second development comes about from what is referred to as the "unification or marriage of taphonomy and anthropology". The goal of this was to remove "palaeoecological information from the overprint derived from site formation and postmortem alteration processes' ' (Dirkmaat et al., 2008: 38). Overprint is defined as taphonomic biases which may occur in certain contexts. These biases are created by a variety of processes (weathering, staining, scavenging, for example) that can overlap in appearance with how they appear or impact remains; these biases may impede accurate identification (Lyman, 1994). Reducing these biases with thorough analysis can create a more accurate understanding as to what might have naturally occurred to a decedent.

One example of the anthropological use of taphonomy is Behrensmeyer's (1978) development of a six-stage scoring system of bone weathering This method allows more standard documentation of the environmental exposure of bone in relation to time. These stages range from less than one year to upwards to 25 years. Bone surfaces are rated on severity of weathering; stage 0 entails no obvious signs of damage to the skeleton which may be categorized as cracking or flaking of bone material caused by weathering. Whereas the opposite end of the spectrum, stage 5, can be observed as skeletal remains falling apart in-situ (or the original place) (Behrensmeyer, 1978).

Studies specific to of forensic taphonomy began to take shape in the 1980's as forensic archaeologists had a need to determine the time span since death (i.e., PMI) and the sequence of how human skeletal remains entered a forensic context (Dirkmaat and Passalacqua, 2012). Early forensic anthropologists like Krogman (1962) and Stewart (1979) began their work addressing issues on a more global scale. The scope of their studies ranged from the identification of remains caught in a mass disaster to those involved in mass murders (Iscan, 1988). The early works of these scholars on forensic taphonomy further enabled biological anthropologists to apply these methods to medicolegal investigations that dealt with looking at remains for police investigations at both the local and national scale (Iscan, 1988).

2.5 Decomposition

Understanding how decomposition occurs and the physical changes a body progresses through is vital to taphonomic studies and also forensic anthropologists aiding in medicolegal work. Decomposition is a progression, characterized by qualitative and sometimes quantitative traits that are either observed or assigned to a body. Qualitative descriptors of decomposition can be attributed to Marks et al. (2009), noting that the destruction of the body is a process which encompasses the “fresh body, skeletal remains, and beyond” of organisms (Marks et al., 2009: 168). Marks et al. (2009) notes a twofold process of decomposition occurring with organisms: internal and external decomposition. External decomposition is seen as being “highly competitive… between moisture and aridity that progressively reduces remains” (Marks et al. 2009: 168). Whereas internal decomposition details cellular death catalyzed by bacteria seeking to further break down remains (Marks et al., 2009). A combination of both qualitative and quantitative traits can be observed in Megyesi et al.’s (2005) work by utilizing in a manner that transforms qualitative data—observed on the physical remains—into quantitative; assigning it a numeric score that best reflects those observations as a composite score.

Decomposition can be further described by two additional driving forces, autolysis and putrefaction (Almulhim and Menezes, 2022). Autolysis occurs during cellular death and the release of “hydrolytic cellular enzymes” (Almulhim and Menezes, 2022). Putrefaction follows, once conditions are set for microbes (bacteria, fungi, etc.) to come in and further break down tissue structure within an organism (Almulhim and Menezes, 2022).

Decomposition is also categorized into various stages by Megyesi et al. (2005), Marks et al. (2009), and Cockle and Bell (2017) wherein each stage is marked by distinctive qualitative traits the body must possess before passing into the next stage. The number of stages vary upon research being conducted, specimens used for the study, and the area in which the study takes place (Cockle and Bell, 2017). Stages can be as little as four (Megyesi et al., 2005) and even up to eight (Cockle and Bell, 2017). For this thesis research, four categories of decomposition will be explained and adopted from Megyesi et al. (2005: 621):

Fresh decomposition

Fresh decomposition is understood that there are no observable changes on the body that are indicative of the flesh turning color or losing its functional structure.

Early decomposition

For early decomposition to occur, discoloring of the flesh begins. Instances of skin slippage or marbling will also become visible. Depending on the area of the body, fluids may begin to leak from extremities on the specimen (head, anus, eyes, etc.) or bloating may also become visible over time.

Advanced Decomposition

Characteristics of advanced decomposition can be observed once the skeleton becomes slightly visible; however, it is important to note that this occurs when it is visible on only less than half of the observed area. Furthermore, it is possible for areas of the remains to mummify during advanced decomposition as well.

Skeletonization

Once decomposition has progressed to a degree where any given portion of the observed body has more than half of the skeleton exposed, is when the decomposition process has entered its final stage, skeletonization. However, even within this category, skeletonization is still a progression system. This means that bones exposed in this area may still possess tissue, fluids, and grease or may become completely dry over time.

2.6 Forensic Entomology

Aiding in the analysis of decomposition comes with the knowledge of Entomology (study of insects) can also provide key insights into PMI estimation on remains (Wescott, 2018). Presence of certain species on remains can be indicative of PMI, due to the nature of when the species are expected to appear, interact with remains, and then leave (Lutz et al., 2021). Common species that appear on a corpse are the "*Diptera",* also known as the house fly, this occurs very early in the decomposition process—as little as 72 hours up to a couple of weeks. (Bolton, 2014: 7-8). In succession, beetles will also appear on the corpse, but it may take roughly four weeks before they appear on the remains (Bolton, 2014). However, the appearance of insects is variable based on several environmental conditions such as, weather, humidity, wind, precipitation, etc. (Wescott, 2018). While entomology was considered as part of the methodology of this thesis, very little insect activity occurred (as will be discussed in the results), so details of how insects are part of forensic PMI investigations will be limited here.

2.7 Accumulated Degree Days (ADD)

Accumulated degree days (ADD) refers to the sum of consecutive average daily temperatures to correlate stages of decomposition (Vass et al., 1992; Megyesi et al., 2005; Myburgh et al. 2013). The ADD represents the heat energy units needed to drive a biological process (Megyesi et al., 2005). Since biological processes halt or slow in freezing temperatures Megyesi et al. (2005) employ a baseline temperature at 0 ºC.

Estimation of ADD is fundamental to estimating the PMI since time, temperature, and humidity have been shown to be the most important factors in decomposition (Galloway et al. 1989; Vass et al. 1992; Megyesi et al. 2005). Calculation of ADD for estimating PMI is based on a scoring system of decompositional stages as outlined by Galloway et al. (1989) and modified by Megyesi and colleagues (2005) who utilized a scoring system known as the total body score (TBS). This TBS is then used as a means to transform qualitative data into quantitative. Within the results of their research, it was discovered that a PMI estimation based on ADD was more accurate (up to 95%) when applying their decomposition scoring method (Megyesi et al., 2005). A total of 68 individuals from across the United States were used in order to build this calculation (Megyesi et al., 2005).

In order to understand the TBS, it is best explained as three separate areas of the body for analysis (head/neck, trunk, and limbs) create a total score; for example, if the head/neck scored a 7, the trunk scored an 8, and the limbs a 4, the TBS would equal 19 in that given moment of time based on observations (Megyesi et al. 2005). This score is then placed into an algorithm developed by Megyesi et al (2005: 623):

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

In order to calculate the ADD (Figure 1), the TBS of 19 would need to be placed into the equation to result in ADD $=10^{(0.002*19*19\pm1.81)} \pm 388.16$. The result would give the ADD of roughly 340 days $\pm$ 388.16 (as this number acts as the standard error) (Megyesi et al., 2005: 624).

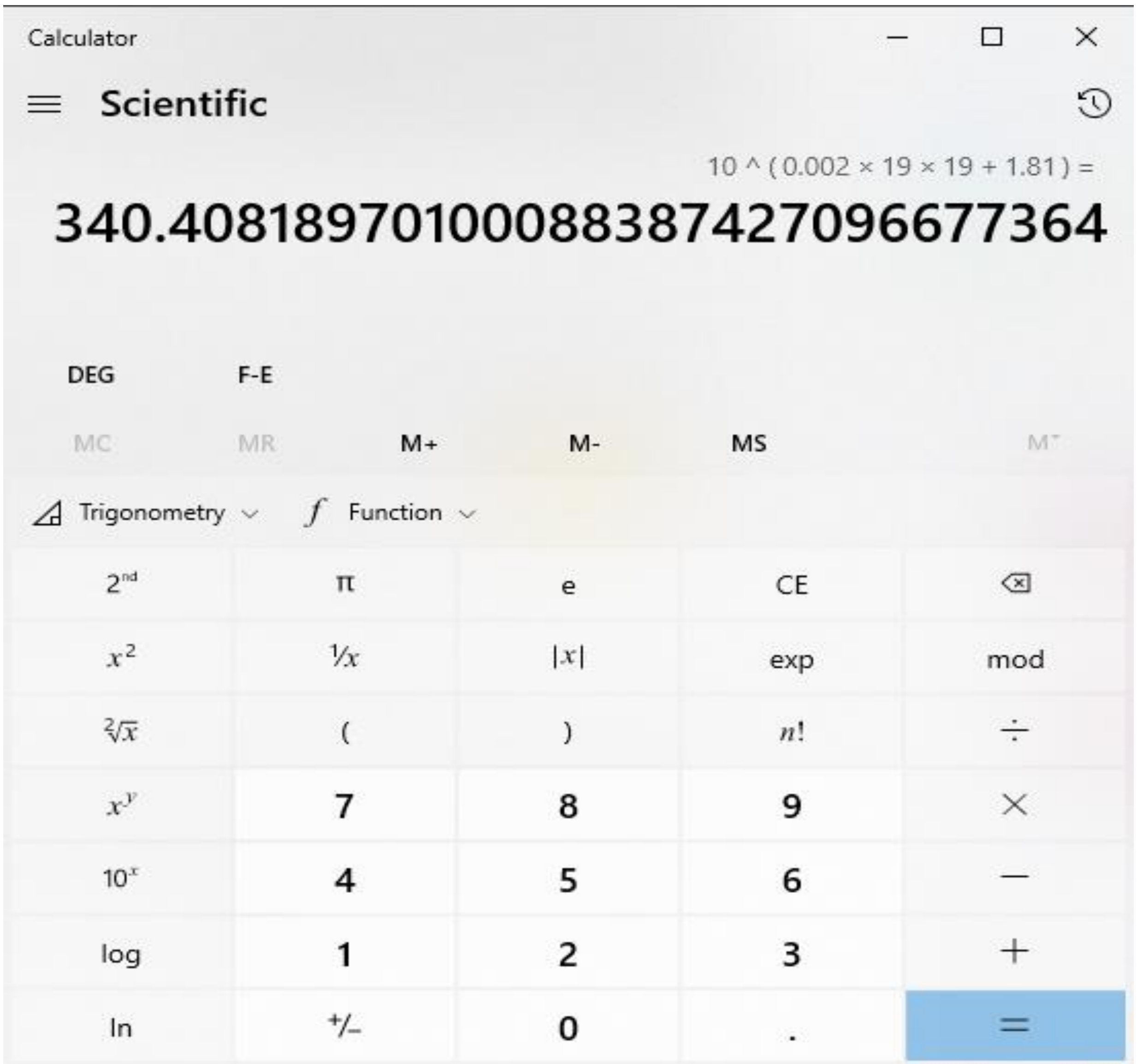


Figure 2.1- Calculator showing how the score can be achieved for Megyesi et al.'s, (2005) algorithm.

The PMI and ADD estimation are dependent upon the environment and context of where the remains are found, which is one of the research questions of this research. This dependency is articulated within Marhoff et al.'s (2016) article, environments— "microclimates within this context—have been argued to require analysis and research, "that are specific to different microclimates…where distinctive environmental conditions of a region have affected the determination of key investigative factors such as PMI" (Marhoff et al., 2016: 24). Thus, one of the goals of understanding taphonomy is being able to recognize these pieces of information, collectively. Taphonomy can be understood by forensic anthropologists to further aid in the interpretations surrounding death, "determining what happened to those remains in the interval from death to analysis (Pokines and Symes, 2014: 2)."

2.8 Review of Relevant Literature

As alluded above, extensive research has been conducted to document processes and patterns of human decomposition and also the taphonomic process. The following section aims to contextualize recent developments in the field that yield information about decomposition in general. In particular, research at the Anthropological Research Facility at the University of Tennessee (known as the Body Farm) has been varied and productive (Blau 2017). Body farms are unique because of the opportunities they present to a number of disciplines, ranging from anthropologists to crime scene investigators. These environments remain controlled, and various testing conditions are done to teach about decomposition using a "holistic sensory experience" (Blau 2017: 484).

2.8A Pigs (and others) as Proxies

In 2018, Steadman conducted taphonomic research using 45 subjects—15 each –of various proxies (rabbits, sus scrofa, and human remains) over the course of three seasons (spring, summer, and winter) to record decomposition located at the Anthropology Research Facility. Steadman's research utilized TBS, insect activity, and ADD to observe "quantitative morphological comparisons between species during decomposition" (Steadman 2018: 3-4). The collection for each trial lasted until a total of 2000 accumulated degree hours were met. Steadman (2018) notes that photos and insect collection lasted until about 45 days, around the time that most of the subjects had undergone through skeletonization processes (Steadman 2018). Trends in decomposition of each species were compared, noting that the decomposition of rabbits occurred much earlier than the human and pig proxies (Steadman, 2018: 6). Other important characteristics were observed around day 25, with insect activity beginning to occur in both pig and human subjects. However, it still took the humans much longer to skeletonize than their pig and rabbit counterparts (Steadman, 2018).

Insect activity in Steadman's (2018) trial also produced varying results. Insect activity was more pronounced during the second trial, paying more attention to both pig and rabbit proxies over the human subjects. Scavenging activity was also recorded within this study by "racoons, skunks, birds, and opossum", with most activity occurring during the third trial. Steadman (2018) noted that while both pigs and rabbits had evidence of scavenging activity, most occurred on the human subjects. Ultimately, based on these trends , it was concluded that humans serve as the best proxy for determining patterns of decomposition within human remains themselves found in forensic cases and contexts (Steadman, 2018). However, it is implied that pigs might serve a close second being able to determine the "carrion insects within an environment, noting that the faster decomposition rates make both pig and rabbit proxies, not as desirable (Steadman, 2018: 9-10)."

Matuszewski et al. (2020) also addressed two sides of the argument of using *Sus Scrofa* as appropriate proxies in determining environmental effects on decomposition for human remains. Noting that animal models have been used to help with our understanding of ourselves and advancements since "the ancient Greek times" (Matuszewski et al., 2020: 794). Use of the domesticated pig is credited to Payne (1965) who noted several criteria as suitable test subjects. These included that from pig cadavers: it was easiest to know the time of death, they were the easiest to acquire for study in the first place, and that the similarities of their skin and subcutaneous fat to humans made them the most suitable models (Matuszewski et al., 2020). It is cited that this research prompted forensic entomologists to begin implementing the *Sus Scrofa* in their own studies, granting understandings of "seasonal variation to insect activity that influence decomposition (Matuszewski et al., 2020: 794)."

Yet, critiques will always be present when looking at comparative analysis and choosing between which species might be more closely representative of human decomposition. The decomposition of any species depends on various factors, including weight, size, and other physical characteristics (Matuszewski et al., 2020). These traits, depending on the species, will no doubt be different from humans, but will also influence the ways it will decompose (Matuszewski et al., 2020). However, Matuszewski et al. (2020) cite that these decompositional differences are necessary; it enables researchers ability to address various degrees of decomposition such as speed or which insect colonies may influence the process as well (Matuszewski et al., 2020).

Many of the reasons why forensic anthropologists will gravitate towards using pigs as proxies are much similar to Payne’s (1965) reasoning. Acquisition of pig remains is relatively inexpensive, more abundant, and enables the ability to recreate studies (Matuszewski et al., 2020). Furthermore, there exists a more “uncontrolled and unpredictable nature” in even gaining access to human cadavers due to donations going to several other locations or facilities (Matuszewski et al., 2020: 800). Matuszewski and colleagues (2020) conclude that pigs will likely remain candidates for studies due to “being more readily available, more uniform in size and age, and less ethically complex to deploy” (Matuszewski et al., 2020: 808).

Additionally, Taylor (2011) studied four pigs in an attempt to validify the accuracy of Megyesi’s PMI estimation in the UK . This work compared the anatomy of humans and pigs against one another, notating that similarities can be observed in terms of “organ structure and bones” (Taylor, 2011: 7). Therefore, while pigs may not be an exact representation of human biology, and how humans decompose, we can have a baseline of data that may suggest the rate if the cadaver was instead human.

2.8B Staining

Studies addressing taphonomic traces left on remains can also be viable pieces of information due to the context where a body may be discovered and the information it can yield. Environmental contexts can alter organic material ranging between bone breakages, scattering, weathering, and even staining (Behrensmeyer, 1978; Dupras and Schultz, 2013). Understanding how a variety of traces seen on remains are different, is pivotal knowledge to understanding decomposition. This is because environments can leave modifications that may mimic other forms of alterations. Dupras and Schultz (2013) conveys this well, highlighting the importance of color and what each color might signify due to its appearance on remains. They note that staining of organic remains can be due to several factors, ranging from other organic materials, metals, and various soils all coming in contact with the remains (Dupras and Schultz, 2013). The standard color of a skeleton will typically possess a "yellowish-white to yellowish-brown appearance (Dupras & Schultz, 2013: 316)." Any deviation from this will be indicative of the context of where the remains were found and also, aid in identifying how environments influenced decomposition (Dupras & Schultz, 2013). Therefore, a bone that exhibits a more vibrant white color may signify exposure to UV light for some time, whereas remains that have staining with color ranging from red and brown to black or even blue, could be indicative of certain soils (Dupras & Schultz, 2013).

2.8C Regional Studies

Specific impacts of arid environments have also been observed to affect decomposition in Galloway et al.'s 1989 study conducted in southern Arizona. A total of 470 individuals were used in this study to observe the decomposition sequences found. (Galloway et al., 1989). Sample size was then cut to 189 individuals to determine the kinds of decomposition based upon photographic evidence collected during the autopsy or by the anthropological team (Galloway et al., 1989). Scoring applied the decomposition categories: "fresh, early decomposition, advanced decomposition, skeletonization, and decomposition of skeletal material" (Galloway et al., 1989: 608). Within this warmer arid climate, the conditions dehydrated the organic material and caused them to mummify (Galloway et al., 1989).

Research in environments closely related to southeastern Idaho are limited. Pig decomposition was observed in Montana, however, where Parsons (2009) outlined the impact of the environment to test the accuracy of Megyesi et al.'s (2005) equation. Parsons' (2009) research lasted approximately 250 days, collecting data ranging from temperature, ADD, PMI, insect activity, etc.. Parsons (2009) also applied TBS following Megyesi et al.’s (2005) guidelines, but ultimately suggested that more research needed to be done in this environment to test accuracy.

Insect activity is also impacted by the temperatures within this area as most of the most common species observed do not prefer the heat (Galloway et al., 1989). Therefore, the laying of larva has higher failure rates unless the insects can access remains without any impediments (Galloway et al., 1989). Due to these complications, decomposition may not be influenced by insect activity within the warmer months, but during the winter the warm sun “aided the development process (Galloway et al., 1989: 612).”

Studies investigating the applicability and accuracy of these tests have come into the scene, and rightfully so. With the advent of body farms, regional contexts are only viable for certain areas. Thus, what is discovered in one context may not be suitable for estimating decomposition at sites across the country or even the globe. Region-based studies haven’t really “had their applicability tested in other regions” so, currently it is unknown if one method developed would even work for another region (Marhoff et al., 2016: 25).

Microclimates are proposed within this study to address concerns about environmental variability (Marhoff et al., 2016). Microclimates are small-scale environments/niches that are a representation of a larger region or environmental context; microclimates are ideal choices in estimating the variability of PMI effects within regions that have various characteristics (such as mountains, forests, marshes, plains, deserts, etc.) (Marhoff et al., 2016). This allows researchers to compare various aspects of decomposition within a context to another, mountain versus desert or forest versus plains (Marhoff et al, 2016). Another main component within this study are the effects temperature (Marhoff et al., 2016) would have upon PMI estimations. So, establishing these distinctions can give anthropologists even more knowledge about taphonomic processes and variables that naturally are expected within results.

Chapter Summary

Because of the potential information that taphonomy can yield on remains within various contexts and how each may influence decomposition, it remains important to address how decomposition occurs within new localized areas. The intent of this chapter was to give historic insight to taphonomy, discuss relevant studies, and highlight the discipline's attempt to understand the decomposition process. This understanding is not only for the benefit of anthropology as a whole, but law enforcement and other disciplines may also find useful information based upon continued research. The research of this thesis is an attempt to employ concepts and ideas from the studies mentioned within this chapter to understand decomposition in microclimates located in southeastern Idaho.

Chapter III: Methods and Materials

In order to study decomposition within southeastern Idaho, two microclimates served as the decompositional scenes for this project (Figure 2). Each microclimate, hereafter referred to as Sites, were chosen because of differing elevations. Each site is situated on private land and access to each was granted according to special instructions. These areas are located near two cities within South Eastern Idaho, McCammon (Site 1) and Lava Hot Springs (Site 2), respectively. Access to each site was achieved via driving and then walking to where each specimen was located.

Figure 3.2. Map of Research Sites. Site 1 (McCammon) and Site 2 (Lava Hot Springs) are located in Bannock County, south eastern Idaho.

Study Areas

Site 1 (Figure 3) is located on farmland in McCammon Idaho. It is approximately 139 meters east from the landowner's home. The elevation of the site is approximately 1425 meters in elevation above sea level, located at 42 degrees north and 122 degrees west on GPS at its lowest point in elevation. Site 1 was chosen because of its distance away from farm animals at the owner's request.

The fauna surrounding this area includes white tail deer, wolves, coyotes, mountain lion, and the local farm animals ranging from, house cats, dogs, horses, and cows (IDFG, 2022). There are also small scavengers consisting of: hawks, eagles, owls, mice, muskrats, and other rodents. The local terrain can be described as marshlands that are covered in weeds. Marsh Creek runs nearby, roughly six meters north of Site 1.

Figure 3.3. View of Site 1, McCammon Idaho.

Site 2 (Figure 4) is located 152 meters off of Interstate-30, near the city of Lava Hot Springs, Idaho and nearly 13 miles east from site 1. The site is approximately 130 meters higher in elevation than site 1 or 1555 meters above sea level. The GPS coordinates are: 42 degrees, 24' North and 122 degrees, 05' W. The local terrain can be described as desert, there are a lot of dry trees and pine trees in the area; most of the vegetation is grass and sagebrush. The local fauna in this area is somewhat similar to site 1, consisting of local farm animals, dogs, horses, cats, whereas, the wild animals are white tailed deer, coyotes, mountain lions, foxes, racoons, groundhogs, skunks, and other rodents (IDFG, 2022).

Figure 3.4: View of *Site 2*, Lava Hot Springs Idaho.

Climate History:

Climate history data (2020) was observed via the National Weather Service (2022) database prior to data collection. Table 1 displays the monthly average temperature of each site. While there are minor differences in temperatures, ranging from 1 °F to up to 6 °F between each location, the historical data suggested that Site 1 (McCammon) was on average warmer than Site 2 (Lava Hot Springs) supporting assumptions made in chapter 1.3, that there would be a temperature difference between each location.

Table 3.1: 2020 Monthly Avg. Temperature data derived from National Weather Service (2022-a & 2022-b).

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Site 1 (2020)	29.0 °F	27.0 °F	40.3 °F	46.0 °F	55.5 °F	60.7 °F	68.3 °F	69.9 °F	60.0 °F	48.9 °F	35.0 °F	29.2 °F
Site 2 (2020)	28.0 °F	23.2 °F	34.8 °F	41.8 °F	53.5 °F	60.4 °F	67.2 °F	70.0 °F	58.2 °F	46.7 °F	33.7 °F	23.1 °F

Test Subjects

For this study, two juvenile domestic pigs (*Sus scrofa*) were used as proxies for human cadavers, donated by Casperson family's farm. Due to the similarity between organ tissue and structure, skin thickness and composition, lack of hair, and gut fauna to humans, pigs have been considered ideal proxies for human decomposition in many studies (Payne 1965; Matuszewski 2018). Each was euthanized with a .22 rifle by the previous owners prior to donation and being placed in the field. The specimens were received and then placed in their respective sites on

Monday October 18th, 2021, in the late morning and early afternoon for analysis of decomposition to begin.

The specimens were relatively small in size, Specimen 1—located at Site 1—was roughly 27 inches long, measuring from snout to tail using a tape measurer, and weighed approximately 38 lbs. Specimen 2—located at site 2—was approximately the same length measuring at 26 inches in length and also weighing 37.6 lbs. Initial temperature readings were also taken of each specimen before being placed into their sites. This was done by using an AMES Instrument 12:1 Infrared laser Thermometer (Figure 5), as the planned meat thermometer could not penetrate the skin effectively for readings. Specimen 1 had an initial body temperature of 65 ºF degrees, while Specimen 2 was 66.4 ºF degrees, respectively.

Figure 3.5—Infrared thermometer used for specimen temperature recordings.

Data collection focused mostly during the Fall and Winter 2021. These seasons were chosen for research because they represent a very important transitional point in Southeastern Idaho weather; temperatures and conditions are expected to drop considerably during these seasons (see Tables 1 and 2). Spring and summer dates are also represented in this research, but in limited capacity as physical changes slowed down around spring time.

While the Institutional Biosafety Committee (IBC) did not need to approve the project (see letter on page iii) safety measures for handling the specimen were still considered. Rubber gloves, masks, and goggles were donned before each specimen was placed into 33" x 24" medium sized dog kennels that were then tied shut using metal wiring. This was to ensure that no large animals could interfere with the specimens or move them. Each specimen was also placed in a manner where they would still be exposed to direct sunlight.

Security of Sites

Due to concerns of bringing in predators onto farmland, each owner expressed that remains are placed in a location that is substantially farther away from their farm animals. Each specimen was placed in a dog kennel enclosure. The enclosures (Figure 6) served to deter domesticated animals, like horses and cattle, from interacting with remains during periods of grazing.

Figure 3.6—Enclosure of site 1 (McCammon), research subject 1.

Data Collection Protocol

Weather Data

Temperature data was collected using a Kestrel data weather logger (Figure 7). The data was recorded using the Kestrel mobile app and also notated with pen and paper on each visit to research sites. The temperatures were then compared to the data captured by the Pocatello Regional Airport Station's radar (Weather Underground, 2022-a and 2022-b) in order to test the accuracy of the data logger and for documentation purposes involving the calculation of the ADD and PMI (Megyesi et al, 2005). After the final day of research, temperature data from the data logger and Pocatello Regional Airport Stations were entered into an excel data sheet for comparison.

Figure 3.7—Image of the Kestrel weather data logger.

Scavenger Activity

Two Campark Trail Camera-Waterproof 16MP 1080P Game Hunting Scouting (infrared motion triggered) cameras were used to record and detect any wildlife that may interact with the carcasses. The data is important throughout the first fifteen days of decomposition, when scavengers are likely most active, scat containing bone fragments will be collected in a 20-meter radius from each site (Micozzi, 1991). Camera data was checked weekly or when batteries needed to be replaced.

Soil analysis

Soil samples were collected each visit from both sites, adjacent to each specimen. Moisture and Ph were recorded with every sample using a soil moisture reader. Ph levels from each day only produced a level of 1 on the reader. Samples were then placed into specimen bags to reduce the amount of contamination that can interact with soils. The moisture and Ph recordings were stored within Dr. Blatt's lab, with recordings of the soil's morphological traits as noted by the characteristics noted by Fitzpatrick (2008) for future studies and therefore will not be discussed further in this thesis.

Insect Activity

Two pit-fall insect traps were dug approximately 12 cm. deep and 16 cm. in diameter on the west and south sides of each site's enclosure, and 40. cm. away from the carcass (Figure 8). Tupperware filled with antifreeze was then placed in each hole to collect insects from the traps and nets in an attempt to collect any insects interested in the specimens during the research duration. During recurring visits, each was cleaned and refilled every third day or when weather had flushed them out. When collection moved to a more bi-weekly approach, the traps were cleaned and replaced upon each visit.

Figure 3.8—image showing the insect traps left in order to attempt to capture any wandering to the specimen

Physical Characteristics: Decomposition Scores (TBS) and Accumulated Degree Days (ADD)

One aim of this study is to determine whether ADD, TBS and estimated PMI are accurate and viable to apply to specimens decomposing in southeastern Idaho. This was done employing Megyesi et al. (2005) equation, first by applying qualitative descriptors and then quantitatively solving the equation. Decomposition of pig carcasses were observed in four stages following Megyesi et al.'s (2005) qualitative descriptions, to notate the process of decomposition in arid environments during the study duration (see Tables 2, 3, 4**)**. Remains were discarded in compliance with Idaho State University's Institutional Biosafety Committee (IBC) which concerns itself with protecting students and faculty from any potential hazards or dangers that one may come into contact with when dealing with decaying remains.

Table 3.2. Categories and stages of decomposition for the head and neck derived from Megyesi et al (2005).

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

Table 3.3. Categories and stages of decomposition for the trunk derived from Megyesi et al (2005).

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

Table 3.4. Categories and stages of decomposition for the hands/feet derived from Megyesi et al (2005).

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

In order to calculate PMI, Megyesi's (2005) method using ADD was employed. Each carcass was scored daily using each of the four stages of decomposition as a guide. Each stage is descriptive, divided into scored categories of decomposition (Tables 4-6), transforming qualitative into quantitative data. Since decomposition rate varies among body parts, major areas (the head and neck, the trunk, and the limbs) are scored independently. The summed scores represent the total amount of decomposition is recorded as the TBS (Megyesi et al., 2005; Payne, 1965). The TBS is then entered into the following equation (where 388.16 is the standard error of the regression) (Megyesi 2005):

$$Log10ADD = 0.002(TBS*TBS) + 1.81 +/- 388.16$$

This result is the number of ADD needed for each carcass to reach the state of decomposition. Figure 1 demonstrates how the calculation works. To calculate the PMI, daily temperatures were calculated from the nearest weather station and the data loggers and working backwards. These temperatures were then added until the accumulated sum from the equation is reached. The estimated PMI (date of death) is the day the accumulated sum of the equation is reached (Megyesi et al., 2005).

The scores were recorded by hand using pen and paper before being transferred into a digital format. Over 600 digital photos (roughly 300 for each site) were taken in order to corroborate the confidence of each score. All scores were also entered into an excel data sheet where they were compared to note when each specimen transitioned into the next phase of decomposition. Accuracy of the estimated PMI was checked by dividing the estimated PMI value by the actual PMI (or how long the research subjects were out for):

$$\text{Accuracy} = \frac{\text{Estimated PMI}}{\text{Actual PMI}}$$

For example, if the estimated PMI produced a value of 16 days and the actual PMI was 32, this would produce an accuracy rating of approximately 50%. The closer both the estimated PMI is in relation to the actual PMI, the higher the % of accuracy rating.

Chapter Summary

This chapter introduced the methods and materials employed for this study. Research specimens were introduced and their characteristics notated. Security of the remains were also detailed and the reasons as to why security was even required. Qualitative descriptions of the research locations and weather data for each location are also mentioned, in an attempt to notate differences between sites. Furthermore, this chapter served to introduce how data was collected, stored, and double checked. It also highlights how qualitative observations of decomposition can be transformed into a quantitative value for analysis to calculate decomposition. Finally, this chapter discusses how the accuracy can be checked for the estimated PMI versus the actual PMI, this helps in determining if the data is reliable in our area.

Chapter IV: Results

The results presented within this work are a culmination of visits between the months of October 2021 until Late December 2021, totaling 65 days of data collection until inclement weather prevented observations (December 22, 2021). Observations continued in the spring of 2022 after inclement weather cleared up, but at less frequent intervals until summer 2022. In this chapter I will present the qualitative data for each specimen. Qualitative data is represented by photographic pictures that a) displays characteristics for when each specimen entered into a stage of decomposition, b) the total body score of the specimen for the stage, and c) physical descriptions of each new stage. I will also present the Quantitative data collected throughout the study as well. The quantitative data is to note temperature readings recorded at each site compared to regional data. The temperature readings are then used to calculate the ADD with the TBS values assigned for each specimen. Finally, this chapter also calculates accuracy ratings of Megyesi et al. (2005) PMI estimations by representation of consistent collection for the fresh and early stages of decomposition and then an additional three dates chosen that represent later stages of decomposition.

4.1 Qualitative Analysis of the Stages of Decomposition (Specimen 1)

Specimen 1 Fresh Decomposition:

Figure 4.9—Specimen 1 within the controlled environment.

Specimen 1 (Figure 9) was placed down in the McCammon research location at approximately 11:02 am on 18 October 2021. Local conditions were cloudy, with the temperature at the time being 65.9º Fahrenheit and 35.8% humidity. This fresh stage continued until October 22nd, 2021, when bloating and early colorization changes began to occur.

Early Decomposition

Figure 4.10- Specimen 1 Head and Neck Showing early signs of bloating.

Specimen 1 began showing signs of bloating around the head and neck regions placing that particular area of the body into the early decomposition stage on October 22nd, 2021 (day 4). Not all portions of the body had entered early decomposition at this time. According to Megyesi et al (2005), portions of the body can remain in earlier decomposition stages while others may progress faster. Figure 10 displays bloating on the neck and head for Specimen 1; at this stage a TBS value of 4 was assigned (2 for the head and neck, 1 for the trunk, and 1 for the limbs, respectively).

Figure 4.11- Various parts of Specimen 1's body can be seen changing in color adopting a more "late" early decomposition stage.

The early stage of decomposition for Specimen 1 lasted until the 27th of November 2021 (day 42). During this time frame, Specimen 1 exhibited color changes (from blue to green). Blood coagulated in the mouth attracting maggots, and the neck ruptured producing a small hole (Figure 11). The final TBS score within this category was a total of 14 with colorization retaining a black/brownish color and the stomach adopting a more post bloat appearance and changing in color adopting a green and black hue as seen above.

Advanced Decomposition

Figure 4.12- Both head (left) and trunk (right) possess various openings allowing for entry of maggots.

On November 28th (day 43) the specimen entered into advanced decomposition. This is due to the eyes on the head caving in and the trunk (lower stomach specifically) decomposing. Specimen 1 stayed in this category for the remainder of the research period. Due to the physical characteristics displayed, Specimen 1 would have a TBS of 16 before snowfall and would retain this score until spring once all the snow would melt (Figure 12). During Spring 2022, (Figure 13) a score of 21 was assigned to Specimen 1, due to each region (head, trunk, and limbs) of the body entering advanced decomposition. A final TBS value of 25 was given to Specimen 1 at the end of the research (day 285). Ultimately, Specimen 1 had mummified over the course of roughly 9 months of environment exposure (Figure 14).

Figure 4.13—Specimen 1 further advanced decomposition phase-due to mummification earning a TBS of 21

Figure 4.14- Final day of research showcasing that Specimen 1 had reached mummification and a TBS score of 25.

4.2 ***Qualitative Analysis of the Stages of Decomposition (Specimen 2)***

Fresh Decomposition

Figure 4.15- Showcasing the Fresh decomposition stage of Specimen 2

Specimen 2 (Figure 15) was placed at the Lava Hot Springs research location at approximately 12:30 pm on 18 October 2021. Local conditions were cloudy, with the data logger reporting the temperature at the time being 64.1 ºF degrees and 34.4% humidity. This stage would continue until October 23rd, 2021 (day 5), when bloating was first observed on the neck, lips, and snout.

Early Decomposition

Figure 4.16—Specimen 2 entering early decomposition on the head, due to the snout, mouth, and neck bloating.

Specimen 2 entered early decomposition (Figure 16) on the 23rd of October 2021 (day 5) and would stay in within this stage until the 28th of November 2021 (day 43). Bloating around the neck and snout would be the first indication of early decomposition (Figure 16). Specimen 2 would go through colorization changes near the neck and trunk (figure 17) around November

15th , 2021 (day 30) The final TBS value assigned for Specimen 2, for the early decomposition phase, was 14 (Figure 17).

Figure 4.17—Specimen 2 showing bloating more consistent throughout the body and adopting a green hue under the neck and on the stomach region, staying within the early decomposition phase.

Advanced Decomposition

Figure 4.18—Specimen 2 entering the early advanced stages of decomposition on the head due to the eyes caving in, snout/mouth degrading, and throat caving in.

Advanced decomposition began for Specimen 2 on the 28th of November 2021, but only in one category, the head (Figure 18) due to the eyes caving in and the mouth taking on a more mummified appearance due to weathering. Like Specimen 1, Specimen 2 would shift through various colors during this time frame adopting blue, green, and even dark purple hues. The hind legs began to develop a dark almost brown color near the rump which would last for the remainder of the study. On November 28, Specimen 2 was scored with a TBS of 15 according to Megyesi's et al (2005) due to a variety of physical changes experienced by the head, trunk and limbs—this was the final score given before snowfall occurred. This score would not change until April 15th, 2022, (day 179) when the remains entered a later advanced decomposition stage due to the thawing and increase in ambient temperatures. The TBS of Specimen 2 would be updated to a 21 due to extreme mummification experienced on the head, trunk, and limbs (Figure 19). A final score of 24 would be assigned to Specimen 2 on July 30th (day 285) the last day of research, due to the more extreme mummification appearances on the body (Figure 20).

Figure 4.19—Specimen showcasing advanced—mummification—stages of decomposition in the spring of 2022

Figure 4.20—Final day of research of Specimen 2 earning a final TBS of 24 due to mummification and even some bone exposure on the lower mouth.

4.3 Additional Results

Insect activity

The four insect traps that were used at each site in an attempt to collect wandering insects near each specimen, ultimately failed in their function. Neither trap captured insects that could be brought back for identification and analysis. The only observable insect activity would be maggots (figure 12).

Trail Camera Data

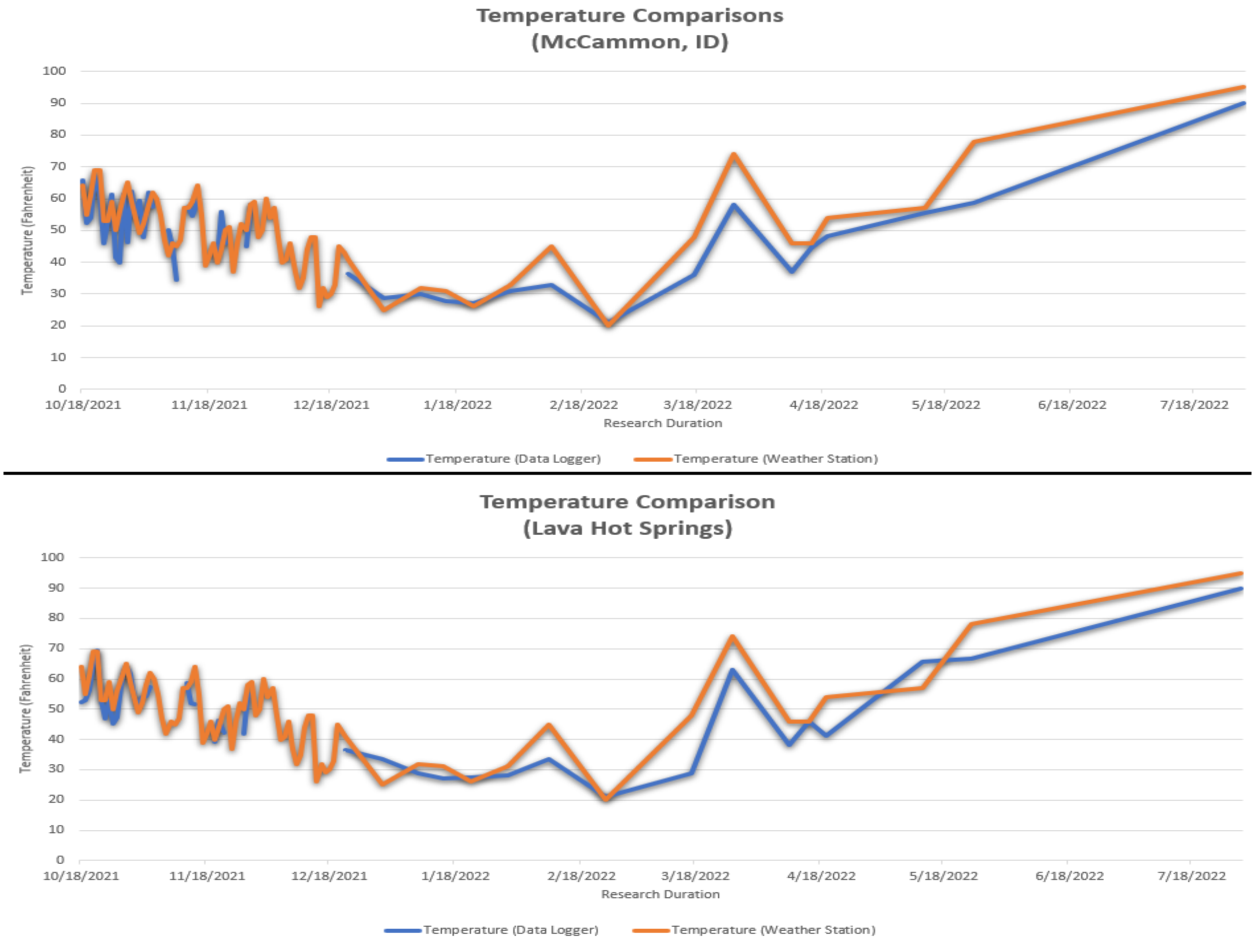
The trail cameras that were placed at each site also failed to capture any data that might reveal any animal interactions with the remains. The SD cards had a technological malfunction causing the data to become corrupt and unusable.

4.4 Quantitative Analysis of Recorded data

Weather/Temperature data

Temperature data is necessary in order to calculate the ADD and also determine the accuracy of Megyesi's (2005) ADD and PMI calculation. When comparing the daily temperature, the readings from the data logger versus the Pocatello Regional Airport Station's radar, display some discrepancies in dates throughout the duration of the research (Table 5). Both recordings were placed into an excel datasheet to make comparisons between the two research sites (Tables 6 and 7). Daily readings between data logger and radar reporting would remain relatively close in temperature, however on rare occasions recordings could produce discrepancies of upwards of 12 ºF degrees differences between the two.

Table 4.5—Temperature recording comparison Site 1 and 2. Data Logger (blue) and Weather radar (orange) (Weather Underground 2022-a & 2022-b).



Specimen temperatures

Specimen surface temperatures were also recorded (Tables 6 and 7) to note any major changes from ambient temperature, on several occasions the specimen's surface temperature deviated from the local recordings. One example can be seen by comparing both the total average of specimen temperatures to radar collected temperatures over the course of 18 days, which produces approximately a two-degree (Fahrenheit) difference.

Table 4.6. Site 1: Daily average temperature for days 1 – 18 (local, recorded using data logger, and pig temperature) and the total TBS for that date (Weather Underground, 2022-b).

Date	TBS	Temperature (Data Logger)	Temperature (Weather Station)	Pig temperature
10/18/2021	3	65.9 °F	64 °F	65 °F
10/19/2021	3	52.4 °F	55 °F	65 °F
10/20/2021	3	54 °F	61 °F	60 °F
10/21/2021	3	67 °F	69 °F	62 °F
10/22/2021	8	61.2 °F	69 °F	55 °F
10/23/2021	8	45.8 °F	53 °F	50 °F
10/24/2021	8	52.6 °F	53 °F	54 °F
10/25/2021	8	61.2 °F	59 °F	43.5 °F
10/26/2021	8	41.4 °F	50 °F	55.4 °F
10/27/2021	8	39.9 °F	56 °F	48 °F
10/28/2021	8	61.2 °F	61 °F	64.2 °F
10/29/2021	8	46.4 °F	65 °F	64 °F
10/30/2021	9	62.1 °F	59 °F	71.1 °F
10/31/2021	9	54.3 °F	54 °F	45.3 °F
11/1/2021	10	59.3 °F	49 °F	50.7 °F
11/2/2021	10	48 °F	52 °F	49 °F
11/3/2021	10	62 °F	58 °F	55 °F
11/4/2021	10	57.3 °F	62 °F	52 °F

Table 4.7. Site 2: Daily average temperature for days 1 – 18 (local, recorded using data logger, and pig temperature), and the total TBS for that date (Weather Underground, 2022-a).

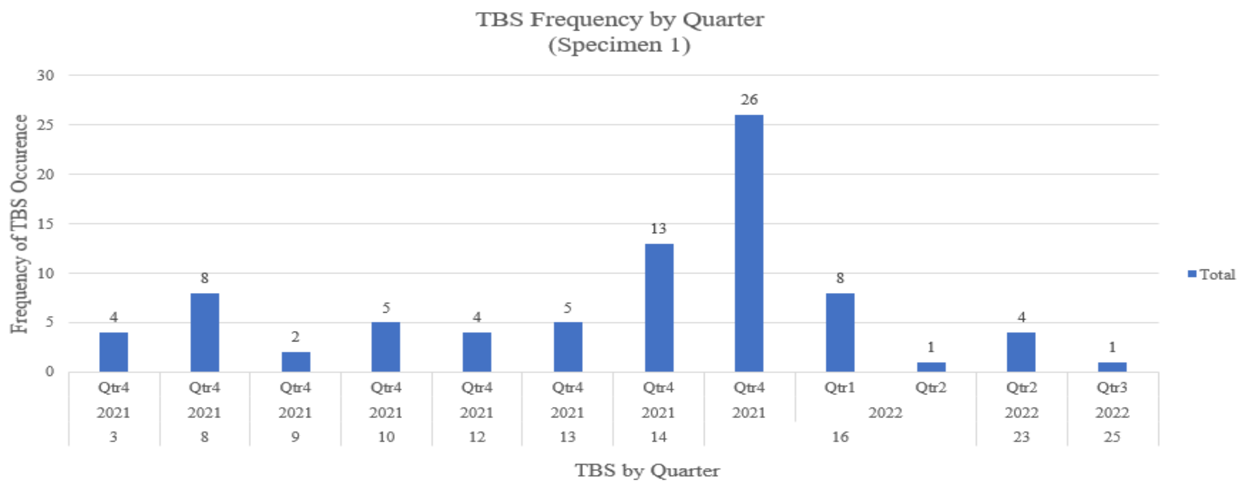
Date	TBS	Temperature (Data Logger)	Temperature (Weather Station)	Pig temperature
10/18/2021	3	64.1 °F	64 °F	66.4 °F
10/19/2021	3	53 °F	55 °F	65 °F
10/20/2021	3	56.4 °F	61 °F	60 °F
10/21/2021	3	65.4 °F	69 °F	65.4 °F
10/22/2021	3	69.3 °F	69 °F	52 °F
10/23/2021	7	53.1 °F	53 °F	50 °F
10/24/2021	7	47 °F	53 °F	54 °F
10/25/2021	7	53 °F	59 °F	47.8 °F
10/26/2021	7	45.4 °F	50 °F	41.2 °F
10/27/2021	7	47.4 °F	56 °F	40.6 °F
10/28/2021	7	61.1 °F	61 °F	50.7 °F

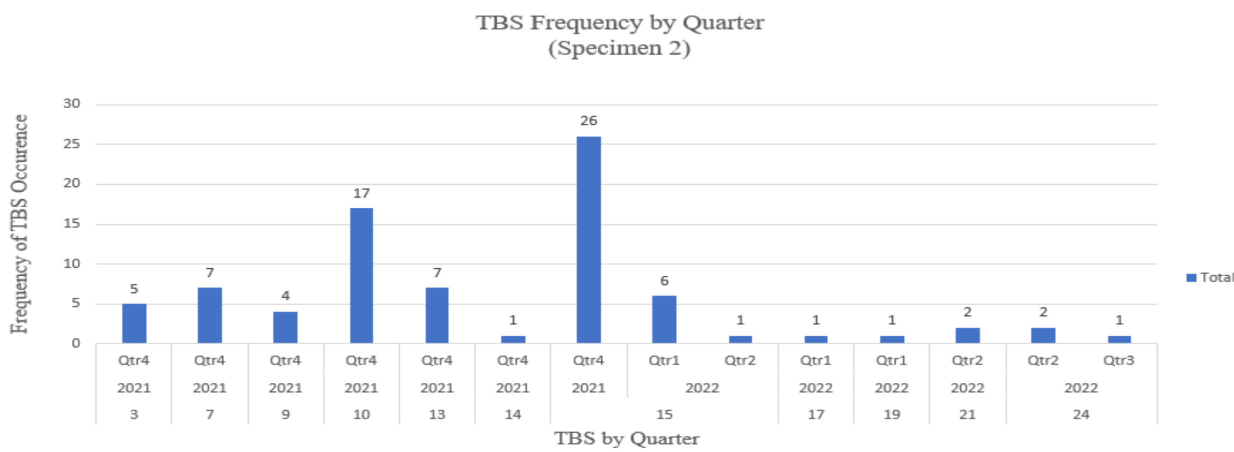
10/29/2021	7	64.5 °F	65 °F	39.2°F
10/30/2021	9	61.7 °F	59 °F	60 °F
10/31/2021	9	54 °F	54 °F	45.6 °F
11/1/2021	9	51 °F	49 °F	47.1 °F
11/2/2021	9	54 °F	52 °F	50.3 °F
11/3/2021	10	54.3 °F	58 °F	51 °F
11/4/2021	10	57.4 °F	62 °F	53.1 °F

Total body scores (TBS)

TBS were assigned and recorded on every visit of the study based upon the qualitative requirements needed for a particular part of the body to reach a stage of decomposition—outlined by Megyesi et al. (2005). Numerical TBS are an integral part of calculating both the ADD and PMI as they represent the “independent variable” in Megyesi’s calculation to be squared and then used to calculate the ADD (Megyesi et al., 2005:623). As the study progressed, the TBS changed incrementally for each specimen, but didn’t rapidly change even though daily temperatures ranged from low 50’s °F to mid-60’s °F. Table 8 illustrates the stagnation of TBS values and therefore, decomposition. Both specimens possessed a similar score with Specimen 1 (TBS:16) and Specimen 2 (TBS:15) retaining these values through three quarters, appearing over 30 times for each specimen during this time period. The TBS wouldn’t change into the 20’s—more advanced stages of decomposition—until around spring 2022. Table 8 also highlights both the TBS scores each specimen received in each respective quarter of the year; it also highlights the frequency at which the scores appeared.

Table 4.8—TBS Frequency by quarter for Specimen 1 and 2 showing how long each phase of decomposition lasted.





Calculating the ADD and PMI

Score calculations for ADD are based on using the first 18 days of the study and then also an additional three times to test the accuracy of Megyesi et al.'s equation. I tested the accuracy using the predicted PMI (Megyesi et al.'s 2005 equation) and comparing it to the actual PMI (the duration of the research). Dates were chosen for two reasons: 1) Assigning a higher TBS became irregular past the first 18 days, as visual observations didn't warrant assigning a new score, thus data collection moved from a daily to biweekly process, and even less due to inclement weather.

Therefore, the first accuracy testing is to highlight consistency in collection. 2) While the main focus of the study was for the fall and winter time frame, the research progressed on the decision to test accuracy in warmer seasons. The second set of accuracy testing is a representation of the less frequent visits and to test PMI in a similar fashion—these dates were chosen in intervals of when each specimen was in a different stage of decomposition. It is important to note that the results from each section do not represent a concrete accuracy of Megyesi et al.'s equation, but only what was observed from this research; therefore, accuracy is specific to the dates chosen and the observations made to warrant such scores.

Assuming that the first day of research is a null value for this data (because we want to count backwards) we can see that accuracy varies upon several conditions (Table 9**)**. Considering that Megyesi's equation uses a standard error of regression of $\pm$ 388.16 extra degree days, this can produce negative ADD values, for each day. This would mean the specimen entered its context several days before I actually placed the specimen at each research site and would not be accurate. Applying the standard error of regression creates some interesting results for accuracy—in the sense of using both the high end and low end of each date (adding or subtracting the 388.16-degree days to the estimated result from the calculation). In order to reflect this in terms of ADD, a range is created for those values but also values for PMI as well. This demonstrates that the equation is estimating that the body could be out for less than or equal to one day (Table 9: date 10/19/2021) or more for each subsequent date. It is important to note that the body scores (Table 9) are relatively low, this is indicative of fresh and early decomposition stages, and are consistently producing negative ADD and also PMI values.

Days 1-18 accuracy testing (Specimen 1)

For the first 18 days of study (Table 9), the most accurate estimation of the PMI begins around day 6 (approximately 85%), continues to gain accuracy for the next 2 days (up to 100%), but then loses accuracy (between 3 to 9% daily) over the remaining course of this sample. This is likely due to the fact that the TBS doesn't significantly change for a majority of this sample. For context, table 11 displays a duration of eight days (October 22, 2021, through October 29, 2021) where the TBS sat at a value of 8; thus, creating a reflection of accuracy rating when the TBS doesn't change due to observational decomposition appearing unchanged.

Table 4.9—Specimen 1. Calculated ADD estimate vs actual PMI of the first 18 days of study (Weather Underground, 2022-b).

Date	TBS	ADD	Temperature (F) Weather Station	Predicted PMI	Actual PMI	Accuracy
10/18/2021	3	-322 to 454 ADD	64	null	1 day	null
10/19/2021	3	-322 to 454 ADD	55	≥ 1 day	2 days	0%
10/20/2021	3	-322 to 454 ADD	61	≥ 1 day	3 days	0%
10/21/2021	3	-322 to 454 ADD	69	≥ 1 day	4 days	0%
10/22/2021	8	-301 to 475 ADD	69	≥ 1 day	5 days	0%
10/23/2021	8	-301 to 475 ADD	53	≥ 1 day	6 days	0%
10/24/2021	8	-301 to 475 ADD	53	> 1 to 7 days	7 days	~85%
10/25/2021	8	-301 to 475 ADD	59	> 1 to 7 days	8 days	~100%
10/26/2021	8	-301 to 475 ADD	50	> 1 to 8 days	9 days	~100%
10/27/2021	8	-301 to 475 ADD	56	> 1 to 8 days	10 days	~89%
10/28/2021	8	-301 to 475 ADD	61	> 1 to 8 days	11 days	~80%
10/29/2021	8	-301 to 475 ADD	65	> 1 to 8 days	12 days	~73%
10/30/2021	9	-294 to 482 ADD	59	> 1 to 8 days	13 days	~67%
10/31/2021	9	-294 to 482 ADD	54	> 1 to 8 days	14 days	~62%
11/1/2021	10	-286 to 490 ADD	49	> 2 to 8 days	15 days	~57%
11/2/2021	10	-286 to 490 ADD	52	> 2 to 8 days	16 days	~53%
11/3/2021	10	-286 to 490 ADD	58	> 2 to 8 days	17 days	~50%
11/4/2021	10	-286 to 490 ADD	62	> 2 to 8 days	18 days	~47%

Days 1-18 accuracy testing (Specimen 2)

Following suit with Specimen 1, Specimen 2's PMI accuracy was also tested for the first 18 days of study. (Table 10**)**. The estimated PMI of Specimen 2 remains relatively similar to that of specimen 1 even with minor changes in the TBS. Values remained at three for the fresh decomposition stage lasting from October 18th, 2021, until October 23rd, 2021. In the early stage of decomposition, Specimen 2's TBS value of seven would be observed for a total of seven days.

Table 4.10— Specimen 2. Calculated ADD estimate vs actual PMI of the first 18 days of study (Weather Underground, 2022-a).

Date	TBS	ADD	Temperature (F) Weather Station	Predicted PMI	Actual PMI	Accuracy
10/18/2021	3	-322 to 454 ADD	64	null	1 day	null
10/19/2021	3	-322 to 454 ADD	55	> 1 day	2 days	0%
10/20/2021	3	-322 to 454 ADD	61	> 1 day	3 days	0%
10/21/2021	3	-322 to 454 ADD	69	> 1 day	4 days	0%
10/22/2021	3	-322 to 454 ADD	69	> 1 day	5 days	0%
10/23/2021	7	-307 to 469 ADD	53	> 1 day	6 days	0%
10/24/2021	7	-307 to 469 ADD	53	> 1 to 7 days	7 days	~85%
10/25/2021	7	-307 to 469 ADD	59	> 1 to 7 days	8 days	~100%
10/26/2021	7	-307 to 469 ADD	50	> 1 to 8 days	9 days	~100%
10/27/2021	7	-307 to 469 ADD	56	> 1 to 8 days	10 days	~89%
10/28/2021	7	-307 to 469 ADD	61	> 1 to 8 days	11 days	~80%
10/29/2021	7	-307 to 469 ADD	65	> 1 to 8 days	12 days	~73%
10/30/2021	9	-294 to 482 ADD	59	> 1 to 8 days	13 days	~67%
10/31/2021	9	-294 to 482 ADD	54	> 1 to 8 days	14 days	~62%
11/1/2021	9	-294 to 482 ADD	49	> 2 to 8 days	15 days	~57%
11/2/2021	9	-294 to 482 ADD	52	> 2 to 8 days	16 days	~53%
11/3/2021	10	-286 to 490 ADD	58	> 2 to 8 days	17 days	~50%
11/4/2021	10	-286 to 490 ADD	62	> 2 to 8 days	18 days	~47%

Selective accuracy testing (Specimen 1)

Estimation of the PMI, in terms of selected dates, also produced less than 40% accuracy readings when compared to the actual PMI of the specimen. Dates were chosen due to varying differences in TBS scores which would represent a different stage in decomposition (early and advanced are represented). Thus, to represent differences in stages the dates, 11/15/2021, 4/15/2022, and 7/30/2022 (Final day) were chosen (Tables 11-13).

Table 4.11—11/15/2021 Predicted PMI vs actual PMI. Early decomposition. TBS = 14

Calculated ADD	159 ADD
Estimated ADD (Megyesi et al. 2005)	-229 ADD – 547 ADD
Estimated PMI	1 to 10 days (up to 34% accurate)
Actual PMI	29 days

Table 4.12—04/15/2022 Predicted PMI vs actual PMI. Advanced decomposition. TBS = 24

Calculated ADD	916 ADD
Estimated ADD (Megyesi et al. 2005)	528 ADD – 1304 ADD
Estimated PMI (in days)	11 to 24 days (up to 6% to 13% accurate)
Actual PMI (in days)	179 days

Table 4.13—07/30/2022 Predicted PMI vs actual PMI. Advanced decomposition. TBS = 25

Calculated ADD	1148
Estimated ADD (Megyesi et al. 2005)	760 ADD – 1536 ADD
Estimated PMI	8 to 15 days (up to 3% to 5% accurate)
Actual PMI	285 days

Selective accuracy testing (Specimen 2)

The same dates were chosen due to varying differences to create a sense of uniformity between both sites and analysis. Stages of early and advanced decomposition are represented. Thus, to represent each stage uniquely the dates, 11/15/2021, 4/15/2022, and 7/30/2022 (Final day) were chosen for Specimen 2 (Tables 14-16).

Table 4.14—11/15/2021 Predicted PMI vs actual PMI. Early decomposition. TBS = 10

Calculated ADD	102 ADD
Estimated ADD (Megyesi et al. 2005)	-286 ADD – 490 ADD
Estimated PMI	1 to 9 days (up to 31% accurate)
Actual PMI	29 days

Table 4.15—04/15/2022 Predicted PMI vs actual PMI. Advanced decomposition. TBS = 21

Calculated ADD	492 ADD

Estimated ADD (Megyesi et al. 2005)	104 ADD – 880 ADD
Estimated PMI	3 to 16 days (up to 6% to 13% accurate)
Actual PMI	179 days

Table 4.16—07/30/2022 Predicted PMI vs actual PMI. Advanced decomposition. TBS = 24

Calculated ADD	916 ADD
Estimated ADD (Megyesi et al. 2005)	528 ADD – 1304 ADD
Estimated PMI	8 to 14 days (up to 3% to 5% accurate)
Actual PMI	285 days

Chapter Summary

The results of this chapter represent analysis of my research in twofold: qualitative and quantitative. First, the qualitative analysis highlights each specimen in three stages of decomposition with pictures of when they were in a specific stage. Each picture also serves as justification why a specific TBS value was assigned. The quantitative analysis presents weather data collected, the totality of each TBS value in a respected quarter, and then testing the accuracy of each value. The accuracy was tested in two manners: the first 18 days and also selective days. All stages of decomposition, except for skeletonization, were tested using these methods. The PMI estimations, the main results of this research, were then assigned in both sets of tests and how accurate those estimations compared to the actual PMI.

Chapter V: Conclusions

The goal of this research was to document patterns in decomposition in southeastern Idaho. Two research questions were posed initially: 1) Are ADD calculations appropriate to the southeastern Idaho environment?, and 2) Will elevation significantly impact the rate and pattern of decomposition in southeastern Idaho? In order to answer these questions further analysis of the data collected is warranted. The ideas presented in this discussion section are an analysis and interpretation of the results seen within this research study. They are not definitive answers in determining if, for example, Megyesi et al.'s (2005) equation for PMI estimation is universal in all scenarios of research utilizing subjects involving, TBS, PMI, ADD, etc. However, it is important to address the accuracy of the equation on the subjects used in this research and for its main duration. Discussions on observable and collected differences at each site will also be interpreted, satisfying the second question of research. Furthermore, limitations will also be addressed as these also had a significant impact on several factors of the research itself.

Research Question One

Determining if the ADD calculations proposed within Megyesi et al.'s (2005) research are appropriate to the southeastern Idaho environment, relies on looking at some factors of the results. Estimating the PMI was tested in various ways to mimic collection consistency for the first 18 days and dates which represent later stages of decomposition. The estimation from each sample was then compared to the actual PMI to produce an accuracy rating within the given time frame. Accuracy can be seen to fluctuate depending upon the score given and also the temperature recorded for each date. Thus, if a specimen was not progressing through decomposition based on observed qualitative traits, the TBS stagnated, which in turn impacted the predicted value. This can be due to a variety of external factors (weather, temperature, sunlight, specimen, etc.) or lack thereof, which can impede decomposition. Therefore, the estimated PMI becomes a reflection of the stagnated score because little to no decomposition activity is observable when the score was assigned.

Observing inconsistent data collection also presents an issue of accuracy ratings of less than 40% (tables 11-16). As the research duration progressed, later dates would produce more inaccurate results. This is supported in Tables 15 and 16 where accuracy is only reliable up to 3% to 13%, based on the TBS assigned and the ADD it produces within Megyesi et al.'s (2005) equation. When the TBS does not progress for a time—score values of 15 and 16 lasting in three separate quarters—it signifies a potential problem with the equation. That is, the equation may not have been constructed to consider that TBS can repeat due to various conditions (weather, temperature, insect activity) which impede decomposition.

By comparison, research conducted by Parsons (2009) in Montana also alludes to a potential issue with the Megyesi et al. (2005) equation in a similar environment. Accuracy testing done for day 29, for this study, produced a negative ADD value of negative 286; negative ADD values were also observed by Parsons around day 156 of study in which an ADD of negative 188 was produced (Parsons, 2009: 65). Parsons notes that lower body scores on subjects tend to produce negative degree days, reducing accuracy rating (Parsons, 2009: 66). This observation is corroborated by the lower scores being tested within this research, which would produce a negative ADD (Tables 11 & 14) . Negative ADD values are problematic to PMI estimations. Counting backwards from an observable date, with a negative ADD, results in a time before the specimens were placed within their contexts.

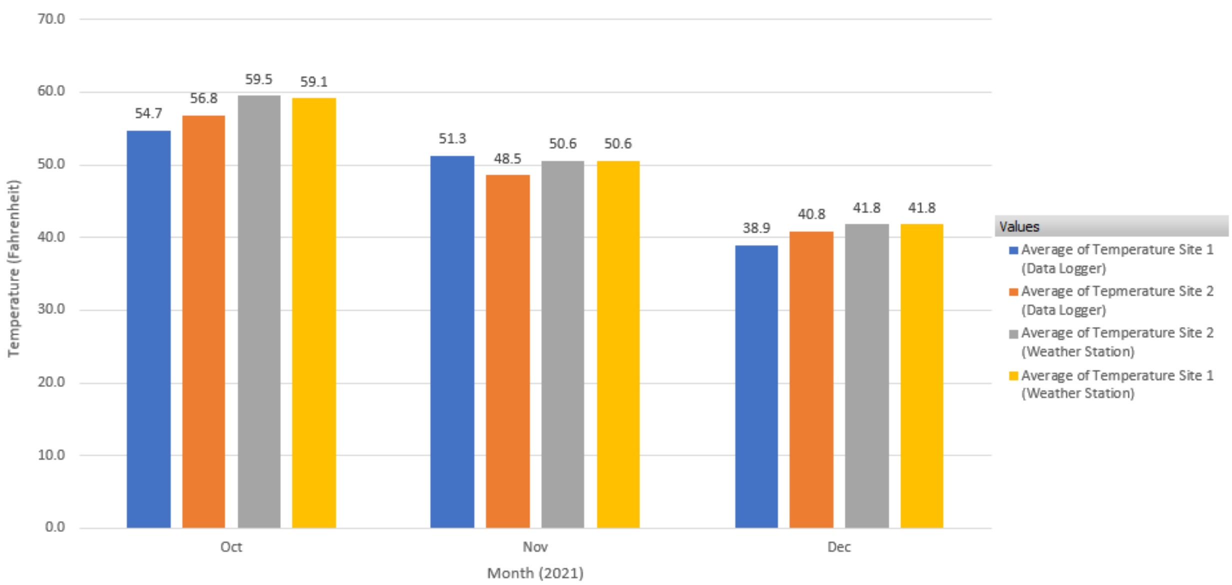
However, accuracy is also contingent upon the guidelines that assign a value for the TBS in the first place. Parsons (2009) notes that the observer is left to their own judgment when determining a score for any part of the body. This score, fundamental to the PMI estimation, is at best an interpretation of loosely written guidelines. For example, Megyesi et al. (2005) states that in order to receive a point value of 6, for example, "brown to black discoloration of the flesh" needs to be present (Megyesi et al., 2005: 621). It does not state however, how much discoloration needs to be present or if it fades over time. Due to this ambiguity, it is difficult to place specimens into a specific decomposition category without subjectivity or observer bias due to inexperience. Observable traits aren't always constant and can fluctuate for a variety of reasons unaccounted for within Megyesi et al.'s (2005) description.

Further ambiguity can also be observed in Megyesi et al.'s (2005) demonstration of the equation as well. For example, once the ADD is calculated, the individual is supposed to count backwards using temperatures from local weather stations in their area to reach the same value as the calculated ADD; this gives the estimated PMI. It isn't clearly stated if the temperature values need to be in Fahrenheit or Celsius during this step (Megyesi et al., 2005). Therefore, misinterpretation can cause one to inaccurately calculate the PMI if the individual uses Celsius and the intent was for Fahrenheit or vice versa.

Research Question two

In order to tell if there would be differences between each site for decomposition, quantitatively, we can only measure aspects between sites through a number of means. Since elevation was used as a primary proxy in order to observe a dichotomy between research sites, it is the first aspect of measurement. Site 1 was only 4676 (1425 meters), whereas Site 2 possessed an elevation of 5102 ft (1555 meters), respectively. This creates approximately 130 meters between each site in terms of elevation, but simply notating this distance isn't enough to quantify noticeable differences. Another aspect available to measure is weather; temperature readings are useful in quantifying differences between sites because it directly affects ADD.

Table 4.17—Average temperature (Fahrenheit) difference between data logger and weather stations (sites 1 and 2).



It was my assumption that the temperature differences between each site would impact decomposition, due to an increase in elevation; this is because, historically, Site 1 was warmer than Site 2 (Table 1). However, temperature readings between each site yielded less than desirable results to support that theory during this research period. When comparing the data from the local weather station to what was collected by the data logger, the average temperatures remain relatively close. In October 2021 there was, on average, just a two-degree difference between Site 1 and Site 2 recorded on the data logger (Table 17). According to the data logger, Site 2 was actually warmer in both October 2021 (possessing an average temperature of 2.1 ºF degrees greater than site 1) and December 2021 (possessing an average temperature of 1.7 ºF degrees greater than site 1) as well. Furthermore, there is the data collected by the local weather station, which shows barely any difference between sites (Table 17). Thus, the idea that the elevation difference between each site would produce enough differences in temperature to influence decomposition is highly unsupported. Therefore, any other means to observe differences between sites rely solely on qualitative characteristics discussed in chapter 3. There is no standard means by which to evaluate significant microclimate differences between sites.

Limitations

Data collection for this project faced some limitations along the way which may explain accuracy issues with Megyesi et al.'s (2005) equation confined to the context of this study. First, I've discussed instances where the TBS hadn't changed. This was likely due to the freeze/thaw conditions over the course of the fall, winter, and early spring which prevented higher temperatures to help with the decomposition process regularly. Furthermore, snowfall at each location (Figure 21) began around December 12, 2021. It produced enough snow where it was impossible to make any observations on each specimen (without impacting the natural integrity of decomposition), thus the TBS stagnated as a result.

Figure 5.21–Snowfall at each location: Site 1, McCammon (left) and Site 2, Lava Hot Springs (right).

This was problematic because the snow would not melt until around spring time, preventing any new observations to be made for the TBS for either specimen. Another factor due to weather, was the amount of weed growth Site 1 had during the springtime. Figure 22 shows Specimen 1 being covered in weeds, which also prevented data collection. This was not the case at site 2, so observations could continue for one specimen, but not the other. This would last the remainder of the project.

Figure 5.22—Specimen 1 (Spring 2022) covered completely by tall weeds.

These natural limitations prove there are unaccounted for complications when assigning TBS using Megyesi et al.'s (2005) guidelines. Such limitations aren't accounted for in the descriptions for decomposition, nor do they appear factored into the equation. If research is to mimic a body being left out undisturbed in a natural environment; any movement of snow, grass, or even the specimen itself ruins the integrity of that principle.

Further limitations of the study can be linked to several other factors: Using one PMI estimation, time, research sample size, security, and elevation, respectively. Using only Megyesi et al. (2005) equation to estimate PMI is a limitation in itself, since its conception there have been attempts to estimate PMI using different methods (Vass, 2011 & Marhoff et al., 2016). However, Megyesi et al. (2005) was chosen within this study, due to how heavily referenced it is (Parsons, 2009; Vass, 2011; Taylor, 2011; Marhoff et al. 2016). Time investment is huge when dealing with sites separated not only by distance but also elevation. There was roughly 4 hours of time needed for data collection. This includes driving and then walking to each location, collecting data, writing notes, taking pictures, etc.

There is no doubt that the sample size for this research was small. Two subjects and micro climates within southeastern Idaho do not represent the possibility of what could happen in the entire region, had more sites and subjects been used. Because Idaho lacks any official body farm, any increase to the scope of this project would have been undertaken by me, which would require much more investment, resources, and help. Security of the specimens can also be viewed as limiting in two folds: first, the study is to represent uncontrolled decomposition. Having each specimen in a kennel does nullify that principle. Second, because the bodies were within a kennel, they were not fully in contact with the soil, as the metal mesh prevented this interaction, soil impact is unknown. Elevation also proved to be a limitation in this study due to the limited quantitative measurements that could be used for analysis. The difference between sites for this study, 130 meters, did not produce enough differences in temperature to suggest it had an influence on either the TBS or ADD observed.

Overall, the results of this study demonstrate that different environments may contain significant variables that the Megyesi et al. (2005) decomposition scoring system does not specifically adequately. In addition, low success rates for the Megyesi et al. (2005) equation to predict ADD from TBS in this thesis demonstrate the need to reevaluate the equation for PMI estimation from TBS.

Future Studies

Though, PMI estimations are still pivotal tools forensic anthropologists utilize to help understand the decomposition process. Future studies need to consider potential limitations when faced with extreme weather or factors that might impede data collection. Current estimations on PMI also focus on the entire body, rather than a hyper-fixation on singular portions (such as the body, neck and head, and limbs). It could be beneficial to conduct comparative studies that focus strictly on a single portion to see if PMI estimations need to be more targeted. This could allow for a database to be created for each respective category of the body, that could then be cross analyzed. Furthermore, when observing decomposition differences between microclimates within such a vast region, larger samples would be preferred (if the resources are available) at various locations to conduct a more in-depth study. This study revealed that the divisions by which color changes on the skin were scored, were too subjective and could not encompass the percentage of the tissue affected.

Dabbs et al. (2016) and Wescott et al. (2018) showed near perfect concordance of observer scores for TBS from photographs. So, the TBS method itself seems valid. However, the Megyesi et al. (2005) equation was developed from crime scene photos and some authors have found significant accuracy discrepancies in TBS scores from field observation versus photographs (Bytheway et al., 2018), resulting in regionally adapted TBS scores. This has called the overall accuracy of Megyesi et al. (2005) into question by some regardless of the call for regional variations.

Elevation and related factors also need to be further explored in future studies. This could be done by increasing the distance in elevation between research sites, which yields far greater temperature differences between a variety of microclimates. There are few studies factoring elevation into PMI estimation (Baigent, 2019; 2022). Baigent (2019; 2022) recently examined variations in high altitude scavenging of human remains and macromorphoscopic changes in physical appearance of human decomposition in the Colorado Rocky Mountains. She found that the TBS system was insufficient in this high-altitude environment and noted the need for a region-specific, predictive PMI model for high altitude. Interestingly, the 2022 study (Beignet, 2022) found drying and retraction of the dermis and common mummification at higher elevations as opposed to skeletonization, similar to this study. Connor et al. (2017) also found that TBS models were inaccurate for pig proxies at higher elevations and De Jong and Chadwick (1999) found that rabbit decomposition was slowed at higher elevations. Since cells, protein molecules, amino acids, and enzymes degrade at different rates and high altitudes have more direct UV exposure, lower temperatures, different flora and scavenging fauna, and different exposure to atmospheric gasses, how tissues degrade are likely going to vary from lower elevations. Further work is called for, but these studies may support, though not explain, the results of this thesis.

It would also benefit cross analyzing decomposition between pigs and humans in future studies as well as this would help understanding how different decomposition could be for each species within a specific context. I'd like to echo the sentiment proposed by Marhoff et al. (2016) suggesting that algorithms for PMI should be produced on a regional basis (Marhoff et al., 2016: 24); if the current methods anthropologists have for estimating PMI prove inaccurate in a wide variety of settings and locations. The next logical step would be revisions to account for limitations, but to also consider the TBS can indeed stagnate and repeat.

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