

Arcadia University

ScholarWorks@Arcadia

Senior Capstone Theses

Undergraduate Research

Spring 3-5-2015

The Taphonomy of Buried Remains in the New Jersey Pine Barrens

Erica Johnson

Follow this and additional works at: https://scholarworks.arcadia.edu/senior_theses



Part of the [Life Sciences Commons](#)

Recommended Citation

Johnson, Erica, "The Taphonomy of Buried Remains in the New Jersey Pine Barrens" (2015). *Senior Capstone Theses*. 18.

https://scholarworks.arcadia.edu/senior_theses/18

This Capstone is brought to you for free and open access by the Undergraduate Research at ScholarWorks@Arcadia. It has been accepted for inclusion in Senior Capstone Theses by an authorized administrator of ScholarWorks@Arcadia. For more information, please contact hessa@arcadia.edu, correllm@arcadia.edu.

The Taphonomy of Buried Remains in the New Jersey Pine Barrens

Erica Johnson

March 05 2015

Edited by Ruth Stetler

Advised by Dr. Chad Hoeﬂer, Kimberlee Moran

ABSTRACT

Forensic taphonomy is the study of all the biological, chemical, and environmental processes that occur postmortem on human remains. Decomposition begins immediately after death and is affected by numerous factors, including temperature, moisture, soil acidity, and microbial activity. Knowing how these factors affect decomposition is necessary in determining the postmortem interval of a recovered body. The effect of the New Jersey Pine Barrens soil environment on the decomposition of buried remains was examined. This area contains soil that is characterized as acidic, low in moisture, and nutrient-poor. Rats were buried and then exhumed at different stages of decomposition (75, 187, 331, 793, and 3245 accumulated degree days). The results were consistent with the expected rate of decomposition which was calculated based on temperature alone. Because of what is known about acidity and moisture, it is suggested that the acidic soil compensated for the decelerating effects of burial and low moisture soil. Results can be applied to postmortem interval calculations in future forensic cases of recovered bodies found in the New Jersey Pine Barrens.

OVERVIEW

Forensic taphonomy is the study of what happens to a living organism between the moment it dies and when it becomes a fossil. It is an important field of study that is applied in death related cases when determining the time since death. Knowing when someone died is essential in determining the cause and manner of death. Many bodies have been discovered in the New Jersey Pine Barrens over the years. This study looks at how bodies buried in this environment decompose.

Certain variables affect the rate of decomposition of buried remains. When a body is buried it is surrounded by soil that contains small living organisms that feed on the decaying flesh and organs. These small living organisms, also called microorganisms, need moisture to move around. Some soils are more acidic than others, depending on their chemical makeup and the mineral composition of the soil. The air temperature above the ground fluctuates, heating up and cooling down the soil. Knowing how these variables affect the rate of decomposition is crucial to forensic scientists when investigating uncovered bodies.

In this study, rats were buried in the New Jersey Pine Barrens. This environment contains acidic (pH = 4.3) and low moisture soil. The rate of decomposition of each rat was determined by observing their bodies post-excavation and applying a point system – 1 being a fresh cadaver to 30 being dry white bone. Since not all parts of the body decompose at equal rates, the head, limbs, and trunk were scored separately and added together to get a total body score (TBS). The TBS values from this study were compared to another study performed on bodies decomposing above ground. To determine when to dig up the rats accumulated degree days were used, which is a system used by forensic entomologists to standardize growth cycles of insects. It takes into account that decomposition does not occur below 3° Celsius, since freezing is a mechanism of preservation.

The results showed that the rate of decomposition of remains buried in the Pine Barrens environment was similar to that of remains decomposing above ground. The TBS values of the rats were in the same range of TBS values that were calculated for unburied remains based on temperature alone. However, it is known that buried bodies decompose slower than unburied bodies. Furthermore, bodies decompose faster in acidic soil and slower in low moisture soil. Thus, it was suggested that the acidic soil in this study compensated for the decelerating effects of burial and low moisture on decomposition.

These results can be applied to future cases of uncovered bodies in the New Jersey Pine Barrens. If a forensic scientist is faced with a body found in this region, they can figure out how long ago it passed away using the method from this study. Having an accurate window of time of death is crucial in solving a crime. It can be compared to a suspect's alibi to determine if their participation in the crime was physically possible. Still, the Pine Barrens is a large region that has several different types of soil environments. Further studies should be done in all areas to determine if decomposition rate varies anywhere else. More research must also be done on the decomposition process of buried remains in order to improve the field of forensic taphonomy as a whole.

INTRODUCTION

The process of cadaver decomposition has recently received heightened attention due to forensic cases and public health issues (Carter, 2008). It is important to understand the factors that affect human decomposition in order to determine the amount of time that has passed since death, also known as post-mortem interval (PMI). An accurate PMI can reduce the pool of potential identities of a cadaver and eventually lead to its identification (Megyesi et al., 2005).

Forensic taphonomy is defined as the study of postmortem processes in human remains. The word taphonomy was developed by paleontologist Ivan Efremov to describe the transition of a body from living to fossil. Taphonomic methods have been used in paleontology, archeology and botany to study aquatic and terrestrial plants and animals, scavenger methods, and water transport in ancient civilizations (Dirkmaat, 2012). Taphonomy was first applied to forensic sciences in the 1980s when William Haglund and Marcella Sorg used scavenger alterations of recovered remains to solve forensic casework (Haglund & Sorg, as cited in Dirkmaat, 2012). Since then it has received increased attention and involvement in several forensic disciplines such as pathology and anthropology (Dirkmaat, 2012).

Decomposition of vertebrate animals begins immediately after death. It exists in four classified stages: fresh, early decomposition, advanced decomposition, and skeletonization. In early decomposition the soft tissues undergo autolysis and putrefaction. Microorganisms from internal organs and surrounding soil break down soft tissues and alter the fat, protein, and carbohydrate content in the body. Anaerobic microorganisms deplete the body of oxygen (Dent et al., 2004). An anaerobic environment favors rapid growth of microbial inhabitants in the gastrointestinal tract and surrounding soil (Gill-King, 1997). In advanced decomposition, liquefaction and disintegration occur, leaving skeletonized remains (Dent et al., 2004).

Factors Affecting Decomposition

Many factors affect the rate of decomposition. Temperature is the most studied and well known factor that has biological and chemical effects on soil surrounding buried remains. Higher temperatures directly affect the activity of microorganisms that play a significant role in cadaver breakdown (Carter et al., 2007). Increased temperatures also boost growth and feeding rates of insect larvae that feed on decaying organic matter (Archer, 2003). Activity of these organisms is an additional source of heat because of their internal temperatures and output of energy. Temperature additionally affects the speed of chemical reactions such as the production of decompositional fluids cadaverine and putrescine (Gill-King, 1997). Generally, the rate of chemical reactions is known to double for every 10° C increase (Prangnell & McGowan, 2009). Low temperatures can slow or halt decomposition. It has been established that decomposition only occurs over 3° Celsius (Megyesi et al., 2005).

Moisture is another important factor that has many biological and chemical effects on the process of decomposition (Archer, 2003; Carter et al., 2010). Sources of moisture in terrestrial graves are most often rainfall and humidity. Moisture, like temperature, can affect microbial activity. Available moisture is held in pores between soil particles. The size of these pores (matric potential) is a key factor in microbial motility (Carter et al., 2010). Too much moisture can allow a cadaver to become water logged and slow mass loss (Archer, 2003). Chemically, water serves as a buffer for extracellular enzymes that are mostly hydrolytic. In moisture deficient soil, enzymatic processes are slowed and microorganisms have decreased mobility (Gill-King, 1997). Moisture and temperature are often studied hand in hand. The high specific heat of water allows it to have a stabilizing effect on temperature. Rainfall can reduce temperature of air and surrounding soil by evaporative cooling, slowing the decomposition

process (Archer, 2003). Therefore, there is an optimum moisture level in each environment that is the most suitable for decomposition.

Soil type has been linked to decomposition rate due to the amount of gas diffusion between different sized particles (Tumer et al., 2013; Haslam & Tibbett, 2009). There are many different types of soil, including sandy, loamy, clay, peat, and silt. As observed by Tumer et al. (2013), decomposition progresses more rapidly in loamy and organic soils compared to sandy and clayey soils. This is likely because of soil particle size and organic substances present. Soil pH in relation to decomposition has received little examination. Although, in a study by Haslam and Tibbett (2009), soil acidity was related to microbial respiration, which is correlated to soft tissue mass loss. Generally, acidic and alkaline soils contain high numbers of fungal communities, whereas neutral soils provide an environment in which bacteria have competitive advantages. Skeletal muscle tissues were buried in acidic, neutral, and alkaline soil. The data showed that tissue buried in acidic soil (pH 4.6) decomposed three times faster than in alkaline soil (pH 7.8) and neutral soil (pH 6.4) (Haslam & Tibbett, 2009).

Microbial communities in soil play a large role in the rate and process of decomposition of buried remains (Lucas et al., 2006; Gill-King, 1997). For example, dead organic matter is a main food source of saprophytic fungi. Mycorrhizal fungi access nitrogen from organic sources in the soil, allowing this species to contribute to decomposition (Lucas et al., 2006). Bacteria in the soil rapidly grow in the anaerobic environment created during the end-stage autolysis. Soil and internal bacteria secrete exoenzymes that break down large proteins present in the cadaver. Other roles of bacteria include adipocerization, elimination of collagen in hard tissues, mineralization of nutrients, and elimination of periosteal covering of bone (Gill-King, 1997).

Other factors seen in forensic cases that influence decomposition include burial depth, time of burial, clothing present on the body, fire exposure, etc. (Weitzel, 2005). However, there is a consensus among literature that temperature is the most dominant factor affecting decomposition. The majority of research on this topic addresses remains decomposing above ground. Therefore, further research is needed on buried remains in environments of various conditions.

Estimating PMI

The ability to use the state of decomposition as an indicator of post-mortem interval is important to forensic anthropologists. Decomposition state calculated with accumulated degree days (ADD) can significantly narrow the range of PMI. Accumulated degree days use heat energy units to quantify time in regards to a biological process. For example, ADD is used by entomologists to normalize fly or larvae growth cycles. Instead of measuring time as 24 hour days, temperatures above a certain threshold in 24 hours are added together. The threshold, or base temperature, represents the temperature at which the process is halted (Megyesi et al., 2005).

Megyesi et al. (2005) used a mathematical formula to calculate ADD of a cadaver given the state of decomposition. A total of 68 human bodies were scored according to a qualitative point system. Since all parts of the body do not decompose at equal rates, the head, trunk, and limbs were scored independently and added together to yield a total body score (TBS). The TBS values were compared to local average temperatures above 0° C. The result was an equation to calculate ADD that could be used to estimate PMI (Megyesi et al., 2005). This equation was applied in this study to investigate if soil environment has a greater influence on decomposition rate than temperature.

New Jersey Pine Barrens

The Pine Barrens spans 1.1 million acres through southern and central New Jersey (New Jersey Pinelands Commission, 2014). The forests consist of mostly dense pitch pine and scattered oak canopy with ericaceous understory that have lichen-moss and grass-sedge communities throughout that arise after a disturbance such as a forest fire (Gray et al., 2012). The region contains soils that developed from the Cohansey geologic formation which have a high proportion of coarse sand particles with thin layers of clay soil. Because of the sandy nature of the soils, water from rainfall is not retained, resulting in low moisture and nutrient collection. Generally, the soils in the Pine Barrens are porous, infertile, and nutrient-poor (New Jersey Pinelands Commission, 2014). Soils in the Pinelands are also acidic, with pH values ranging from 3.8 to 4.8 (Foreman, 1979).

There are four categorized layers (also known as horizons) of soil: A1, A2, B, and C. Horizon A1 consists of leaf litter, duff, and sandy particles gray in color. A2 has similar sandy soil that is darker in color. Horizon B soil changes to light yellow-brown, due to a buildup of iron. C is comprised of light gray sandy soil and reaches down 60 inches (New Jersey Pinelands Commission, 2014).

There are no current studies published on decomposing remains or forensic taphonomy in the New Jersey Pine Barrens. Data on the rate of decomposition in this environment would be useful to forensic scientists in determining PMI of a body found in this region. The goal of this study is to examine the rate of decomposition of buried remains in relation to the particular characteristics of the New Jersey Pine Barrens soil. I hypothesized that the rate of decomposition is faster in comparison to other researched environments because of the acidic soil.

METHODS

A plot of land in a wooded pine forest was selected in Sicklerville, NJ, seen in Figure 1.

Holes measuring seven to nine inches in diameter were dug down to where the soil changed

color (about one foot deep). Each hole was five feet apart (Figure 2). The soil pH was determined to be 4.3 via a 1:1 DI water:soil slurry.

Thirty-six deceased rats (*Rattus rattus*) were provided by researchers from The Fredric Rieders Family Renaissance Foundation. The rats had been treated with ketamine for a prior reaction-time study.

Rats were dosed at three levels: 20mg/kg, 30 mg/kg, and 40 mg/kg. There were eleven rats in each dosage, along with three control/untreated rats. Each rat was wrapped in a mesh sheet to lessen the risk of dismemberment and scavenger activity and allow for easier retrieval, then placed into its individual hole and buried tightly with soil. The burial layout, including line names provided by researchers, is shown in Figure 2. Decomposition was scored



FIGURE 1 - Photo of Burial Site. Holes were dug in lines and marked as shown.

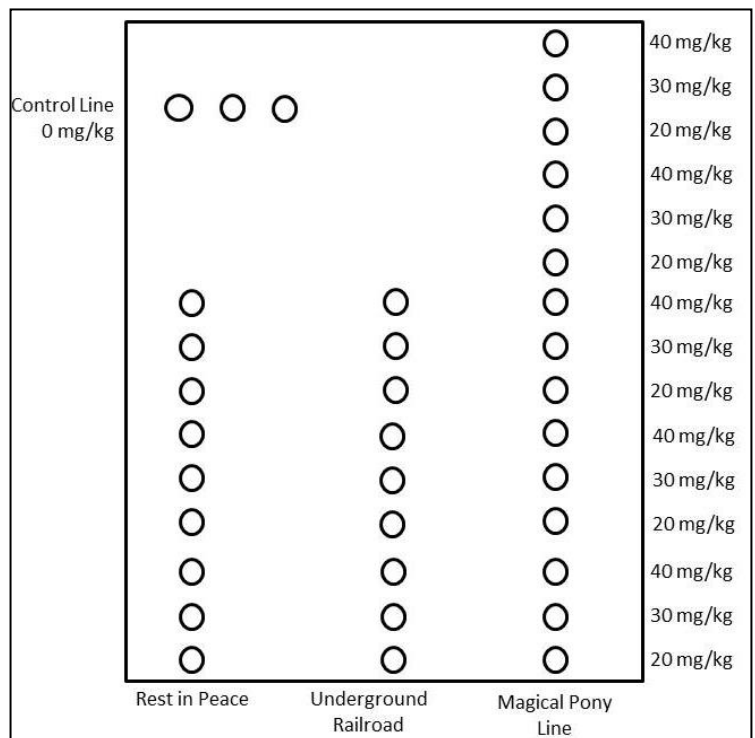


FIGURE 2 - Layout of Burial Site. Each rat was buried an equal distance apart in parallel lines. Rats were buried based on ketamine dosage, shown in the right and left margins.

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

Figure 3 - Categories of decomposition (Megyesi et al., 2005). There are five classified categories of decomposition with the above descriptions.

using the application of Megyesi et al.'s (2005) method. Decomposition is categorized into five stages: fresh, early decomposition, advanced decomposition, skeletonization, and extreme decomposition (Figure 3). Within these categories are subcategories that correspond to physical characteristics of the decaying body. Each subcategory has a number, or point value, assigned to it that represents body score. Because the head/neck, trunk, and limbs decompose at different rates, each area is scored

separately and added together for a total body score (TBS). Five point values were chosen to observe, each in different subcategories of decomposition: 3 - Fresh, 10 – Early Decomposition/purging from facial orifices, 16 – Early Decomposition/bone exposure of head <0.5 bloating of abdomen, 23 – Early Decomposition/bone exposure of head <0.5 bone exposure of thorax and limbs, 29 – Advanced Decomposition/bone exposure of thorax and limbs.

A schedule of dig-days was established using the Megyesi et al.'s (2005) method of accumulated degree days (ADD). This method was more accurate than using 24-hour day schedule because decomposition is a normalization process that is temperature sensitive in that it only advances at temperatures above 3° Celsius. Average daily temperature records and predictions for Sicklerville, NJ were obtained via WeatherBug. Each degree above 3° C was

added up until the ADD corresponding to the desired total body score(s) was reached via the following equation (Megyesi et al., 2005):

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

Rats were dug up according to dosage so that results could be used for a future study on ketamine in decomposing remains. With that, one rat of each dose was excavated from all four lines on each dig day. All rats were scored at the scene no more than 20 minutes after excavation.

Statistical analysis was performed on the observed total body scores, comparing them to the expected total body scores corresponding to Megyesi et al.'s (2005) equation and the recorded ADD. A two-sample t-test assuming equal variance was performed using Excel™ 2010. Further, a two-way ANOVA test was performed to analyze the difference between each dose.

RESULTS

Data from each dig can be seen in Table 1 and Figure 5. The accumulated degree days

TABLE 1 - Expected vs Observed Total Body Score. The accumulated degree days (ADD) were calculated for each dig day. The Megyesi et al. (2005) equation was applied to each ADD to predict the average expected TBS of rats on each dig. Rats were scored upon excavation to determine actual TBS.

Dig Day	Actual ADD at Dig Day	Expected TBS	Observed TBS
1	75.55555556	5.842362676	7.8
2	187.66666666	15.22148383	13.1
3	331.44444444	18.8468929	19.8
4	793.0000003	23.33745046	21.66
5	3245.333333	29.16555597	32

were totaled for each dig day and applied to the Megyesi et al. (2005) equation to calculate the expected total body scores. The



FIGURE 4- Rat dissection from the fourth excavation date. Organs are liquefied and skin showing slippage. Rat was given a TBS of 20.

first dig showed a more advanced stage of decomposition than was expected. There was bloating observed in the trunk and skin slippage along the entire carcasses. Inside organs had turned dark red but were still intact and identifiable. The observed TBS for dig one lies in the Early Decomposition category, rather than Fresh. Digs 2-4 were consistent with the expected decomposition stages, in that

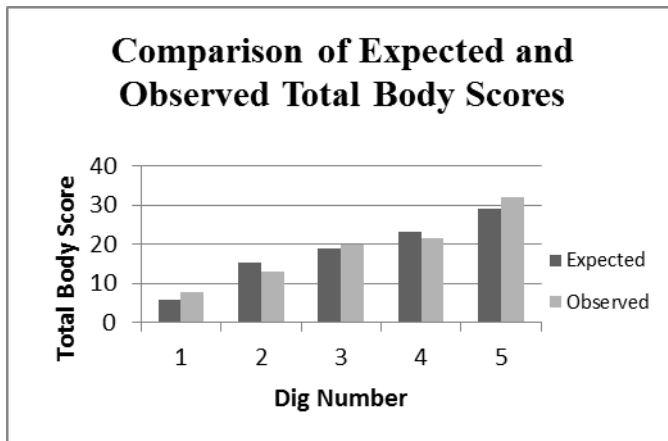


FIGURE 5 - Distribution of Expected and Observed Total Body Scores. Digs 1,3 and 5 appear to have greater observed TBS values than expected. Digs 2 and 4 observed TBS averages were less than expected.

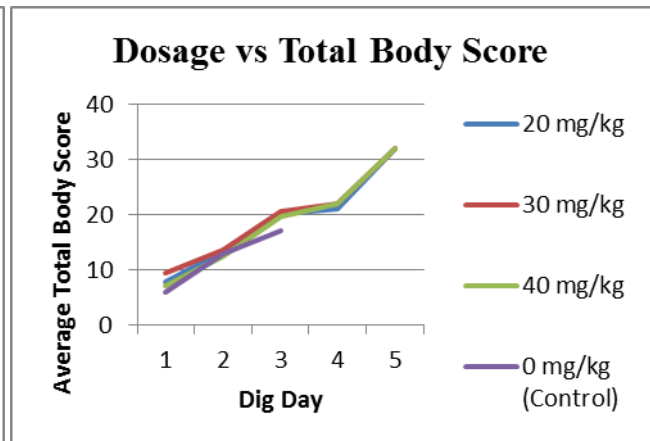


FIGURE 6 - Comparison of Dosage and Average TBS per dig. Average TBS for each dose (0 mg/kg, 20mg/kg, 30mg/kg, 40mg/kg) was compared to one another. The distribution shows little variation between dosage.

the expected and observed TBS values were in the same category range. Cadavers from dig two had yellow/brown decompositional fluids that had a pasty consistency. These fluids were prominent in all rats from digs 2-4. In dig three was the first appearance of maggots, which proved the mesh was not blocking entrance of organisms in the soil. At this point, organs were completely liquefied and in some cadavers the decompositional fluids were seeping out of the mesh. In dig four most of the rats were totally liquefied, with no organs intact (Figure 4). Decompositional fluids darkened in color and bones started to become visible. Rats from the fifth dig were dry pelts and bone, with mites residing inside the mesh. Roots had grown through the mesh. The TBS of 32 was categorized as Skeletonization.

A two sample t-test assuming equal variance was performed on the expected vs. observed TBS values with an alpha-level of 0.05 (Table 2). The p-value of 0.473 did not allow rejection of the null and therefore the observed and expected TBS values are not significantly different.

TABLE 2 – T-Test of Expected TBS vs Observed TBS. The expected and observed TBS values were analyzed. A p-value of 0.94 at an alpha-level of 0.05 suggests the two variables are not significantly different.

t-Test: Two-Sample Assuming Equal Variances		
	<i>Expected calculated TBS</i>	<i>Determined TBS by Megyesi Method</i>
Mean	18.48274917	18.872
Variance	77.05957717	84.22092
Observations	5	5
Pooled Variance	80.64024859	
Hypothesized Mean Difference	0	
df	8	
t Stat	-0.068536769	
P(T<=t) one-tail	0.473520218	
t Critical one-tail	2.896459448	
P(T<=t) two-tail	0.947040437	
t Critical two-tail	3.355387331	

Comparison of ketamine doses shows little variation in respect to TBS values (Figure 6).

The ANOVA test resulted in a p value of 0.1167, concluding there is not a significant difference between the three levels of dosage (Table 3).

TABLE 3 – *ANOVA Test of Dose Effect on TBS*. The data from the first three digs was analyzed using a two-way analysis of variance (ANOVA). The R-Squared value of 0.9435 shows this two-way model is a good fit for the data. The p value of 0.1167 suggests the TBS values between each dose is not significantly different.

Number of obs = 27			R-Squared = 0.9453		
Root MSE = 1.50308			Adj R-squared = 0.9183		
Source	Partial SS	df	MS	F	Prob > F
Model	678.518519	8	84.81481	37.54	0
dose	10.962963	2	5.481481	2.43	0.1167
dig	665.407407	2	332.7037	147.26	0
dose#dig	2.14814815	4	0.537037	0.24	0.9133
Residual	40.6666667	18	2.259593		
Total	719.185185	26	27.66097		

DISCUSSION

I examined the effect of the Pine Barrens environment on rate of decomposition of buried remains, with a focus on the soil acidity. My results show that the observed total body scores of the excavated rats did not significantly differ from the expected total body scores using the Megyesi et al. equation (2005). However, literature supports that burial and low moisture environments slow decomposition while acidic soil speeds decomposition (Archer, 2003; Carter et al. 2010). I suggest that the soil acidity compensated for the burial and low moisture effects, resulting in a decomposition rate similar to unburied subjects. The Megyesi et al. equation (2005) was formulated for organisms decomposing above ground. Because the data show no significant difference between observed and expected total body scores, this suggests that the equation is suitable for buried specimens as well.

Ketamine present in the rats from a previous study was not expected to affect decomposition. Throughout literature ketamine has not been shown to have any preservation effects (Morgan & Curran, 2012). Data are consistent with this claim in that there was no significant difference among doses of ketamine.

As previously mentioned, there is only one published study on the effect of soil acidity on decomposition rate. Haslam and Tibbett (2009) observed skeletal muscle tissue buried in soils with different acidities at a constant incubated temperature. Results showed that tissues decomposed three times faster in acidic soil (pH 4.6) than alkaline soil (pH 7.8) because of the increase in microbial respiration. The pH of the soil in the present study (4.3) was very close to Haslam and Tibbet's acidic soil sample. However, the present study incorporated realistic temperature fluctuations. The data do not show an increase in decomposition rate, but factoring

in the burial and low moisture environment, the acidity may have compensated for these decelerating effects.

The data are consistent with current literature in that temperature is a highly influential factor of decomposition rate (Carter et al., 2008). Carter et al. (2008) showed that rat cadavers buried in controlled temperature climates decomposed at different rates. Increased mass loss occurred in higher temperatures, in which higher microbial activity was present. Archer (2003) similarly reported that higher temperatures increase microorganism activity, along with the growth and feeding rate of larvae and other detritivores.

As seen in Figure 3, there is variation between observed and expected total body score values. The variance between these values could be from many factors. Although scoring bodies was done using a quantitative method, the method is subjective depending on the scorer. For example, different scorers may perceive discoloration differently. I scored all cadavers in this study and my opinions of discoloration and/or drying of limbs may be different than that of Megyesi et al. (2005).

Variance could have also been introduced by the numerous other factors that affect the rate of decomposition such as humidity, microbial activity, mesh wrapping around the bodies, or burial depth (Weitzel, 2005). Burial depth plays a role in decomposition rate – shallow graves are affected by the temperatures above ground whereas deeper graves are not (Dirkmaat, 2012). In this study, the subjects were likely to be affected by temperature fluctuations above ground since they were buried at a shallow depth of 1-foot. Moisture is known to effect decomposition because of its effect on enzyme activity, microorganism mobility, and the diffusion of nutrients. Carter et al. (2010) reported that moisture availability in soil surrounding remains can modify the

relationship between temperature and decomposition rate. Too much moisture in the soil will make mobility of microorganisms difficult and hydrolyze extracellular enzymes that are important in breaking down tissues (Archer, 2003). Too little moisture will also slow microorganism mobility (Gill-King, 1997). The soil in this study was from the New Jersey Pine Barrens and originated from the Cohansey geological formation. Soils from this phenomena are sandy and do not retain water or nutrients. Although moisture was not measured in this study, it can be assumed that the soil contained little moisture. As such, the low moisture could be another source of variance in the data.

Forensic taphonomy is still a new and developing field that contains much room for improvement. Many published studies conflict in regards to the factors affecting decomposition. Our study in the New Jersey Pine Barrens resulted in insignificant differences in decomposition despite the acidic, low moisture, and nutrient poor soil. Further research should be done to validate this claim. A study of buried subjects in acidic soil with optimal moisture levels would provide information on the impact moisture plays. Similarly, a study of buried subjects in neutral soil with low moisture would take away the acidity impact. In regards to the goals of this particular study, a larger sample size would be useful to decrease the variance of data. Also, a study of buried remains in different zones of the Pinelands is recommended due to the large area and ecological diversity of the region. While studies with controlled variables are useful for examining how one factor affects decomposition, realistic postmortem forensic cases will not exist in controlled environments and there will be many overlapping factors such as temperature, moisture, soil nutrients, clothing, etc., that interfere with decomposition rate. It is important to perform further studies on possible grave sites that will be exposed to all of these factors.

The present study is relevant to forensic taphonomy. If a body is found in the New Jersey Pine Barrens, the results of this study can be applied when calculating the postmortem interval. The data suggest that the acidic soil, low moisture, and burial work counteractively to yield a decomposition rate similar to that of unburied remains. Decomposition of unburied remains relies primarily on temperature. Therefore, the PMI can be calculated from accumulated degree days alone and yield a reliable interval. The data supports the accurateness and utility of the Megyesi et al. equation (2005). The region-specific aspect to this study is also useful. The Pine Barrens is a 1.1 million square acre territory, of which 45% is publically owned. More than half of the region is designated as government owned for preservation (New Jersey Pinelands Commission, 2014). The uninhabited thick pine forests have been a dumping ground for bodies throughout the years. Several news reports have been published on bodies found in the area (Anonymous, 2013; Newsroom New Jersey, 2010; Casiano, 2008). The results from this study would be useful to forensic scientists investigating future cases in the Pinelands.

When applying these data to human postmortem situations, it is important to note the differences in animal proxy and human remain decomposition. Humans have more fat stores than most animals – a study by Widdowson (1950) averaged human neonates to have 16% of fat, whereas piglet neonates had 1%. Another study showed that soil microbial activity surrounding decomposing tissues was much higher by bovine and porcine tissues than human remains. These non-human tissues also showed higher concentrations of the nutrients NH_4^+ , PO_4^- and K^+ . Also, human remains are commonly wrapped in clothing or other materials, which slows decomposition rate by increasing the barrier between the body and microorganisms in the soil. It was concluded that no non-human tissue is an adequate model for human decomposition (Stokes

et al., 2013). However, studying the decomposition of non-human mammalian tissue provides an acceptable foundation of information, given the ethical circumstances of using human subjects.

In conclusion, this research supports that the decomposition rate of remains buried in this region of the Pine Barrens with acidic and low moisture soil, is similar to the rate of unburied remains. Because there was no statistical difference between expected and observed total body scores on the excavated rats, it is assumed that the rate increasing and decreasing factors worked counteractively and compensated for each other's effects. Further research should be done to validate this claim. Other factors such as microorganism activity, burial depth, and animal proxies used do contribute to the rate of decomposition but at a smaller scale. These factors create variance in the interval and should be considered when reporting the PMI of a body. The research supports that the Megyesi et al. equation (2005) can be used for buried remains in the New Jersey Pine Barrens as well as remains above ground. Further research should be performed on the decomposition of buried remains to benefit and improve the field of forensic taphonomy.

ACKNOWLEDGMENTS

I would like to thank the Fredric Rieders Family Renaissance Foundation for providing the rats, and Kimberlee Moran for allowing the use of her property. Thanks to Dr. Rod Gulberg for statistical analyses. I would like to thank Cassandra Prickett for assistance in burial, excavation, and dissection. Special thanks to my advisers Dr. Chad Hoefler and Kimberlee Moran, and editor Ruth Stetler. Additional thanks to Dr. Karen Scott for advising in the continuation of research.

BIBLIOGRAPHY

- Anonymous. Body found in N.J. ID'd as missing woman. (2013, March 28). *United Press International*. Retrieved March 5, 2015, from http://www.upi.com/Top_News/US/2013/03/28/Body-found-in-NJ-IDd-as-missing-woman/99251364450400/
- Anonymous. Father, son accused of burying N.J. man in Pine Barrens. (2010, December 23). *Newsroom New Jersey*. Retrieved March 3, 2015, from <http://www.newjerseynewsroom.com/state/father-son-accused-of-burying-nj-man-in-pine-barrens>
- Archer, M.S., 2004. Rainfall and temperature effects on the decomposition rate of exposed neonatal remains. *Science & justice : journal of the Forensic Science Society*, 44(1), pp.35–41. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14964820>.
- Carter, D.O., Yellowlees, D. & Tibbett, M., 2010. Moisture can be the dominant environmental parameter governing cadaver decomposition in soil. *Forensic science international*, 200, pp.60–66.
- Carter, D.O., Yellowlees, D. & Tibbett, M., 2008. Temperature affects microbial decomposition of cadavers (*Rattus rattus*) in contrasting soils. *Applied Soil Ecology*, 40, pp.129–137.
- Casiano, J. (2008, April 5). Staten Island teen charged in connection with body found in Pine Barrens. *NJ.com*. Retrieved March 3, 2015, from http://www.nj.com/news/index.ssf/2008/04/staten_island_teen_charged_in.html
- Dent, B.B., Forbes, S.L. & Stuart, B.H., 2004. Review of human decomposition processes in soil. *Environmental Geology*, 45, pp.576–585.
- Dirkmaat, D., 2012 A companion to forensic anthropology. *John Wiley & Sons, Ltd*, pp. 477-524.
- Gill-King, H., 1997. The Postmortem Fate of Human Remains. In W. Haglund, ed. *Forensic Taphonomy*. CRC Press LLC, p. Section II. Available at: <http://www.crcnetbase.com/doi/abs/10.1201/9781439821923.sec2>.
- Gray, D.M., Swanson, J. & Dighton, J., 2012. The influence of contrasting ground cover vegetation on soil properties in the NJ pine barrens. *Applied Soil Ecology*, 60, pp.41–48.
- Haslam, T. C. F., & Tibbett, M. (2009). Soils of contrasting pH affect the decomposition of buried mammalian (*Ovis aries*) skeletal muscle tissue. *Journal of Forensic Sciences*, 54, 900–904. doi:10.1111/j.1556-4029.2009.01070.

- Lucas, R.W. et al., 2007. Soil microbial communities and extracellular enzyme activity in the New Jersey Pinelands. *Soil Biology and Biochemistry*, 39, pp.2508–2519.
- Megyesi, M. S., Nawrocki, S. P., & Haskell, N. H. (2005). Using accumulated degree-days to estimate the postmortem interval from decomposed human remains. *Journal of Forensic Sciences*, 50 pp.618–626.
- Montesano, C., Johansen, S.S. & Nielsen, M.K.K., 2014. Validation of a method for the targeted analysis of 96 drugs in hair by UPLC-MS/MS. *Journal of pharmaceutical and biomedical analysis*, 88, pp.295–306. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/24095804> [Accessed January 22, 2014].
- Morgan, C.J. & Curran, H.V., 2012. Independent scientific committee on D ketamine use: a review. *Addiction*, 107, pp.27–38.
- New Jersey Pinelands Commission, 2014. Pinelands soil environment. Retrieved from <http://www.state.nj.us/pinelands/infor/curric/pinecur/psb.htm> [Accessed February 5, 2015].
- Prangnell, J. & McGowan, G., 2009. Soil temperature calculation for burial site analysis. *Forensic science international*, 191(1-3), pp.104–9. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19656646> [Accessed February 7, 2014].
- Scheller, R.M. et al., 2008. Simulation of forest change in the New Jersey Pine Barrens under current and pre-colonial conditions. *Forest Ecology and Management*, 255, pp.1489–1500.
- Stokes, K.L., Forbes, S.L. & Tibbett, M., 2013. Human versus animal: contrasting decomposition dynamics of mammalian analogues in experimental taphonomy. *Journal of forensic sciences*, 58(3), pp.583–91. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23550805> [Accessed January 24, 2014].
- Tumer, A.R. et al., 2013. Effects of different types of soil on decomposition: an experimental study. *Legal medicine (Tokyo, Japan)*, 15(3), pp.149–56. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23312864> [Accessed February 19, 2014].
- Weitzel, M.A., 2005. A report of decomposition rates of a special burial type in Edmonton, Alberta from an experimental field study. *Journal of forensic sciences*, 50, pp.641–647.
- Widdowson, E.M., 1950. Chemical composition of newly born mammals. *Nature*, 166, pp.626–628.