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Effect of Coastal Environments on the Post Mortem Interval of a Pig Carrion: Implications for Human Decomposition

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by

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ABSTRACT

Forensic taphonomy involves the use of forensic techniques to determine the post mortem interval of a corpse. There are many factors that are known to influence the rate of decomposition, such as the temperature, season, soil type, moisture potential of the soil, and presence of insects or other decomposers. Previous studies in this field have focused primarily on decomposition patterns in mountainous environments in terms of terrestrial habitats or strictly aquatic environments, leaving this particular aspect of coastal settings to be unexplored.

To study these effects, the superior portion of a female pig was buried in sandy soil in mid-October in Ocean Springs, MS. The site was a couple of meters from the edge of Halstead Bayou that directly empties into the Gulf of Mexico about 0.1 miles away. The corpse was checked weekly, with a variety of qualitative observations being made. During the first week, the corpse was bloated, and the body deflated. Advanced decomposition began four weeks after burial, and continued until the cessation of the observations after the eleventh week. Due to the winter and sandy conditions, insect activity was severely limited, and thus, the rate of decomposition was slower than studies performed in warmer environments with a less sandy soil. The salinity of the bayou water did not appear to have an effect on the decomposition. The results of this experiment followed the original expectation that the variables would slow decomposition, and further research in different settings would provide additional insight into decay patterns.
Keywords: Forensic taphonomy, entomology, decomposition, post mortem interval, coastal environments, bayou

DEDICATION

This is dedicated to my mother, Nancy, for instilling a love for forensic science by watching crime shows with me at a *slightly* unreasonably young age. Well, I made it, mom; I am a real Abby Sciuto.

ACKNOWLEDGMENTS

I would like to thank Dr. Danforth for her patience as I went off on this new adventure. I would have never known where to begin without her help. Thank you for taking time out of your busy schedule to trek down to the coast to look at a rotting corpse, and most importantly, thank you for believing in me.

Thank you to Boe Farms in Moselle, MS for kindly donating the pig sample. Much appreciation to Dr. Heitmuller for assisting in the soil particle size, and Dr. Yee for identifying the insects that were collected. Also thank you to Lucas Applewhite and personnel at the Gulf Coast Research Laboratory for permission to use their campus and for preparing the site.

I would also like to thank my mother for driving down to the coast and helping me dig up a dead pig every week — you certainly have earned the Mother-of-the-Year Award.

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ATP	Adenosine Triphosphate
GCRL	USM Gulf Coast Research Lab
PMI	Post Mortem Interval
PMSI	Post Mortem Submergence Interval
USM	The University of Southern Mississippi

CHAPTER I: INTRODUCTION

It is a rule that everything that lives must die. Once deceased, the organism's body goes through a series of ordered processes that begin to break down the organic matter that is eventually recycled within the biosphere. Taphonomy is the study of how the body decomposes over time, and can be described as interdisciplinary (Pokines et al., 2022). Some of the fields included in taphonomic research are anthropology as it involves the study of human decedents, paleontology as this field focuses on non-humanoid, long-deceased remains, and forensic science as it employs scientific techniques to determine the Post Mortem Interval (PMI) (Dirkmaat & Cabo, 2016).

Because of the many factors present at a gravesite that can influence the PMI, it cannot be determined utilizing only a select few factors of the site, but must include all of them in order to estimate the most accurate time of death possible. If the site is not inside a controlled environment — but rather is in the outside elements — variables that affect the rate of decomposition include temperature, humidity, organism size, soil moisture and pH, insects and microbial presence (Alfsdotter & Petaros, 2021; Tumer et al., 2013). Each environment has different manifestations of each of these external factors; thus, each environment will have a unique effect on the organism that is being broken down. For example, Los Angeles, California, and Houston, Texas both have similar average temperatures throughout the seasons, but Houston is dramatically wetter than Los Angeles ("Climate", 2022). Provided this information, the taphonomist would not put the same amount of emphasis on each factor — such as humidity — at each scene. Rather, the taphonomist would cater to each specific environment as it presents itself. Another detail a taphonomist would consider is the influence that factors can have on each other.

Moisture is dependent on soil type (loamy, sandy, clayey) and microbial presence, and humidity can be dependent on temperature to an extent. This is why it is imperative that the taphonomist takes all possible factors into account when determining the PMI.

Previous studies have focused on various settings with different types of climates, temperatures, humidity, amount of water present, and other applicable variables, but the effect that coastal environments — specifically the Mississippi coastal environment — has on the rate and degree of decomposition is severely lacking, if not absent. Such studies are typically performed at so-called 'body farms' associated with a university's research program. These body farms serve as a space for researchers to document the postmortem changes of cadavers in specific environments to provide insight into the variables involved (Wolff, 2015).

There is a total of seven research sites across the U.S., located in Tennessee, North Carolina, Texas (two sites), Illinois, Colorado, and Florida. The facility located in southern Florida had opened in 2019 but has an ending contract with the Sheriff's Department and will close in May of 2022 (Schreiner & Lalino, 2019). Cadavers at the sites are subjected to different conditions, including caged on land and submerged in water in order to study the PMI of the bodies. As indicated by the locations, the majority of these sites are located in mountainous regions, and otherwise dry, deserted environments. Because these environments are vastly different from coastal Mississippi, the information collected in this study would provide insight as to the effect that the coastal variables have on the PMI of a corpse.

In this particular study, the setting utilized was a small plot of soil a few meters away from the Halstead Bayou in Ocean Springs, Mississippi. This bayou empties out into the Gulf of Mexico approximately 0.1 kilometers away from the site. The superior half of a female pig carcass was buried at this site, and its decomposition was observed and recorded from late October until early January. The variables of interest in this study were temperature, the type of soil the cadaver was buried in, insect presence, and any effect any exposure of the brackish water had on the rate of decomposition. The hypotheses of the study are outlined below:

- Primary hypothesis: Decomposition will occur more slowly in a cooler coastal environment
- Subhypothesis 1: The temperature will slow the rate of decomposition processes such as increasing the time needed for the corpse to proceed through each stage of decomposition
- Subhypothesis 2: Fewer insects will be present at the site, thereby slowing decomposition
- Subhypothesis 3: The salinity from the adjacent brackish water will not impact the rate of decomposition
- Subhypothesis 4: The sandy soil with slow the rate of decomposition

Overall, it was expected that the results of this study in a coastal setting in late fall/early winter would show a slower rate of decomposition than if the experiment were performed in a warmer environment with less sandy soil and increased insect presence as indicated by findings from previous studies.

The setting of this project is unprecedented, as all of the distinct conditions worked together to generate a unique situation that is applicable in the study of forensic taphonomy. Each corpse investigated in a forensic situation is unique to the specific setting in which it is located. As such, it is imperative that the PMI of cadavers is studied in a variety of situations to gather as much information as possible in order to apply it to such investigations. This study aids in this regard as it focuses on elements not examined previously.

CHAPTER II: LITERATURE REVIEW

Forensic taphonomy has been studied since the mid nineteenth century, but has rapidly developed within the last 40 years (Miles, 2020). As defined by Dirkmaat & Cabo, forensic taphonomy is “the study of what happens to a human body after death (2016, p. 441).” Such changes of the body include the stages of death and decomposition, and can be catalyzed or inhibited due to extrinsic or intrinsic factors. These factors include, but are not limited to: temperature, soil type, and water presence and salinity (Wescott, 2018). The expected results of this study are to observe a slower rate of decomposition than if the experiment were performed in a warmer environment with less sandy soil and no brackish water nearby.

Stages of Death

Immediately following death, changes occurring on the molecular level occur throughout the body. They are sequential in nature, and proceed one after the other. Without the heart beating continuously to pump blood and warmth throughout the body, as well as other cellular functions that release heat when producing work, the temperature of the body decreases (Brooks, 2016; Shedge, 2021). This is called algor mortis, or “cold death”. Despite extensive studies done on algor mortis in various species of animals, including deer, pigs, and humans, there is no exact model that can determine the time of death simply on the temperature of the body during algor mortis (Matuszewski, et al., 2019). This is due to the several intrinsic and extrinsic variables that influence the rate at which the body cools after death, including external temperature and body mass. However, a formula has been constructed to illustrate the relationship between temperature and PMI, and is shown below (Brooks, 2016):

PMI (in hours) =Normal body temperature (98.6°F)−rectal temperature (°F)/1.5

The formula is only applied in situations in which the deceased is in the first few stages of death, as the temperature gradient would not be applicable after reaching room temperature (Goff, 2009).

The second post mortem change is livor mortis. Because the heart is no longer pumping blood throughout the body following death, the blood in the vessels will settle, pooling in their specific area according to rules of gravity. The pooling — also known as lividity — begins 30 minutes to about 2 hours after death, and presents itself as a reddish-purple blotch under the skin. As the blood vessels begin to break down further at about 8 to 12 hours, the blood is released into surrounding tissues. Medicolegal death investigators utilize the location of the lividity to determine the post mortem position of the body; if the lividity is not consistent with the rules of gravity, then the conclusion that the body was moved after death can be made (Goff, 2009).

Besides cooling of body temperature and pooling of blood, another post mortem change occurs in the muscle fibers. Adenosine triphosphate (ATP) is a compound that is consumed and broken down in order to release energy within the body. Muscles utilize these molecules by creating a 'hook' between actin and myosin muscle fibers, resulting in a contraction of muscle. After death, however, ATP synthesis halts, and the body lacks the necessary amount of ATP to 'unhook' the muscle fibers. This leaves the muscles contracted, and manifests itself in a characteristically stiff way in the deceased body. The term that describes this activity is rigor mortis. As with other stages of death, the time interval is variable, but typically occurs between 2 to 6 hours after death, and decreases in severity 36 hours after death, but can extend until 84 hours after death (Goff, 2009). The body begins to become flaccid once more when the actin and myosin fibers begin to fragment, releasing the stiff hold in the muscles.

External variables that affect the rate of rigor mortis are the ambient temperature, as well as the metabolic state of the body before death and body muscle mass. The warmer the outside temperature, the slower the body goes into rigor mortis, and if the ambient temperature is cooler, the body will proceed into rigor mortis faster (Goff, 2009). In cases where the decedent participated in aerobic activity shortly before death, the muscles go into rigor mortis sooner than if the body was not physically active prior to death. If the body has a high muscle mass, rigor mortis is more pronounced than less built bodies (Brooks, 2016). A verified principle that investigators use relating between algor mortis and rigor mortis is illustrated in Table 1 (Brooks, 2016):

Table 1. Relationship Between Body State and Estimated PMI

Body Conditions	Estimated PMI (in hours)
Warm, flaccid	< 3
Warm, rigid	3-8
Cool, rigid	8-36
Cool, flaccid	>36

The relationship between algor mortis and rigor mortis has been well studied in human subjects, with rather limiting studies performed with non-human animal subjects (Goff, 2009). However, it is assumed that the physiological mechanisms are consistent in non-human animals.

Stages of Decomposition

The number of stages of decomposition has been disputed for some time, with researchers outlining specific stages that they believe are separate from the others. The number has ranged from as few as two discrete stages (Howden, 1950) to as many as eight stages (Megnin, 1894), and nearly every number in between (Payne, 1965). Categorizing the stages of decomposition gives logic to abstract topics that overlap one another, and makes it easier to explain to a lay member of a jury if the circumstances of the death are relevant to the facts of the case. The reason behind the variability in the number of stages of decomposition is because the molecular breakdown and changes that occur happen simultaneously, and may or may not affect the manifestation of the other processes. There is no, one universal reference as to the stages of decomposition, but the widely accepted stages, which were originally developed for paleontological purposes, are as follows (Payne, 1965):

1. Fresh stage (0-5 days post mortem)
2. Early Decomposition stage (1-21 days post mortem)
3. Advanced Decomposition stage (3 days - 18 months post mortem)
4. Skeletonization stage (2-9 months post mortem)
5. Extreme Decomposition stage (6 months to >3 years post mortem)

The first stage, Fresh, occurs immediately following death, and includes the first three stages of death mentioned above — algor mortis, livor mortis, and rigor mortis. Alongside these stages of death, autolysis is happening. After the heart has stopped beating and cells are degrading, enzymes inside the body start to break down the nearby tissue, beginning decomposition on a cellular level (Goff, 2009). The physical product of autolysis is subtle, as most of the changes are occurring internally. Soon after autolysis begins, putrefaction starts. Similar to autolysis, putrefaction is also decomposition on a microscopic level, but rather than breaking down due to digestive enzymes, bacterial microorganisms consume the tissue. Because of this, various gasses are released inside the body and lead into the next stage of decomposition, the Early Decomposition stage.

In the Early Decomposition stage, microbes enter the carcass through any open wounds or the respiratory tract, and begin consuming any visible tissue. This releases gasses into the cavities, including carbon dioxide, methane, ammonia, hydrogen sulfide, and others (Brooks, 2016; Shedge, 2021). A buildup of these gasses leads to a greenish discoloration of the cadaver, swelling of the abdomen, and loosening of the skin from deep tissue. It is during this stage at which insects are most likely to appear and begin feasting and laying eggs on the deceased (Goff, 2009).

The next stage of decomposition is Advanced Decomposition. Once the external tissue separating the accumulation of the gasses from the microorganisms has been punctured or compromised due to the bacteria themselves or the presence of insects, the built-up gasses are released from the cavity. The body is no longer characteristically bloated, and the abdomen recedes upon itself (Goff, 2009). This stage includes a multitude of insects being present to consume the body or utilize it as a breeding ground for future generations. The tissue itself can be described as wet and slimy due to the high levels of breakdown from bacteria, insects, and autolysis, and the odor is putrid.

Following Advanced Decomposition is the Skeletonization stage, in which the majority of the remains are dry, and the bones are exposed. Wet tissues may be present, but with the assumption that more than half of the remains are dry, exposed bones. Insect activity is comparatively low; however, insects or other small creatures that live in the soil have increased activity despite the smaller availability of tissue.

The last recognizable stage of decomposition is Extreme Decomposition. This stage builds upon the previous stage, Skeletonization, in the sense that there is minimal to no tissue present on the corpse, leaving only bone and possibly teeth or hair (Goff, 2009). Due to the absence of tissue, no insects or other organisms are apparently present, and the stench is relatively mild. Bleaching of the bones is possible as well as exfoliation or other types of physical breakdown to the bone can occur.

It is important to reiterate the idea that these stages are not exceptionally discrete, as there is no positive way of determining whether the remains are in one category rather than another. This system is strictly based on accumulations of observations and can lead to a presumptive time of death.

Factors Affecting Decomposition Patterns

Temperature

It is a well-established notion that the rate of decay in bodies is proportional to the temperature; an increase in temperature will lead to an increased rate of decomposition, and a decrease in temperature will slow the rate of decomposition (DeBruyn et al., 2021). This is typically due to high levels of insect and microbial activity in warmer months and environments, which lead to a faster breakdown of tissue (Steadman et al., 2018).

Because of the effect that temperature has on decomposers, one study has labeled temperature as being the most influential factor on the rate of decomposition, followed by insect access (Mann, et al., 1990). Microbial activity has been established as increasing two or three fold by every 10 degree Celsius increase in temperature, until the 35-40 degree Celsius point, in which the optimum productivity will decrease due to the high temperature. Thus, as the temperature increases, the microbial activity will increase exponentially until a point, and so will the overall decomposition (Pokines, et al., 2022).

This general idea has been investigated in several studies, including some which were performed in temperate Tennessee weather during the spring, summer, and winter seasons (Dautaras, et al., 2018; Steadman, et al., 2018). Tennessee's climate is not identical to coastal Mississippi's, but due to lack of research in similar environments, it is used as a reference. An example of the lower numbers of carrion insects is seen in a Master's Thesis performed in Tennessee presented the same rate of decay in terms of seasonal temperatures — the two caged cadavers left on the surface in the spring and summer had a higher number of insects with a faster rate of decomposition than the two cadavers placed during the fall (Rodriguez, 1982). No numerical difference was made between the individual insects at the site in the summer versus the winter, but the qualitative measurement given suggested was a significant amount. What was provided was the time frame needed for each cadaver group to proceed through each of the decomposition stages. The amount of time it took for each cadaver to proceed to the next stage of decomposition is outlined below in Table 2 (Rodriguez, 1982). The average temperatures for the duration of the study in May 1981 to April 1982 are recorded in Figure 1 below. As illustrated in the table, the summer subject took significantly less time to proceed through the stages than the other subjects. The third subject, placed in October, took three and a half times the amount of time to proceed into the 'Bloated' or Early Decomposition stage than the cadaver placed in the summer, and was still in the 'Decay' or Advanced Decomposition stage in May of the next year (Rodriguez, 1982).

Table 2. Timing of Stages of Decomposition of Subjects by Season in Tennessee.

Timing of Stages of Decomposition				
Subjects and Placement Dates	Stages of Decomposition			
	Fresh	Bloated	Decay	Dry
Subject 1-81 5/13/1981	**10 days**	**5 days**	**19 days**	**27 days**
Subject 2-81 6/5/1981	**4 days**	**3 days**	**8 days**	**13 days**
Subject 3-81 10/12/1981	**14 days**	**7 days**	**Still in progress**	
Subject 4-81 11/11/1981	**38 days**	**15 days**	**112 days**	**Still in progress**

Taken from Rodriguez (1982: 35).

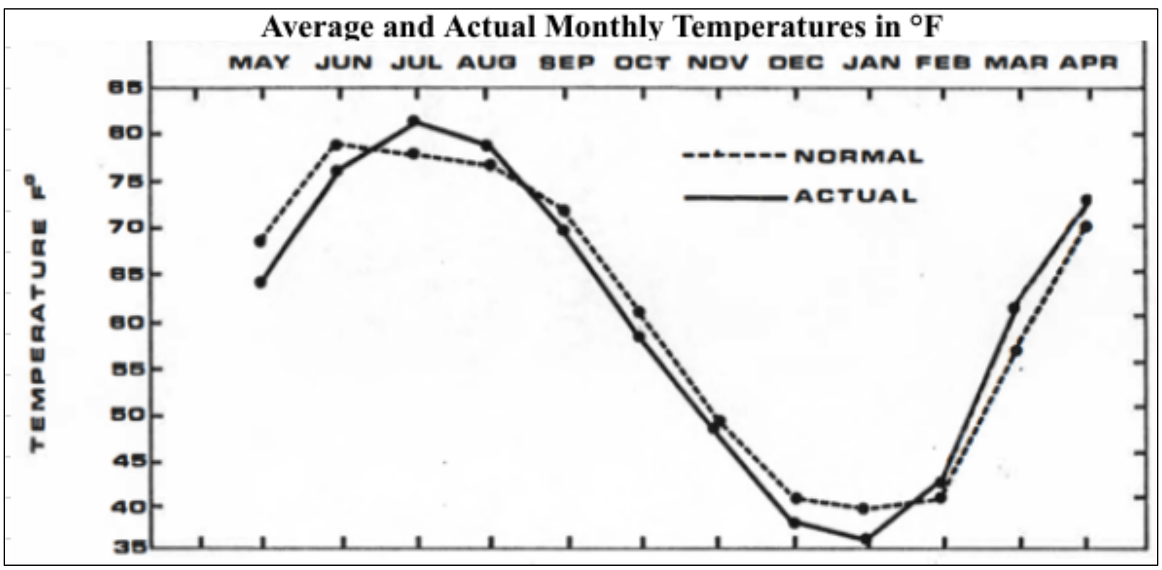

Figure 1. Average and actual monthly temperatures in °F in Tennessee.

Taken from Rodriguez, 1982, p. 36).

Soil Type

The effect that the type of substrate the carcass lies in has on the rate of decomposition has been studied previously in multiple focuses. The three most studied categories of soil are clay, sand, and loam/organic. As no soil is likely to be purely one of these, but rather a mixture of two or more types of soil, there is no formula that can calculate how long the PMI is based on the substrate. However, applying the idea that the soil type is continuous rather than discrete categories, the PMI can be adjusted according to the amount of a specific soil present in the sample.

Previous studies have shown that soils with a high percentage of organic or loamy soil will have a positive effect on the rate of decay, whilst sand and clay tend to retard the rate of decomposition (Parson, 2019; Tumer et al., 2013). This is primarily due to the amount of nutrients and moisture present in the soil: organic soil will have a higher level of nutrients available for microbes to thrive and therefore speed up the decomposition process. Meanwhile, sandy soil lacks the ability to retain moisture — an unfavorable environment for microbes — and clay's low porosity has a higher chance of not providing sufficient moisture to support microbial activity, thus slowing down the decomposition (Tibbit, 2008). In Tumer et al. (2013), the pigs were buried in four soil settings, loamy, organic, clay, and sand, for six months from May to November. At the conclusion of the study, the bones of the carcass in the loamy soil had been completely separated from muscle and other bones, and had a presence of adipocere. The carcass located in the organic soil had similar results, in which the bones were detached completely, and the skin was fully decomposed. In contrast, the carcass located in the clay soil had adipocere formation, but otherwise no significant skin tissue breakdown, and there was still the presence of muscle on the bones. The pig sample in the sandy soil had significant tissue still present on the bones (Tumer, et al., 2013). Thus, the study confirmed the effects of soil type as observed by others.

Soil temperature will vary by environmental conditions, such as the amount of sun exposure and depth from surface. Sandy soil also tends to warm up faster than more dense clay soils. However, Zheng et al. (1993) reported that there is a strong general correlation between air temperature and soil temperature, with the latter usually being slightly higher under most conditions.

Water and Salinity

Carrion studies typically focus on purely terrestrial or purely aquatic environments, rather than the presence of a nearby body of water or the water table. Because of this, it is difficult to measure the effect that the water has on the decomposition of the carcass; however, examining the holistic effect of the type of environment — either terrestrial or aquatic — is helpful. When a body is found in a body of water, rather than PMI, the interval is called Post Mortem Submergence Interval (PMSI) due to the different effect that water has on the decomposition process. The high specific heat of water allows it to act as a buffer for temperature and pH, meaning the temperature of the aquatic environment would not fluctuate much, and neither would the pH (Wescott, 2018). This causes a lower temperature of the water than the surrounding air and land, and generally retards the rate of decomposition. One major instance in which decomposition is accelerated in water rather than slowed, is if the perimortem injuries are fairly extensive, increasing access to scavengers (Boyle et al., 1997). Additionally, it has been noted that the stages of decomposition appear differently and at a different rate than carcasses located in a terrestrial environment (van Daalen, 2017). An example of such can be an increased chance of adipocere formation on a corpse in an aquatic environment, algal formation, or the presence of skin slippage and nail shedding. In fact, adipocere is largely dependent upon water presence, hence why it rarely appears in terrestrial-lying carcasses.

In terms of the effect that salinity of the water has on the rate of decomposition, studies are limited. Studies that do include marine or freshwater environments typically center around microbe communities or insect presence rather than the salinity of the water. If a carcass lies in salt water, osmosis occurs, and the water in the blood will be transported into the lungs (Boyle et al., 1997). This causes a difference in autolysis rates, due to the lower bacterial activity. Therefore, it is reasonable to assume that the presence of saltwater surrounding the body will inhibit the decomposition process rather than accelerate it.

Insects

A huge portion of studies in forensic taphonomy focus on the relationship between decomposition and insect patterns. Insects are commonly found at a large variety of settings in which bodies might be recovered, and their behavior has been studied beginning in the 1850s (Haskell et al., 1997); this focus is called forensic entomology. Researchers study the insect's life cycle as well as eating and breeding habits in order to establish a relationship between stages of decomposition and the insect developmental status. Overall, there are hundreds of insect species that can be found at decomposition sites, but the two orders that make up over one half of the total are Coleoptera and Diptera (Payne, 1965).

The first insects to appear at the scene within minutes of death, depending on the temperature, are Diptera, or the common fly. Within this order is the family Calliphoridae — or blow flies — consisting of the blue and green bottle flies. The blue bottle fly has a characteristic blue color on its back, and is seen in temperate areas during the cooler seasons (Haskell, et al., 1997). Their green counterpart, however, flourishes in the warmer months, typically being seen during the summer. Because these flies deposit eggs starting minutes after death, the life cycle of blowflies is crucial to determining the PMI at a scene loaded with insects. Hours after laying the eggs, the first instar larvae, or the larvae that have not molted, hatch. The larvae then molt, proceeding into the second instar larval stage. Within 12 hours, the insect then feeds and goes through developmental changes, and goes into third instar larvae. Growth increases as they feed upon the tissue. The larvae begin to search for an area of protection before their transformation, and thus go into the post feeding larvae stage. Similar to a butterfly's metamorphosis, the insect's outer shell hardens, and days later, the adult fly will surface from their exoskeleton. Approximately 3 to 5 days after emerging, the flies become sexually mature. In whole, the life cycle differs depending on the species of blowfly, and other environmental facts such as temperature and food availability. As a general rule, blue bottle flies take approximately 21 to 35 days for a whole cycle to complete, while green bottle flies take 14 to 21 days to complete the life cycle (Çetinkaya, et al., 2008). This is why it is paramount to identify the insect's species to determine the life cycle. Otherwise, the PMI could be days off of the true date.

Figure 2. *Calliphora vomitoria* (cf.). (Wikipedia.com).

Coleoptera is an order that consists of beetles, which prey on the fly larvae present at the site. Common beetles seen at such areas are Silphidae, or carrion beetles, Histeridae, or Hister beetles, and Staphylinidae, or rove beetles. Carrion beetles are a type of beetle that are known to feed off carcasses, and adult beetles typically appear at the carcass within the first 24 hours (Byrd & Castner, 2010). After the adults arrive, they begin to lay eggs, and two to seven days later, the eggs hatch. The insect will continue to grow, molting a total of three times in the duration of 10 to 30 days later. They undergo metamorphosis, and fully develop after 14 to 21 additional days. Hister beetles are similar to carrion beetles, but only have two instar stages, and have a total developmental time of 20 days (Arnett & Thomas, 2001). Rove beetles share the same developmental time of Hister beetles, and typically are present from 9 days after death to 2 months. All three of these families of beetles feed off of the carcass, as well as prey off of the Diptera fly larvae at the site.

Another arthropod found on carrion belongs to the insect family Tachinidae. These flies usually serve as parasites to other insects, but are also known to feed off of flowers, and have been seen feeding on corpses (Payne, 1965). They are attracted to the corpse, and use it as a breeding ground as well as a feasting site (Gómez et al., 2010). The life cycle for this family of flies differs drastically according to species, ranging from weeks to almost a year. This makes it more difficult to accurately determine the PMI strictly from the presence of Tachinidae flies, but the information can be used supplementally as needed.

Figure 3. Tachinidae. (https://www.gardeningknowhow.com/garden-how-to/beneficial/tachinid-fly-information.htm).

This is not an exhaustive list of insects that are known to be attracted to corpses, but simply list a couple of insects and a few of their characteristics. Other common insects that are present at decomposition sites are Sarcophagidae, or flesh flies; Muscidae, or house flies; wasps, and spiders (Payne, 1965). The quantity and type of insects that are present at a site will vary, depending on the environmental conditions.

Pig versus Human Analogues

A significant portion of studies focusing on the decomposition of a cadaver — whether the emphasis be entomological (focused on the presence of insects) or taphonomical (focused on the rate and pattern of decomposition) — is performed using a non-human corpse. This can be due for several reasons, such as a limited availability for a human cadaver due to legal paperwork, the high price associated with acquiring one, and the ethical concern of using human cadavers. Thus, it can be practical to use a substitute, or analogue, in place of the human body. The most commonly used non-human carrion for forensic studies is the pig (Matuszewski et al., 2019), which began flourishing in the 1980s, most likely due to the newly developed 'body farm' in Tennessee. In order to address the concern of a difference between the two, the decomposition process of pigs has been observed and compared to that of a human. The results have shown that while pigs do have a different decomposition pattern than those of a human, the pig is the mammal that most closely matches the decay of a human (DeBruyn et al., 2021). Specific differences between the two mammals are the body proportions, gastrointestinal anatomy, and diet, as pigs ingest more plant products. The similarities include a similar body mass, anatomy, body composition, skin coverage, gut microbiota, gross process of decay, and are generally more ethically tolerated (Matuszewski et al., 2019). Therefore, utilizing a pig corpse in the absence of a human subject is acceptable, but is expected to have some difference in the pattern of decay.

There are countless variables that influence the rate at which a carcass will decompose, many of which are discussed above. In this study, the factors that will be focused on include the soil, temperature, insects, and salinity of the nearby water. By documenting the weekly changes in the carcass, the stages of decomposition were observed, and the effect each variable had on the changes were examined.

CHAPTER III: MATERIALS AND METHODS

In this experiment, an adult pig was buried at a site adjacent to a bayou on the Mississippi Gulf Coast. The details concerning the burial site and data collection are given below.

Materials

In lieu of a human cadaver, a young female pig donated by Boe Farms in Moselle, MS, was used. The pig was about three months old when it was slaughtered, and weighed approximately 110lbs. This live weight would be appropriate in substituting a human cadaver for a pig cadaver, as it is similar to that of a small, adult woman. It was then sectioned cut transversely at the level just above the legs and hips; only the superior half of the body was used for the project.

The site chosen for the burial was near the banks of Halstead Bayou at the USM Gulf Coast Research Laboratory (GCRL) in Ocean Springs, MS, as seen in Figure 4. The immediate area surrounding the burial site consisted of trees surrounding the edge of the bayou, and was clear of infrastructure. The grave was about 25 feet from the water, and the ground had patches of sporadic grass (Figure 5).

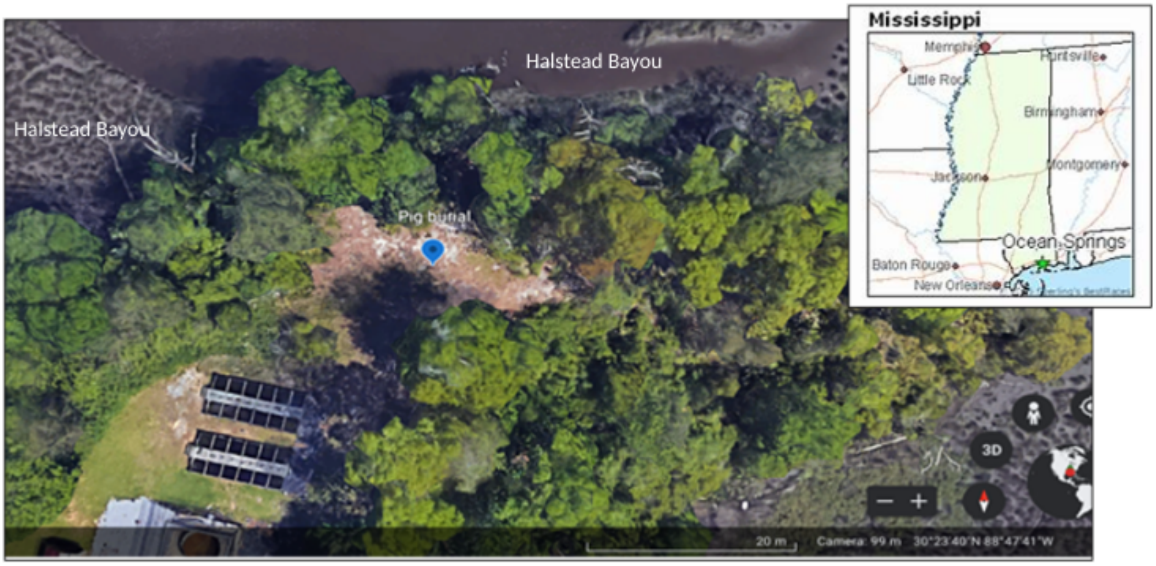

Figure 4. Aerial view of the site and the waterways. The circled area is where the carcass was buried. (https://earth.google.com/web/)

Figure 5. View of the site, with the grave circled in red; Halstead Bayou is located behind trees in rear of photo.

Methods

The pig carcass was measured and photographed and then buried in a shallow grave 60 inches long and 28 inches deep that had been dug by GCRL staff using an excavator. To protect from large scavenger activity, such as from alligators and coyotes, a tarp was used to cover the carcass and a piece of chicken wire was placed in the soil about halfway between the pig and the surface.

The specimen was observed for 11 weeks, starting in October 2021, until New Year’s Day in January 2022. The sample was unburied with a shovel and observations were made every week, with the exception of two weeks at the end of December. At each visit, photographs were taken and physical observations were documented. Qualitative observations taken include:

- Odor
- Insects, including type and density
- The skin color and status (such as bloating or firmness of tissue)
- Bone exposure (not attached to muscle tissue)

Soil and water samples were taken at the initial burial. During the first couple of visits, representative samples of the insects present were also taken. All specimens were brought to the appropriate dedicated laboratories at The University of Southern Mississippi where faculty aided with their analysis.

The results and analysis of these observations of these visits are outlined in the next chapter.

CHAPTER IV: RESULTS AND DISCUSSION

For this chapter, a diary of the observations made at each weekly visit is provided. Then the various factors affecting the decomposition patterns are individually discussed, and a final evaluation of the implications of the findings is given.

Observations by Week

At each visit, the gravesite was hand dug with shovels to uncover the carcass, with the chicken wire removed to fully document any observations. After making the necessary observations, the soil, as well as the chicken wire, was placed back on top of the carcass. Depending on personal obligations and weather conditions, the days the carcass was observed varied from Saturday to Sunday, but observations were consistently performed during the late afternoon.

Week 1 (October 17—23)

After the first week of burial, the skin of the pig carcass turned black all across the body, but had no external signs of tissue decomposition (Figure 6). The odor emitted from the grave was fetid as soon as the body was uncovered with the smell of rotting flesh, and a swarm of dozens of flies landed on the body and surroundings. A few of the bugs were recognized as blue bottle flies. The internal tissue of the pig was not exposed, but the cavity was obviously bloated and puffed. As indicated by the characteristic bloating, the pig was determined to be in the Early Decomposition stage. Since there was no indication of scavenger activity, the tarp and chicken wire were removed from the grave.

Figure 6. View of pig carcass with blackened, bloated shoulders, legs, and head.

Week 2 (October 24—30)

After the second week of burial, the pig remained black all across the skin, with a few quarter-sized blemishes of a light orange on the shoulder region as indicated in Figure 7. The skin of the pig was quite loose on the exterior. The odor was just as pronounced as the previous week and smelled foul. Approximately two dozen or so flies were attracted to the smell, and were identified as blue bottle flies. The internal bloating had subsided, and the internal cavity of the pig was less inflated as the skin was more form-fitting to the structure of the bones beneath. This reduction in bloating is characteristic of the late stage of Early Decomposition or the early stage of Advanced Decomposition.

Figure 7. View of right shoulder of pig carcass with orange blemish circled.

Week 3 (October 31—November 6)

On November 7, the pig's skin had tightened against the muscle and fat tissue underneath (Figure 8). Fewer insects were attracted to the smell of the decaying carcass once uncovered, only about a dozen or so, one of which was eventually identified as a Tachinidae fly. The still black tissue was firm across the superior position of the pig, with small pockets of bloating near the abdominal area as indicated by prodding various locations across the exposed carcass. The skin of the pig's head had also tightened against the limited muscle underneath, and the bone was more pronounced. Due to the decreased amount of bloating, the corpse was considered to be in Advanced Decomposition.

Figure 8. View of shoulder of pig carcass, with skin tightening against the fat and muscle tissue.

Week 4 (November 7—13)

After four weeks, the pig's skin began to loosen from the underlying tissue as it was easy to remove the muscle and fat tissue from the carcass' bones (Figure 9). The black color of the skin did not change, and the odor was still putrid. After unearthing the carcass, no insects were found at the site, including flies. Because the tissue had become punctured through the decomposition process, no bloating was seen. The fat of the pig underneath the skin was slick, and a humerus bone became loose from the remains. Because the remains were wet, the sample was still in Advanced Decomposition.

Figure 9. View of shoulder area of pig carcass, with fat and muscle tissue becoming loose from the bones.

Week 5 (November 14—20)

Five weeks after burial, the pig's skin and superficial fat was very loose from the deeper tissue, and was easily peeled from the shoulder (Figure 10). The skin was still blackened, and the stench was putrid. No insects were present at the site during this unearthing nor any other successive observations. The pig's legs displayed tissue loss as it appeared shrunken, and the outline of the bones could be seen below the skin. The continued presence of wet tissues on the pig corpse indicated the corpse was still in the Advanced Decomposition stage.

Figure 10. View of the shoulder of pig carcass, with the skin and fat extremely loosened from bone.

Week 6 (November 21—27)

In week six, more of the pig's skin and fat was becoming detached from the muscle from below. The skin remained black in color, and the stench reeked of decaying flesh. No flies gravitated towards the site during the observation. Several long bones in the front legs were disarticulated from the joints and detached from the skin, and a large quantity of superficial fat was gelatinous in texture. The pig was determined to still be in the Advanced Decomposition stage.

Week 7 (November 28—December 4)

After the seventh week of decomposition, even more of the pig's skin was loosened from the deeper tissue. The skin color had no change, and the smell of the corpse was still fetid. No insects were present at the site during the observation. The mandible had separated from the rest of the cranium, but no other bones became loose. The amount of skin peeling off from the leg bones increased from the previous week. These observations indicated the corpse was still in Advanced Decomposition.

Week 8 (December 5—11)

The following week marked eight weeks of decomposition, and the corpse's skin was easily manipulated to fall off of the underlying bone, especially the scapula (Figure 11). The skin remained black in color, and the stench was still as rank with the smell of decay as noted in earlier weeks. No insects were found at the site during the observation. The exposed fat was wet and slimy, but resisted tearing off from the body with the skin.

Figure 11. View of pig shoulder, with skin and muscle peeled from scapula.

Week 11 (December 26—January 1)

With an observation break period of three weeks, the pig was observed again on January 1. The blackened skin and cream-colored fat peeled off the bone underneath, with the latter still wet-textured and gelatinous (Figure 12). The odor emitted from the site was equal in intensity as from the previous weeks, not decreasing or increasing in putridness. The fat and muscle tissues of the pig's head were very loose from the cranium, and were moist. The pig remained in the Advanced Decomposition stage, as noted by the still-wet tissues. Due to the lack of obvious changes in the decomposition during the observations over the past several weeks, the study was brought to a close.

Figure 12. View of shoulder of pig carcass, with gelatinous fat.

At the beginning of the study, the pig sample had advanced through the first two stages of decomposition fairly quickly, with the first observation indicating Early Decomposition, and the next week at the end stages of the stage, or the beginning of Advanced Decomposition. However, once the pig had entered the Advanced Decomposition stage in the beginning of November, decomposition had slowed. The fat and muscle tissues had become more loose from the bones and more wet, but did not lose sufficient tissue to proceed to the next stage, Skeletonization.

Factors Affecting Decomposition

Temperature

Many studies focusing on the patterns of decomposition of pigs are conducted during the warmer seasons, whereas this study was performed during the cooler season of fall and winter in southern Mississippi. The average weekly temperature during the months of October, November, and December, 2021, are recorded in Figure 13 (Southern Regional Climate Center, 2022). These temperatures were typical of the season in south Mississippi. The soil temperature during the survey was not recorded, but is assumed to be similar to the ambient temperature.

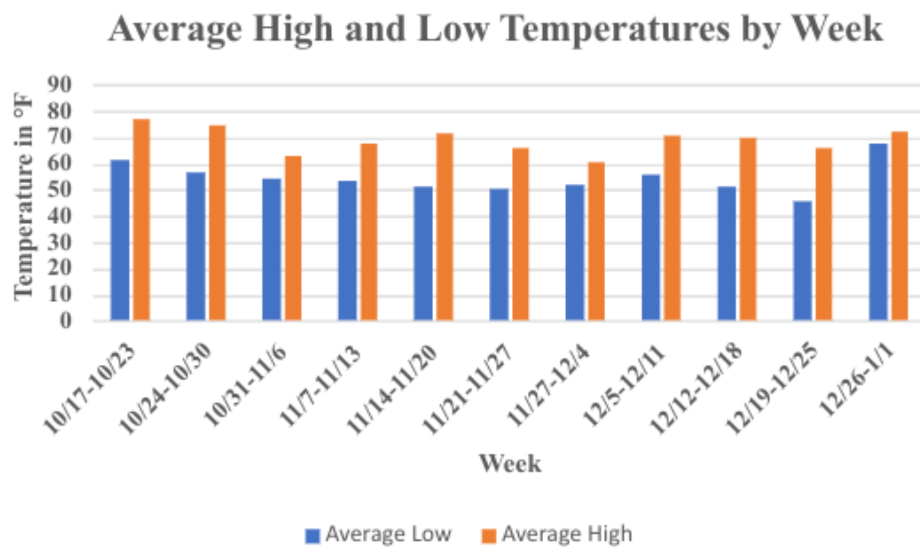

Figure 13. Average air temperatures by week during the study period.

Case studies performed during warmer months have shown a much faster rate of decomposition. In a study performed during the summer in Tennessee, the pig carcass had reached the bloated stage of decomposition within a few days of the start of the experiment (Rodriguez, 1982), whereas the pig in this study was bloated only after the first week of burial (see Table 1). Similarly, it has been observed that the decomposition process during the warmer months only takes about two to four weeks to be complete (Mann & Bass, 1990). Using this information, it is apparent that the sample in this study still would have potentially taken a few weeks beyond the eleven weeks of observation to reach extreme decomposition with the increased presence of insects to aid the breakdown of tissue.

In contrast, studies performed during the cooler seasons have reported slowed decomposition and reduced insect presence (Turner & Wiltshire, 1999; Woollen, 2019), which was seen in this particular case as well. In Turner & Wiltshire (1999), the ambient temperature during their study, conducted in England, was cooler than the temperatures recorded in the present experiment, with the temperature at the beginning of the study averaging 2 degrees Celsius, or 36 degrees Fahrenheit, and increasing to 15 degrees Celsius, or 59 degrees Fahrenheit, by April. Due to the decrease in temperature from this study, the carcass in that instance did not reach advanced decomposition until Day 105, in which the skin was easily becoming detached; that occurred in this study about Day 32.

Another instance in which a corpse was decomposed in a cooler environment was part of a study by Woollen (2019) in which pigs were buried in January in central Illinois, with an average temperature of 33 degrees Fahrenheit at the beginning of the study, and 43 degrees Fahrenheit at the conclusion. The pig was determined to be late in the Early Decomposition stage after two months, while the sample in this study appeared to be in the later stage of Early Decomposition at week 4. The difference in decomposition stage rates between the two studies again support the pattern of faster rates of decomposition with warmer temperatures.

Insects

As mentioned, insects are also important in decomposition and also increase in presence with warmer temperatures. Not many insects were present during the duration of the present study — only flies were at the site the first few weeks, and then no other arthropods afterwards. During the first two observations, there were several flies collected, and later identified as blue bottle flies, During the third observation, there was a single tachinid fly collected. Both blow flies and tachinid flies are common in decomposition sites, as they are known to be attracted to the smell of the corpse within minutes of death (Gómez et al., 2010; Haskell et al., 1997; Payne, 1965).

The absence of insects at the decomposition site was unexpected, as nearly every taphonomic study had various arthropods present. The lack of insects, however, can be attributed to the cooler season, as flies, beetles, and other insects typically are more active during the warmer weather. Their increased activity -has been recorded in many studies in which taphonomic changes were observed during the summer months, and include hundreds of species of flies, including blow flies, flesh flies, and house flies; beetles, including carrion, Hister, and rove beetles; wasps, ants, and spiders (Dautartas, et al., 2018; DeBruyn, et al., 2021; Haskell et al., 1997; Mann et al., 1990; Payne, 1965; Reed, 1958; Rodriguez, 1982; Steadman et al., 2018; Wescott, 2018).

In studies with cooler temperatures, however, the quantity and species of insects is limited. In the previously mentioned investigation by Turner & Wiltshire (1999), insects only appeared after the buried corpse was unearthed by larger scavengers, and blow flies proceeded to lay eggs on the corpse. In Woollen (2019), no insects were observed until the end of April, which is the beginning of the warmer months in central Illinois. The temperatures in Woollen's study in April were slightly cooler than the temperatures seen during this study, which supports the results of only witnessing select insects during the observations.

Salinity

Another major variable that was of interest in the coastal setting of this experiment was the effect the nearby bayou water had on the rate and pattern of decomposition. The salt level of the water was found to be 1.5 ppm, which is consistent with brackish water found in a bayou ("Saline Water and Salinity | U.S. Geological Survey", 2022). However, due to the carcass not directly touching the water, the bayou proximity evidently had no significant impact on the decomposition of the pig. The carrion was approximately 25 feet away from the edge of the bayou, and the water table below the soil does not appear to have reached the carcass.

Water with a high salinity generally has lower bacterial activity levels, which may in turn slow decomposition of a corpse (Alfsdotter & Petaros, 2021; Ayers, 2010); however, bodies of water with a lower salinity than saltwater — such as brackish — have not been investigated. Cadavers that reside in water during the decay process have been known to either decompose with an increased or decreased speed, depending on factors including temperature of the water and access to scavengers such as carnivorous animals in the water (Caruso, 2016). In cooler and cold water, the decomposition of the corpse is inhibited, and can even be halted completely if the temperature is low enough. Had the carcass in the present study been exposed to the water for the length of the study, it would be likely that the decomposition would be slowed due to the cold temperature of the water as well as the level of salinity in the water.

Sandy Soil

The soil the pig resided in during the duration of the study was determined to be sandy. The majority of the soil in this environment had a particle size of 0.125-0.25 mm, or fine sand,-or 0.0625-0.125 mm, or very fine sand (Natural Resources Conservation Services, n.d.). As suggested in the literature, sandy soil tends to slow down the rate of decomposition, especially if in a dry environment due to its inability to retain moisture well (Carter, 2006; Parson, 2019; Tumer et al., 2013). This environment was not dry enough to desiccate the carcass; however, the sandy soil appeared to have likely slowed down the decomposition of the pig, although the degree cannot be determined.

Carnivorous Scavengers

It is not uncommon for large mammals~~,~~ and reptiles~~,~~ to be attracted to the smell of a rotting corpse. Such creatures include foxes, racoons, vultures, bears, coyotes, dogs, and even alligators if there is a severe lack of food in the environment (Steadman et al., 2018). Many of these species would potentially have been present in the burial area, even alligators due to the proximity of the site to Halston Bayou and the Gulf of Mexico. However, no evidence of scavenger activity other than insects was observed. Part of this might have been due to the fact that the study was designed in a way to limit the amount of damage that scavengers, namely alligators, could do to the subject. The sample was buried at a depth of two feet, and the carcass was covered with chicken wire. However, even so, there was no indication, such as digging activity on the surface, that any scavengers even tried to access the pig.

Summary

Many variables were involved in the rate that the corpse decayed at the site, including temperature, the presence of insects, water and its salinity, and the type of soil the pig laid in. All of the factors at the time period the study was conducted worked together to slow down the decay of the pig, as expected, and can be compared to studies performed in similar conditions. Due to the location of the brackish water, the salinity of the water likely did not impact the soil, and therefore did not influence the pig's decomposition. The winter temperatures of the region played a huge factor in the rate of decomposition, as it reduced the number of insects present at the scene.

CHAPTER V: CONCLUSIONS

The PMI of a cadaver can vary depending on dozens of factors, including temperature, soil type, insects, water, and rainfall (Alfsdotter & Petaros, 2021). In this study, the effect that a coastal setting in the late fall had on the rate of decomposition was investigated. The pig sample slowly decomposed over an eleven week duration beginning in mid-October, and findings were compared to the patterns of decay recorded in studies performed in different environments.

Before the start of the study, it was hypothesized that the cooler temperatures, sandy soil, and reduced insect presence would negatively impact the rate of decay, and the nearby brackish water would not affect the rate. The study was performed in fall and the beginning of winter, and as such, the temperature had cooled off dramatically from the warmer months. Due to the cooler temperatures, insects were increasingly absent as the winter season approached, and the fine sand soil the pig resided in decreased the rate at which the pig decomposed. The nearby bayou water had no noticeable impact on the decomposition of the pig, and neither did the salinity of the water. Had the environment been notably warmer, more insects were present at the site, and the soil type been less sandy, the time it would have taken for the pig to reach each stage of decomposition would have been significantly lessened. As such, all of the hypotheses were supported.

Because no research study is ever perfect, there are some revisions to the design that would further provide insight into the process. One might be making observations daily rather than weekly, although it could be argued that more frequent disturbance of the remains might impact natural processes. Another change to the design might be collecting all insect samples present at the scene rather than just a sample to have make sure that the less common species are identified. Lastly, extending the duration of the study to observe further decompositional changes could have provided a more definitive close to the study and identified the time necessary to progress through all five stages of decomposition. These changes could potentially provide a more in-depth analysis of the decompositional changes of the pig in a more detailed scale, rather than generalized documentation of the processes.

In terms of future research, there are numerous directions in which investigations can go when examining the decomposition patterns of a pig, or human. Variations of the study parameters that might be considered include the following:

- The pig could be closer to the water, or in the water completely
- The pig could be placed on the surface of the soil
- The pig could be placed in a position with more leaf cover or different soil type
- The study could be performed in warmer weather, therefore having increased attraction to the corpse from bugs.

Any of the above alterations would bring light to a new situation in which the corpse has a different PMI. Because this type of research has never been done before in this coastal setting, especially in the winter, the results would be particularly valuable to medicolegal investigators examining bodies found in the Mississippi Gulf Coast region.

Forensic cases involving decomposing remains take place in various sites including wet, dry, hot, cold, cloudy, sunny, and those with high/low altitudes. Most studies similar to this one are done primarily at so-called ‘body farms’, usually founded by state colleges and universities, in which several corpses donated to science are placed in specific conditions to document the decomposition process. The number of such academic sites are limited in the United States, however, and all currently are located at inland locations. Limited research has been done on several aspects of this study, including the cooler temperatures, the coastal sandy soil, and the proximity to the bayou water. By focusing on these specific variables, the results are flowing into uncharted waters.

Because there are so many different climates and environmental conditions, it is critical to gather as much information as to the seasonal and environmental decomposition patterns of each of these climates. By fine tuning the PMI, innocent suspects could be exonerated, and the guilty parties can be held accountable. Medicolegal death investigators, coroners, and forensic pathologists can utilize the information presented in this study to the conditions found at a death site and develop the most accurate estimation PMI of a corpse to advance their investigation and bring a case to a just resolution.

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