AQUATIC DECOMPOSITION IN CHLORINATED AND FRESHWATER ENVIRONMENTS

THESIS

Presented to the Graduate Council of
Texas State University-San Marcos
in Partial Fulfillment
of the Requirements

for the Degree

Master of ARTS

by

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San Marcos, Texas
May 2007

AQUATIC DECOMPOSITION IN CHLORINATED AND FRESHWATER ENVIRONMENTS

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ACKNOWLEDGEMENTS

I would like to thank the following people for their support and encouragement throughout this research endeavor:

To my committee members:

Dr. Beth Erhart: Thank you for your camaraderie and superior editing skills.

Dr. Turhon Murad: Thank you for your support and interest.

To my committee chair and mentor, Dr. Jerry Melbye: Thank you for putting up with my incessant questions and visits to your office. You have become more to me than just my professor, you have become my friend. I will miss your jokes and Hawaiian shirts. Thank you for your support and your confidence in me gave me confidence in myself.

To Dr. Jerry Melbye's better half, Vicky Melbye: I am well aware that if it was not for you, nothing would get accomplished. Thank you for being our "Mother Hen." You are the best.

To Dr. Dietz: Thank you for helping me with the statistical aspect of my research. You made the statistics fun and significantly less painful.

To my family:

My mother and father, Cherie and Robert E. Alley: It is true what they say, it is not until we get older that we truly understand and respect the sacrifices and love that our parents give to us throughout our lives. Absolutely none of this would have been possible without your unwavering love and support. You both helped me talk out my frustrations and worries and would inspire me to do more, never quit, and that I could be a capable, functioning adult…someday. Thank you. I love you both.

My sister, Lanyi Alley: My sister, my friend. Words cannot convey our bond. Through the bickering of childhood came a friendship without boundaries and a support system that is infinite. I wish you luck with your own academic endeavors and hope to be a source of support and advice for you. I love you.

My aunts and uncles, Kathy and Tom Batten, and Drs. Virginia and Robert Cherry III, and my cousins: Your support and interest in my research would always reignite my own interest. Thank you. I love you.

My grandmother, Irma Alley: The matriarch. I love you.

To fellow graduate students: Thank you for your support and knowing exactly what I was going through…because you were going through it too. Margaret Hyder: Thank you for our late night brainstorming sessions. I think without them, neither one of us would really have a thesis right now. Thank you also for reminding me that the world is small and you could move a thousand miles from home and still meet a friend. Bryan Connolly: Thank you for helping me construct my cages and for repeatedly driving me to pick up my pigs. To my friends: I couldn’t ask for any better. Thank you for not being creeped out and overall sorry whenever you asked me what I was doing in Texas. I love you all.

A special thanks to Dr. Grady Early: For the use of your land to conduct my research and your patience, Thank you.

This research was funded by the FSF Lucas Research Grant.

This manuscript was submitted on March 23, 2007.

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I. INTRODUCTION

Forensic investigations involving human remains frequently occur in aqueous environments. Deceased individuals have been discovered in aqueous environments such as fresh water, sea water, and chlorinated water. Of the numerous questions posed when a human body is found, "when did this individual die," is always near the top of the list. In any forensic investigation, the establishment of the postmortem interval (PMI) is a priority. The estimation of PMI in aqueous environments is complex and has just begun to be researched (Payne and King 1972, Reh et al. 1977, Haskell et al. 1989, Haglund 1993, Rodriguez 1997, O'Brien 1997, Haglund and Sorg 2002, Seet 2005). Additionally, of the research that has been conducted in regards to aquatic environments, there is an absence of research utilizing chlorinated water. The absence of such research could be the result of the assumption that a deceased individual would be quickly discovered in such an environment. However, there has been a failure to establish whether the chemical composition of the chlorinated water will have an impact on the PMI when compared with freshwater.

This research attempts to make a comparison between rates of decomposition in freshwater and chlorinated water environments. In establishing a research design, it is the intention of the author to create a constant environment in which the effect of chlorine on PMI could be observed. The chlorinated water environments that were created for this research were adjusted to be as close to a standard pool environment as possible. Factors that were considered when designing these environments for accuracy consisted of: water movement, filtration, and chlorine level of the water. Freshwater environments acted as controls for the study and were compared to the chlorinated water environments. The freshwater environments mimicked the chlorinated environments with the exception of the chlorine. Additionally, diatoms and other freshwater inhabitants were absent allowing for a more consistent and accurate comparison for the chlorinated subjects.

The ability of investigators to establish the PMI of an individual can not only expedite the identification of the individual, but in a homicide investigation could help establish possible suspects of the crime. This study is an attempt to bring to light the possible significance of alternative chlorinated water environments during the process of decomposition. This thesis is a preliminary study into the possible effect that a chlorinated water environment could have on the process of decomposition. If a distinction can be made between the processes of decay in freshwater and chlorinated water environments, this research could assist investigators in more accurately determining the postmortem interval.

This thesis will try to explicate the following questions:

1) Does the presence of chlorine in a water decomposition situation have an effect on the postmortem interval?

2) What additional factors could contribute to the rate of decomposition in freshwater and chlorinated environments?

3) Does the addition of superficial trauma have an effect on the rate of decomposition in these environments?

4) How could this be valuable information to forensic anthropologists?

II. LITERATURE REVIEW

Research in aquatic decomposition is an expanding area of study in taphonomy. Studies that have been conducted observing decomposition in aquatic environments are relatively recent and sparse. In order to fully explain this thesis, it is imperative to look back to what has been accomplished in research of aquatic decomposition. Studies of decomposition in aqueous environments address additional phenomena including: adipocere, insect activity and succession, and taphonomy. Since this research is focused on the taphonomic aspect of aquatic decomposition, most of the literature reviewed here will also focus on taphonomy.

ADIPOCERE

The oldest research pertaining to aquatic decomposition addresses the presence of adipocere on human remains. Adipocere (adipo-fat; cere-wax) is defined as the "postmortem chemical alteration of normal adipose tissue rendering it firm, grayish white, and of wax-like consistency" (Cotton et al. 1987:1128). These publications are typically published as case studies in which adipocere is observed on human remains and described. Adipocere is classified as a feature that is not typical of most examined decomposition cases (Mansfield 1800, Dalton 1859, Gandy 1884).

More recent publications address the formation and preservative qualities of adipocere. Mant and Furbank (1957) published a review on adipocere formation on humans and variables that can affect the process. In this work, current and past theories and research are discussed and evaluated for accuracy. Adipocere formation is examined for burial and aquatic decomposition situations. Generally accepted factors that can have an effect on the formation of adipocere consist of "an excess of moisture, warmth, the presence of skin and subcutaneous tissues, and…a relative diminution of air and micro-organisms" (Mant and Furbank 1957:20).

A few years later, Evans (1963) makes similar observations regarding the formation of adipocere on humans. Evans states that factors that promote the formation of adipocere consist of: 1) the body must be in a warm, moist, environment, 2) humidity, and 3) constant presence of bacterial enzymes. He also stated that the consistency of adipocere is dependent on the environment in which the individual is interred. For example, bodies that are buried will have dry and brittle adipocere, whereas bodies that are in water will have sodden adipocere. Evans concluded that there was no correlation between the age or sex of an individual and the formation of adipocere.

Tomita (1984) analyzes the adipocere formation of white mice in various situations. Chemical analysis and gas chromatography are conducted on the adipocere formed by the mice. Hydroxy fatty acids and fatty acid oligomers, such as dimer acids, are produced through the formation of adipocere.

Cotton et al. (1987) examines the formation of adipocere of two individuals that were submerged underwater for five years. A large amount of adipocere is observed throughout the bodies of the individuals. The authors also note that the adipocere acts as a protective shield preserving the gross anatomy of the bodies. Additionally, the authors conclude that temperatures that are seventy degrees Fahrenheit or above promote the formation of adipocere and as a result arrest skeletonization.

Dix (1987) recounts cases of disposed corpses that were discovered in the lakes of Missouri. Different decompositional changes of the corpses are noted, such as the presence of adipocere and the sloughing off of soft tissue. Dix stresses caution when analyzing remains that have been in an aqueous environment when trying to distinguish between what appears to be antemortem trauma and what could just be decompositional changes of the body.

Mellen et al. (1993) study the formation of adipocere in ten human adipose tissue samples that were submerged under water of different temperatures and situations for approximately eighteen months. The authors focus on attempting to establish how much time is required for the formation of adipocere, how frequently adipocere forms, and what impact clothing would have on the formation of adipocere. They conclude that the formation of adipocere is accelerated by the presence of clothing and warm water.

O'Brien (1994) conducts an aquatic decomposition study focusing on the formation of adipocere at the Anthropological Research Facility (ARF) in Knoxville, Tennessee. O'Brien defines the "Goldilocks Phenomenon," in which the most optimal temperatures for adipocere formation were stated. He found that the "Goldilocks Phenomenon" temperature range for adipocere formation is approximately seventy degrees Fahrenheit to one hundred and thirteen degrees Fahrenheit.

Finally, Kahana et al. (1999) recount the retrieval of fifteen individuals from a shipwreck in the East China Sea and the different intensities of adipocere formation that were observed. As individuals are recovered from the water, adipocere is first observed after thirty-eight days of submergence in water that was ten to twelve degrees Celsius.

Kahana et al. contradict earlier studies on adipocere formation (e.g. O'Brien 1994) with evidence of significantly cooler environments producing adipocere rapidly.

INSECT ACTIVITY AND SUCCESSION

Insect succession is also a revalent topic in aquatic decomposition research. Payne and King (1972) analyze the decomposition of pig carrion in water and established a series of stages that are indicative of aquatic decomposition. The stages consist of:

1) ***Submerged Fresh****: This stage occurs when the carcass is under the water. The pigs typically bloated in one to two days in the summer and two to three weeks in the fall/winter. No insects are noted at this stage.*
2) ***Early Floating****: The bloated abdomen is the first aspect of the body to be above the water and to acquire blow fly eggs. A large amount of insects arrive at the carcass, the majority consisting of blow flies, chiefly flies, and other small flies. Predatory insects, such as yellow jackets, were also present feeding on the adult flies, fly eggs, and fluids of the pigs. Decay odor is noted as well as discoloration of the carcass.*
3) ***Floating Decay****: The fly eggs present hatched at this stage by Day 3. Massive feeding of the maggots resulted in larger openings in the carcass allowing access to under the skin. Beetles are also noted and a strong odor of decay.*
4) ***Bloated Deterioration****: Heavy maggot activity noted as well as froth on the surface of the water and carcass. The majority of the soft tissue is consumed by Day 7. The maggots began to migrate from the carcass to pupate and many were forced into the water. Maggots that were still feeding below the waterline were observed doing so vertically with only their posterior ends exposed. The head, shoulders, abdomen, and hindquarters were absent by the conclusion of this stage.*
5) ***Floating Remains****: Very few maggots and beetles remained at this stage. An abundance of dead maggots was noted in the water. This stage is extremely variable can last from 4-14 days. The length of this stage is dependent on the frequency in which the carcass is deteriorating and the number of remaining maggots.*
6) ***Sunken Remains****: The length of this stage is markedly variable and can last from 10-30 days. At this stage, only some skin and bone remain of the carcass. The bones of the carcass eventually sink to the bottom of the water and bacteria and fungi complete the decomposition process.*

Payne and King (1972) conclude that there is a considerable amount of variability associated with aquatic decomposition.

Haskell et al. (1989) analyze the possible aquatic insect indicators in establishing the submersion interval of pig carrion. When determining potential aquatic indicator insects, the authors contend that the researcher should take into account factors that could effect colonization of the carrion such as water current speed, depth of the water, position and size of carrion, and algae growth. If the previously mentioned factors are taken into account, insects such as the caddisfly (*Trichoptera*) and chironomid midges (*Diptera*, *Chironomidae*) can be used as indicators of the interval of submergence.

Davis and Goff (2000) conduct a study comparing the patterns of decomposition in Hawaii of terrestrial and intertidal environments. Differences in the decomposition between the two environments are apparent throughout the study. The terrestrial environments observed in this study mimicked past studies of arthropod succession and decomposition. The intertidal environments react similarly to those of marine environments and it was observed that *Diptera*, bacteria, and tidal activity were the main contributors to decomposition in this habitat.

Hobischak and Anderson (2002) studies four domesticated pig carrion in four separate still pond environments for one year in an attempt to determine aquatic invertebrate succession. The authors describe what aquatic invertebrates were present at various stages of the aquatic decomposition process; because these all vary and they will not be listed here. Hobischak and Anderson note the presence of seasonality of the appearance and absence of certain species of insects, which should be taken account in a forensic investigation. A more accurate assessment of stages and traits of aquatic decomposition is needed in order to “establish a better baseline to compare cases” (Hobischak and Anderson 2002:149).

TAPHONOMY

As stated previously, the bulk of this literature review focuses on taphonomic studies of aqueous environments. Reh et al. (1977) examined the interior and exterior of three hundred and ninety-five human corpses recovered from aquatic decomposition situations. The exposure to water of the corpses ranges from two to forty-seven days with water temperatures ranging from twenty-two to three degrees Celsius. The authors conclude that there are no significant differences observed when comparing stagnant and running water environments. Additionally, adipocere is noted at two and a half to three months, and washer woman's skin on the hand and feet was observed after five hours of exposure to water of the Rhine River. Washer woman's skin is defined as the "wrinkling of the skin of the hands and feet as a result of prolonged immersion in water" (Spitz 1965:505).

Davis (1986) discusses various deaths that are associated with water and presents case examples of such casualties. The author states that water deaths are one of the more challenging fatalities that pathologists investigate and that logic must also be employed when assessing these deaths. Additionally, the author examines methods in which drowning can be established and distinguishes between environmental factors, human factors, and intentional drowning. He cautions against falling prey to clichés that could cause the pathologist or investigator to jump to conclusions.

Various publications address bodies that are recovered from marine aquatic environments (Sorg et al. 1997, Boyle et al. 1997, Ebbesmeyer and Haglund 2002). Giertsen and Morild (1989) examine the remains of two bodies that had drifted five hundred kilometers in the Norwegian Sea before their discovery. Adipocere was observed in one body and extensive damage from aquatic scavengers was noted in the case of the other individual found. The decedents had traveled North on the Gulf Stream, which originates in the Gulf of Mexico. The authors stress the need for an international database of people missing at sea in order to facilitate identification of individuals that are found floating in international waters.

Haglund (1993) analyzes the remains of eleven human bodies that were recovered from various water environments (salt water and freshwater). The postmortem interval, which is calculated from the identification of the individuals and the last date they were known to be alive to the date of discovery, ranges from five weeks to thirty-six months Haglund examines the sequence of disarticulation and soft tissue disappearance of the eleven individuals and creates a scoring system for the presences or absence of "soft tissue (skin, muscle, and fat overlaying bone), exposure of bone, and loss of body parts" (Haglund 1993:810-811). This scoring system consists of:

0 *= all soft tissue complete*
1 *= partial exposure of bone due to loss of overlying soft tissue in some areas*
2 *= total exposure of bone due to loss of all overlying soft tissue with articulations maintained by ligaments only*
3 *= total exposure of retained bones with partial loss of bones from a defined region*
4 *= complete absence of the region*

Haglund (1993:811) observes that the "mandible, hands, head, and interior tibial crest" are the first aspects of the body to lose soft tissue. The separation of the regions of the human body proceeds in the following sequence: "hands and wrists, mandible and cranium, lower legs, forearms, and upper arms (excluding the pectoral girdle)," and lastly "portions of the trunk plus the pelvic girdle with the femora articulated" (Haglund 1993:811). The disarticulation of major joints of a body in water tends to advance from the distal to the proximal. The suspension of the body in water creates an environment in which movement of the body can be three-dimensional, which has a significant effect on the more mobile joints such as the ankles and wrists (Haglund 1993). Major variables that effect the disarticulation and soft tissue disappearance related to the body and the environment are also noted. The separation of the bones from the body seems to transpire when the body loses buoyancy and sinking occurs. Haglund (1993) concludes by stating the different environments will produce different disarticulation patterns as well as soft tissue alteration.

Rodriguez (1997) discusses the sequence of decomposition that a human body progresses through when it is in water. Rodriguez concludes that decomposition of submerged individuals occurs at approximately half the rate of bodies that are outdoors. The various factors that can affect the rate of decomposition in an aqueous environment are also presented.

O'Brien (1997) discusses the case of a woman whose body is discovered in Lake Ontario and the factors that should be taken into account by an investigator when assessing the status of such an individual (e.g. temperature, wind, and water movement). O'Brien describes the process of adipocere formation and how it can be utilized when determining the postmortem interval. The need for detailed accounts of the recovery of a body from an aqueous environment is stressed because it would assist in making an accurate assessment of the condition and possible postmortem interval of the individual.

Finally, Haglund and Sorg (2002) present an overview of current and past publications of research dealing with the recovery and study of human remains in aqueous environments. Haglund and Sorg discuss the following topics: body floatation/sinking, body positioning when floating/sinking, aquatic decomposition, disarticulation, fluvial transport, and aquatic bone modification (Haglund and Sorg 2002). The lack of understanding of aspects of aquatic environments and decomposition places an importance for the need for future research on this topic (Haglund and Sorg 2002).

III. MATERIALS AND METHODS

In this research, domesticated pigs (*Sus scrofa* L.) were utilized as a substitute for human cadavers. Human subjects would be preferable in conducting research such as this for the direct comparisons to forensic cases. For this study, however, there was no access to human cadavers available, hence, the use of domesticated pigs. Pigs are often used in decomposition studies as a substitute for humans due to the similarities in tissue and muscle structure and progression of decomposition (Goff 1993).

Four domesticated pigs were used in this study. The pigs were purchased from a pig breeder who frequently disposes of pigs that do not meet certain show criteria. Each of the pigs weighed approximately 35 pounds, and each was euthanized by a gun shot wound to the head with a .22 caliber weapon. Subsequently, two of the four pigs were stabbed in the abdomen (the wound being approximately 5 inches in length) producing a superficial wound before beginning the experiment in order to simulate sharp force trauma to an individual. The pigs were placed in Rubbermaid® storage containers that contained ice encased in Ziploc® bags for transport. The ice was placed in Ziploc® bags in order to prevent any unnecessary contact with water before the initiation of the project. The pigs were transported to the Early Ranch near San Marcos, Texas, where the research project was conducted. The research site in the Early Ranch was chosen because of its level ground, the amount of shade during the day, and its proximity to a water and power source. Each of the four pigs was placed in a vat containing approximately

75 gallons of water. The source of the water for this project was a pipeline that runs to the Early Ranch which is connected to the Edwards Aquifer artisan zone (see Appendix A).

Four Rubbermaid® agricultural one hundred gallon tubs were used to hold the carcasses throughout the duration of the research. The measurement of the Rubbermaid® tubs are as follows: Length = 52”; Width = 31”; Height = 25” (see Figure 1). The tubs were approximately 10 feet apart from each other in an effort to minimize insect cross contamination. The tubs were labeled as follows: Tub A = chlorinated water; Tub B = chlorinated water with trauma; Tub C = freshwater; Tub D = freshwater with trauma (see Figure 2). Tubs A and D were exposed to the most direct sunlight and Tub C was virtually in complete shade throughout the day. In the event that one of the subjects would become fully submerged, mosquito screen was laid across the width of the tubs with rope handles on the sides to aid in the recovery of the subject. A sturdier tray was not constructed due to the awkward shape of the tub and expense of construction.

Additionally, four cages were constructed to protect the research subjects from the local fauna. The cages measured 78” x 48” x 48” and consisted of a wood frame with wire fencing that covered all of the sides but one (see Figure 3). The frames were constructed of untreated wood (2” x 4”) that were connected by screws, and the fencing was 1 ½” chicken wire. Upon completion, the cages were placed over the tubs and removed when measurements and observations needed to be taken.

The chlorination of the water was accomplished with the addition of powdered commercial pool chlorine to the water. Continuous release tablets were not used because of their large size and the relatively small size of the tubs. The chlorinated water tubs

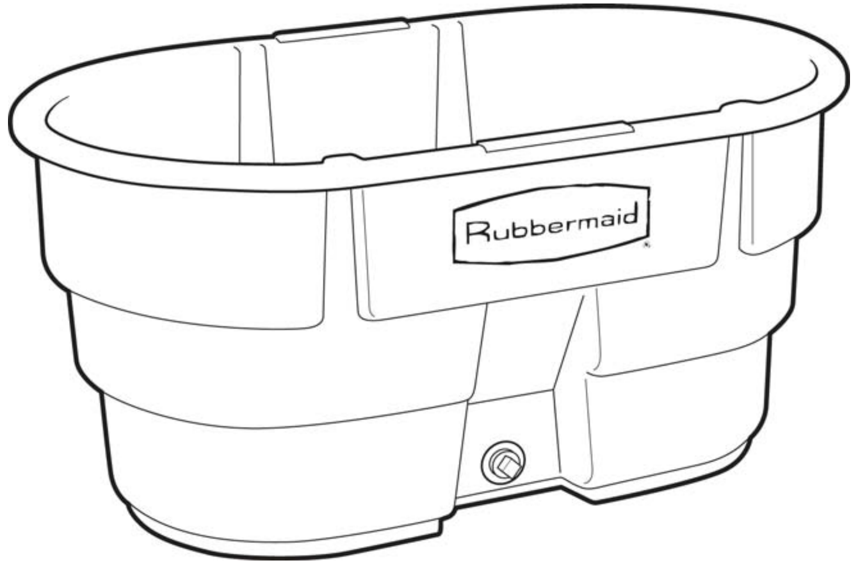

Figure 1. Schematic of Rubbermaid® Agricultural Tub (52” X 31” X 25”).

Figure 2. Image of Layout of Tubs.

Figure 3. Image of Cage (78”X 48”X 25”) and Tub.

were recorded as 1.0 ppm at the time of placement of the carcass in order to be in the range to closely simulate a chlorinated pool environment. Water pumps were used to recreate the turbation and water movement typical of chlorinated pools and similar river/stream-like freshwater environments. Generally, all chlorinated pools have some variation of a water pump system. In this project, Rio 2100 water pumps were used to simulate water movement. Rio 2100 pumps 500 gallons of water per hour. The pumps were wrapped in a layer of mosquito screen in order to prevent clogging due to hair, decomposition, etc.

Prior to the arrival of the pigs, water and the water pumps were added to the tubs. Also at this time, the temperature, pH, and chlorine levels of the water were recorded for each of the tubs. The pigs had been deceased approximately one hour when they were placed in the tubs of water. Chlorine was then added to Tub A and Tub B. There was an additional fifteen minute delay while the chlorine dispersed in the water. Chlorine measurements were then re-checked to ensure that the chlorine levels were in the range of a typical swimming pool (see Table 1), and each of the four pigs were placed in a tub containing approximately 75 gallons of water. The pigs were placed in the center of the tubs on their sides (see Figures 4-7). After the research subjects were placed in the water, photographs were taken with a Canon Digital Power Shot Camera. For the duration of the research project, photographs and notes were taken at regular intervals to document the stages of decomposition. A standard Rainbow brand pool chlorine and pH testing kit was used to measure the chlorine levels and pH of the water (see Table 2). Floating pool thermometers were placed in each of the tubs and used to record the water temperature.

Table 1. Rainbow Brand® Chlorine Testing Levels.

Chlorine Level (ppm)	Ideal Chlorine Level for Pool
5.0	
3.0	
2.0	X
1.5	X
1.0	X
0.5	

Figure 4. Tub A Pig Placement.

Figure 5. Tub B Pig Placement.

Figure 6. Tub C Pig Placement.

Figure 7. Tub D Pig Placement.

Table 2. Rainbow Brand® pH Levels.

pH	Ideal pH Level for Pool
8.2	
7.8	
7.6	X
7.4	X
7.2	X
6.8	

Water temperature and the chemical composition of the water were measured and recorded in order to illustrate any changes in the individual water environments. Individual observations and measurements can be noted in Appendices B and C. Water temperature was recorded in Fahrenheit with the use of floating thermometers that remained in the tubs for the duration of the study. Water pH and water chlorination were measured with the use of a standard Rainbow Brand® pool pH and chlorine testing kit. Air temperature and humidity were recorded with the assistance of Weather Underground, Inc. (2006) and noted in Fahrenheit in order to mark any similarities and/or differences between the environments inside the tubs to the environment outside of the tubs.

The program SPSS 14.0 was used to analyze data record from daily observations throughout the duration of the study in which the chlorine levels were still relevant (approximately the first thirty days). A partial correlation was utilized in order to isolate, but not exclude certain variables and focus on the stages of decomposition and the presence of chlorine. The day and treatment (e.g. Pig A, Pig B, etc.) of the project were controlled so that the relationship between chlorine and the stage of decomposition could be observed. Through the partial correlation, the effect that chlorine has on the stages of decomposition is apparent. Results below the 0.05 level are classified as significant.

In order to accurately observe the subjects' shift in the stages of decay, observations were made two times a day for the first 18 days of the experiment. As the project progressed, the carrion were checked once a day for 31 days, then two times a week for three weeks, and finally once a week for five weeks to the conclusion of the study.

IV. RESULTS

After placement in the tubs, each of the research subjects progressed and fluctuated differently from the next. For the sake of simplicity, each research individual's progress will be analyzed and illustrated by week instead of by the exact number of observations. A list of commonly utilized terms when discussing aquatic decomposition can be viewed at Table 3. Additionally, individual carrion will be reference by which tub they occupied (e.g., the pig in Tub A will be referenced as Pig A).

TRAUMA

All the carrion involved in the study displayed .22 caliber gunshot wounds to the head. Pig B and Pig D both had stab wounds located centrally on the abdomen approximately five inches in length resulting in a slight protrusion of the intestines.

PLACEMENT

Day 1

Pig A did not remain submerged when placed in the water. The carcass floated back to the surface of the water with the lower abdomen and proximal aspect of the thigh exposed. A small amount of blood exuded from the gunshot trauma and dispersed throughout the water.

Table 3. Commonly Used Terms in Aquatic Decomposition Deaths.

Term	**Definition**
Cutis anserina	"Gooseflesh" Result of "postmortem rigidity of muscle fibers (arrectores pilorum) of hair follicles" (Spitz 1965:28-30).
Washer Woman's Skin	Wrinkling of the skin of the hands and feet as a result of prolonged immersion in water (Spitz 1965: 505).
Gloving	The peeling back of the skin of the hands and feet, including fingernails and toenails, as a result of immersion (Spitz 1965:504).
Adipocere	"Grave wax" Result of the hydration and dehydration of body fats Grayish-white, waxy, and greasy in appearance Mostly observed at "the subcutaneous tissue of the face, extremities, buttocks and female breasts" (Spitz 1965:38).

Pig B floated when placed in the water. The right lateral aspect of the carcass was exposed from the lower neck region down to the distal aspect of the thigh. The posterior aspect of the forelimb and hindlimb were also exposed. A moderate amount of blood secreted from the gunshot wound and stab wound and dispersed throughout the water.

Pig C did not fully submerge when placed in the water. The distal aspect of the abdomen and proximal aspect of the thigh were exposed of the carcass. A small amount of blood emitted from the gunshot trauma and dispersed throughout the water. Gas was also discharged from the anus of the carcass.

Pig D floated to the surface when placed in the water. The right lateral aspect of the carcass was exposed from the lower neck region down to the distal aspect of the thigh. A significant amount of blood emanated from the gunshot and stab wounds and dispersed throughout the water.

OBSERVATIONS

WEEK 1

Pig A remained unchanged for the first two days after placement. On Day 3, the subject began to show a green discoloration throughout the torso. The intestines of the carcass also began to protrude on the third day and were fully exposed by Day 4. Bloat stage was reached at Day 4 which was illustrated by the rotation of the carcass onto the back and subsequent splaying of the limbs. Flies were not observed at the carcass until Day 4. Fire ants arrived at the subject on Day 4 and stayed with varied intensity throughout the duration of the week. Fire ants reached the carcass by traversing the splayed limbs that made contact with the walls of the tub and the rope connected to the screen that was underneath the carcass (see Figure 8). Maggot eggs were noted in the water and on the hindlimbs on Day 5. At Day 6, the intestines of the carcass deflated and an infestation of maggots was noted at the mouth and hindquarters. The subject remained floating throughout the week.

Pig B began to have a faint odor and exposed intestines by Day 2. Flies and fire ants were noted on the carcass (see Figure 9). Additionally, the intestines of the carcass fully deflated on Day 4. Discoloration and marbling and the presence of maggot eggs were all noted on Day 5. The rotation on the back and splayed body position of the carcass denoted the arrival of the bloat stage on Day 6. Greenish discoloration of the torso and maggots in the intestinal area were also noted at Day 6. On Day 6 fire ants were also observed harvesting maggot eggs and first instar maggots (see Figures 10-11). The carcass also remained floating throughout the week.

Pig C showed evidence of *cutis anserina* by Day 2. *Cutis anserina*, commonly known as “goose-flesh,” is defined as “erection of the papillae of the skin, as from cold or shock” (Agnew et al. 1965:371). The carcass remained relatively unaffected until Day 4 of the study. Discoloration of the subject and the protrusion of the intestines were visible on Day 4. Bloat staged was reached by Day 5. At Day 6, maggot eggs and dark black and blue discoloration was observed at the intestinal area. Fire ants were noted on the carcass at Day 7. The subject remained floating throughout the week.

Pig D changed more rapidly the first week after placement. The carcass remained floating throughout the week. The intestines of the carcass were protruding by Day 2. By Day 3, the subject showed a green discoloration of the chest, as well as the presence of flies and air bubbles escaping from the nasal cavities. Marbling and the advancement to

Figure 8. Fire Ants Harvesting Maggot Eggs and 1st Instar Maggots. Fire ants are taking the 1st instar maggots and maggot eggs across the limb to the hoof and off the carcass.

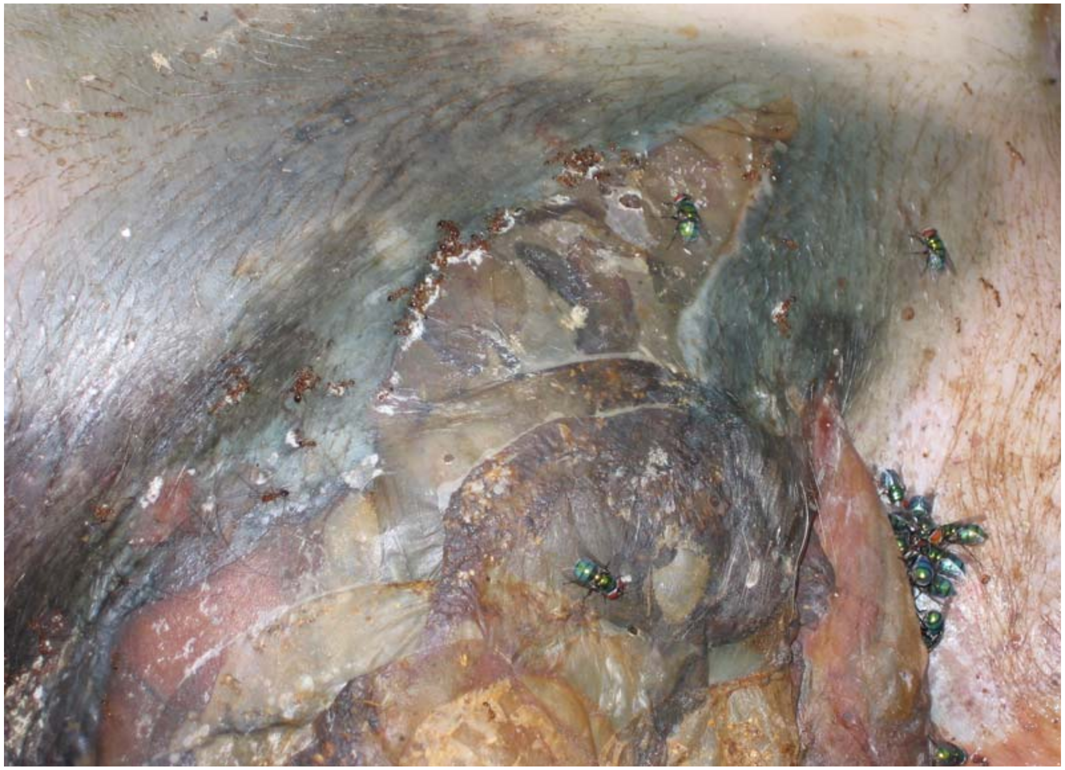

Figure 9. Fire Ant Activity at the Intestinal Area of Pig B. The fire ants are harvesting the maggot eggs at the border of the distended intestinal area.

Figure 10. Fire Ants Transporting 1st Instar Maggots. Fire ants are transporting the 1st instar maggots across the mosquito screen along the sides of the tub.

Figure 11. Fire Ants Transporting 1st Instar Maggots across Tub. Fire ants are carrying 1st instar maggots across the rim of the tub.

bloat stage occurred at Day 4. Additionally on Day 4, flies were present in great numbers and more intestine and internal organs became visible and protruding. The subject became almost completely green in color at Day 5. An abundance of maggot eggs was also noted at Day 5. Exfoliation and partial mummification of the subject was observed on Day 6. The hair of the subject also began to slough off and the intestines deflated. Maggots covered the torso and were visible under the skin. The subject became dark purple and black throughout and had an abundance of maggots. No fire ants were noted during the first week which could be a related to the more rapid decomposition of the subject as well as the concentration of fire ants on Pig C.

WEEK 2

Pig A was floating and began to mummify at the hindquarters at Day 8. The intestinal area of the subject contained an abundance of maggots and had turned black on the ninth day. On Day 10, beetles were noted and the hair and skin began to slough off the right forelimb of the carcass. Additionally, bubble-like protrusions appeared at the intestinal area at Day 10. At Day 11 dead maggots were present in the water. The maggots became larger, but fewer, by Day 13. Maggot eggs, but no maggots, were visible by Day 14. Mummification of the skin revealed the outline of the subject’s hipbones.

Pig B had maggots in the oral cavity, at the neck, and along the exposed dorsal surface on Day 8. The intestines of the carcass, though still attached, floated separately from the rest of the body at Day 9. Beetles also were observed on the carcass at Day 9. Beetles gained access to the carcass by either traversing on the rope attached to the screen that was underneath the carcass or when the carcass reached the bloat stage, walking on to the splayed limbs that touched the edge of the tub. On Day 10, the hair of the subject began to slough off at the forelimbs. Maggots were noted in the intestinal area and concentrated under the shade and cover of the forelimb, in the mouth, and along the spinal column at Day 10. At Day 12, the intestines of the subject became completely detached from the rest of the body. Beetles were observed on the carcass in large numbers on Day 13. The ribs and bones of the hind limbs were visible on Day 14. Additionally on Day 14, a large maggot mass and *cutis anserina* on the skin where it borders the water were observed.

Pig C possessed a large amount of fire ants and flies on Day 8. Many maggot eggs were located at the mouth, throat area, intestines, and under the hind limbs. Fire ants were harvesting the colony of maggot eggs located at the intestines and a bubble-like protrusion was noted in the intestinal area on Day 10. Maggots were finally observed on the subject at Day 12. The skin of the carcass began to exfoliate on Day 12. On Day 13, the appearance of more maggots at the intestinal area led to the subsequent increased maggot harvesting by the fire ants. An abundance of fly and beetle activity was also observed on Day 13. At Day 14, a very slight decrease in fire ant activity was noted.

Pig D began to mummify while it floated at the surface of the water. All the limbs and neck area were observed to be mummified on Day 8. Many dead maggots in the water and a major maggot concentration on the ventral surface of the torso were noted on Day 8 as well. A thick, opaque, beige film on the surface of the water appeared on Day 8. Day 8 also yielded the appearance of beetles on the subject. On Day 9, the maggots continued to deteriorate the head, intestinal area, and lower torso with the mandible being exposed. Fire ants were also observed walking across the film on the water to and from the carcass on Day 9. By Day 10, the bones of the ribs, the mandible, and the pelvic bones were visible, as well as a cornucopia of beetles. Maggots on the ground outside of the tub were observed being attacked by fire ants on Day 11. All the ribs, clavicles, hind limbs, mandible, and the lumbar vertebrae were exposed on Day 12. The water on day twelve was noted to be completely opaque with gnats on the surface. On Day 14, half of the mandible sank in the water and the vertebral column became visible. By Day 14, bones of the subject were almost completely clean of tissue except for the area in direct contact with the water.

WEEK 3

Pig A was floating throughout the week and had mummification of the torso area by Day 15. Also at Day 15, new maggot eggs were present at the left forelimb, as well as beetles throughout the carcass. At Day 16, there was increased fly activity and maggot activity was visible under the black mummified skin, hip area, and mouth of the subject. Maggot presence increased in the pelvic region at Day 17. Day 18 produced gnats on the surface of the water as well as the deflation of the throat area of the carcass. Additionally, a bee was observed carrying off a fly, and the initial appearance of adipocere was noted at the hind limbs on Day 21.

Pig B began to partially mummify and the bones of the hindlimbs, forelimbs, and some ribs were visible by Day 15. All the ribs, bones of the hindlimbs, and the outline of the vertebral column were visible by Day 16. Additionally, the left forelimb was completely disarticulated at Day 16. A slight re-hydration of the mummified tissue was observed on Day 17. On Day 18, skeletonization of the carcass was almost complete with the exception of the head and distal ends of the forelimbs and hindlimbs. The maggots at Day 18 turned static showing little movement. Beetles were also noted to be present on

Day 18. Adipocere formation was observed around the perimeter of the carcass at Day 19. The vertebral column of the carcass remained articulated. The head and both forelimbs of the carcass became submerged in the water at Day 20. In addition, adipocere formation was noted on the vertebral column at Day 20. By Day 21, both forelimbs have detached and became completely immersed in the water. The right ribs also began to sink at Day 21. The carcass continued to float throughout the week.

Pig C had maggot masses in the intestinal area as well as at the right forelimb at Day 15. Fire ant activity also decreased at Day 15. Exfoliation of the torso area and a large amount of beetles was noted on Day 16. The torso of the carcass was deflated outlining the bones underneath the skin at Day 17. Intensive maggot activity was noted at the mouth and right forelimb working distally towards the ribs. The maggot activity slowed significantly by Day 18. The sternal aspect of the ribs were visible and the right forelimb partially skeletonized by Day 21. Furthermore, adipocere was present and noted on all limbs at Day 21. The flotation of the carcass persisted throughout this week of the study.

Pig D had maggots on the vertebral column, hip bones, forelimbs, and hind limbs at Day 15. The head of the carcass detached and sank in the water at Day 15. A portion of the central vertebral column was completely exposed and maggots remained on the vertebral column at Day 16. The right forelimb sank under water at Day 16. Gnats were noted on the surface of the water on Day 16. The anterior aspect of the vertebrae began to detach at Day 18. The hind limbs disarticulated and sank at Day 19. By Day 20, the entire carcass was under water except for the vertebral column, some ribs, and scapulae. At Day 21, the vertebral column was the only part of the carcass that was still afloat.

WEEK 4

Pig A had heavy fly activity on Day 22. A greenish-black discoloration of the carcass and skin slippage at the right forelimb was noted on Day 24. The proximal aspect of the bones of the hind limbs and the hip bones was exposed at Day 24. A red, rust coloration of the flesh was observed at the right forelimb on Day 25. Partial mummification of the torso was visible on Day 25. On Day 26, the left hindlimb detached from the rest of the carcass and sank under the water. Flies were present on Day 26 but there was an absence of maggot activity. Deflation of the chest area occurred by Day 27. Partial sinking of the pelvic region was noted on Day 27. Flies and gnats were present in and around the tub on Day 27. A greenish-purple coloration of the skin was noted on Day 28.

Pig B had no live maggots visible from the surface on Day 24. Flies were noted concentrating at the vertebral column and gnats on the surface of the water on Day 24. A milky film was observed on the surface of the water on Day 26. The head and neck area of the carcass detached and sank under the water on Day 26. Additionally, the right ribs were almost completely submerged under the water on Day 26. Days 27 and 28 had a frenzy of flies and gnats in and round the tub.

Pig C had a fly concentration at the hindlimbs and open chest cavity on Day 22. The jaw area and abdomen became deflated by Day 24. Black-red color of skin at the hindlimbs, forelimbs, and around the perimeter of the body at the water line was noted at Day 24. Maggot activity was noted at the proximal aspect of the hindlimbs at the border of mummified tissue on Day 26. Deflation and mummification of the carcass was observed on Day 28.

Pig D was almost completely sunken with the exception of the vertebral column and a few right ribs by Day 22. No live maggots and very few flies were noted throughout the week. Gnats on the surface of the water were also observed during the week. By Day 26, the remaining bones and fatty material above the surface of the water began to crust and harden.

WEEK 5

Pig A had heavy maggot activity at the right aspect of the chest on Day 29. The black mummified tissue became re-hydrated and nearly liquefied at Day 29. Heavy fly activity and a few maggots were observed at the vertebral column and proximal aspect of the torso at Day 30. Pre-pupa maggots were noted attempting to leave the carcass and tub to pupate on Day 31. These pre-pupa maggots did not progress beyond the tub and subsequently drowned. The tip of the head and snout began to sink on Day 32. The water turned a red-rust color on Day 32. The hip bones, femora, and lower portion of the vertebral column became visible on Day 33. On Day 35, the left hindlimb of the carcass detached and sank under the water.

Pig B had a milky film on the surface of the water on Day 29. The right ribs sunk just below the surface of the water also on Day 29. Flies and gnats were observed in and around the tub. No live maggots were observed on Day 30. The articulated vertebral column was inundated with flies on Day 31. The ribs of the carcass began to disarticulate on Day 32. The right hindlimb and both forelimbs had sunken by Day 32. Beetles, gnats and flies were all present and observed also on Day 32. All limbs have disarticulated and have sunk by Day 34.

The insect activity of Pig C consisted of flies, maggots at the neck region, and gnats on the surface of the water. Maggot activity was also noted at the hindlimbs, chest and pelvic area. Maggots were visible in a cavity, inside the carcass, that was at the right forelimb on Day 31. Beetles were noted on the abdomen and left forelimb on Day 33. Maggots were no longer visible on the surface of the carcass at Day 34.

Gnats, a few flies, and fire ants all make reappearances at Pig D. The fire ants were no longer visible by Day 30, and the flies had gone by Day 31. Subsequently, no remarkable changes occurred to the carcass.

WEEK 6

In Pig A, maggot activity was observed under the vertebral column. White chunks of fatty tissue were present around the carcass. The left and right sides of the throat split open revealing second and third instar maggots. The distal aspect of the hindlimbs disarticulated from the rest of the carcass and sunk under the water. White mold or fungal growth on the right aspect of the neck and distal end of the right forelimb was noted on Day 40.

Pig B consisted of many flies, fire ants, and gnats. Extremely heavy gnat activity at the tub was recorded on Day 37. The vertebrae began to disarticulate from one another. Only a section of vertebrae and a few ribs remain floating by Day 41.

The right forelimb of Pig C sank by Day 36. The skin around the carcass at the water line was white and red in color with bumps, often referred to as *cutis anserina*. Gnats, flies, and beetles were present at and around the tub. The abdomen of the carcass was completely deflated by Day 38. Fire ants were observed on the right hindlimb and traveled the length of the carcass to a cavity in the neck region. The water of the tub had a red tint at Day 41.

The gnats in Pig D were numerous and were observed on the surface of the water and on what was left of the carcass. All that remains floating of the carcass are a few thoracic vertebrae in fatty tissue.

WEEK 7

The gnats of Pig A were absent throughout the week. The right ribs of the carcass began to protrude out of the mummified skin. Many beetles of all different types were noted on the carcass. Maggot activity was visible at the abdomen and vertebral column on Day 43, but was no longer visible by Day 45. Both hindlimbs and the left forelimb sank beneath the water at Day 45. Some re-hydration of the vertebral column and the skin on the abdomen was observed on Day 46. The mandible and skull of the carcass sank on Day 49.

The bones that were floating on the surface of the water in the fatty material pieces of Pig B are no longer identifiable. Three separate fatty material pieces were floating in the tub on Day 43. White fat/tissue chunks peppered throughout the tub. No insect activity is noted by Day 45. By Day 49, one strip of fatty material (which contained mostly hair, an unidentifiable bone, and fat material) was left floating on the surface of the water.

The abdomen of Pig C appeared to be slightly distended by Day 43. A potpourri of beetles was noted on Day 44. Flies and maggots were noted. Maggot activity was observed at the pelvic area and the right side of the abdomen. A milky film on the surface of the water was observed on Day 45. The *cutis ansernia* at the water line began to peel back on Day 47. Maggot activity ceased to be observed on Day 47. The hindlimbs and most of the pelvic bones are submerged. The abdomen has turned darker in color and the ribs collapsed and became more visible.

Pig D had no significant changes. The gnats returned to the tub on Day 44.

WEEK 8

The entire carcass in Pig A completely deflated by Day 55. The deflation of the carcass suctioned the skin and tissue to the bones in the chest. No flies were observed and some maggots were noted in the pelvic area.

As the result of a bout of rain, what remained of Pig B was scattered throughout the tub. Some large fatty material pieces were observed just under the water surface. Gnats were present in the tub, but there was a noticeable absence of flies and beetles.

Except for the left forelimb, all the limbs of Pig C disarticulated and sank beneath the water by Day 55. The proximal aspect of the left forelimb was mummified and was laying across the carcass and still floating. Flies and beetles were still present in and around the tub. No maggots or maggot eggs were observed.

Pig D had no noteworthy changes. One piece of the carcass still floated in the tub.

WEEK 9

Pig A had partial re-hydration of the skin. The carcass was flattened and deflated and continued to float at the water surface. A limited portion of gnats, flies, and beetles were also present.

What is left of Pig B was further obliterated by rain leaving approximately three pieces of carcass floating. The rest of the carcass transformed into a peach-flesh colored sludge at the surface of the water. No insect activity of any kind was noted.

All the limbs and a fraction of the pelvic region of Pig C had submerged in the water. The position of the carcass had shifted ninety degrees in the tub. Some mummified tissue remained at the abdomen and the left forelimb where the forelimb crosses over the chest. Some gnat activity was noted. There was an absence of flies and beetles at Day 59. Some maggot activity was observed in the abdomen area.

Pig D had no significant changes. Some spinous processes of thoracic vertebrae could be identified in the remaining floating piece in the tub.

WEEK 10

Pig A had maggot activity at the left aspect of the vertebral column (cervical and thoracic). Some sporadic flies were noted, but there was no heavy insect activity.

Pig B had no eminent changes. Only a few pieces of the carcass remain floating in the tub and no insect activity was noted.

Maggots were visible on Pig C on the outskirt of the last patch of mummified tissue on the torso. A gray sludge material was observed at the hind limb area.

Pig D had no insect activity except for several gnats. The carcass showed no remarkable changes.

WEEK 11

The limbs of Pig A had disarticulated from the rest of the carcass. The majority of the carcass still remained floating. Maggot activity was observed along the vertebral column. A few flies were noted, but no beetles were observed.

Only a few pieces of Pig B soft tissue remained floating, none of which contained bones. A significant amount of gnats were noted on the surface of the water and the pieces of the carcass. No beetles or maggots were observed.

Maggots were observed in the gray matter at the distal end of the torso of the carcass Pig C and at the midsection of what is left of the head. A few flies were observed and an absence of beetles was noted.

Pig D had a plethora of gnat activity. The carcass showed no significant change.

WEEK 12

Pig A had no visible maggot activity and no significant fly activity. A large portion of the carcass remained floating. No beetles were observed and the carcass consisted largely of mummified tissue.

Two pieces of the carcass of Pig B remained floating. A large amount of gnats were observed in the tub, on the surface of the water, and on the pieces of the carcass that remained floating in the water. No remarkable changes to the carcass were noted.

The head and hind limbs of Pig C were disarticulated, but the hindlimbs were still floating on the surface of the water. No beetles, maggot, or significant fly activity were recorded.

Pig D had a great amount of gnat activity. No noteworthy change to the carcass.

WEEK 13

No observations taken.

WEEK 14

Dead beetles were noted on Pig A. The carcass showed no significant change.

Pig B had no significant change.

Pig C had no significant change and no insect activity.

Pig D had no significant change.

WEEK 15

A large portion of Pig A was still floating on the surface of the water. The vertebral column and the left ilium were visible at the surface. The flesh of the carcass had retained the hair and mummified tissue remained.

Pig B had a film on the surface of the water. Many dead gnats were observed in the water and on the sides of the tub.

A moderate portion of Pig C was still floating. Some vertebrae and portions of ribs were still visible. A section of mummified tissue remained on the carcass.

A film was noted on the surface of Pig D. A fair amount of gnats were observed in the water and the sides of the tub.

WEEK 16

Pig A had no significant change and no insect activity.

Pig B had no significant change and no insect activity.

Pig C had no significant change and no insect activity.

Pig D had no significant change and no insect activity. Bones were no longer visible in the one remaining floating piece of the carcass.

Images of the subjects at the onset of bloat stage and on the last day of the day of the study can be viewed at Figures 12-15.

Throughout the duration of the study, all of the carcasses remained floating, which made the establishment of aquatic decomposition stages difficult. Therefore, the stages of decomposition were noted using aquatic decomposition standards, with the absence of the initial sinking stage (see Table 4). Terrestrial decomposition stages were not utilized, but are listed in Table 5.

Figure 12. Pig A. The image on the left shows Pig A at the onset of Bloat stage (Day 4). The Image on the right shows Pig A on the last day of the study (Day 105).

Figure 13. Pig B. The image on the left shows Pig B at the onset of Bloat stage (Day 6). The image on the right shows Pig B on the last day of the study (Day 105).

Figure 14. Pig C. The image on the left shows Pig C at the onset on Bloat stage (Day 5). The image on the right shows Pig C at the end of the study (Day 105).

Figure 15. Pig D. The image on the left shows Pig D at the onset of Bloat stage (Day 4). The image on the right shows Pig D on the last day of the study (Day 105).

Table 4. Aquatic Decomposition Stages.

Stage of Decomposition	**Description**
Float	Variable how long will float Body will sink when air vacates lungs
Initial Sinking	Autolysis Putrefaction
Float	Variable when refloatation will occur Result of gas formation in abdomen
Differential Decomposition	Region of body above water endured insect ovapositioning The insect consumption of the remains causes the second submersion
Secondary Sinking	The remains sink again and finish the decomposition process beneath the water
a. Free	Remains free floating in water
b. Snagged	Remains caught underwater

Source: (O'Brien 1994:2).

Table 5. Stages of Decay and Associated Gross Morphological Changes.

Stage of Decomposition	External Signs
Fresh	Algor Mortis Livor Mortis Rigor Mortis
Discoloration	Initial skin slippage Abdominal discoloration Progressive discoloration of thorax and neck Marbling
Bloating	Abdominal distention Bloating progresses throughout the body Initial skeletonization of face
Skeletonization	Bloating completely subsided Soft tissue continues to deteriorate
Skeletal Decomposition	All soft tissue consumed Skeleton completely disarticulated Cortex of bone begins to crack and age

Source: (Love and Marks 2003:169).

Statisitically, there appears to be a significant correlation between the presence of chlorine in the water and stages of decomposition (see Table 6). When the partial correlation for this project was enacted in the program SPSS 14.0, the result was a significance of 0.003. The significance of the statistical partial correlation analysis will be discussed in the following chapter.

Measurements taken during this study include air temperature, humidity, water temperature, water pH, and water chlorination. The individual water temperatures compared to the ambient temperature can be seen at Figures 16-19. Additionally, the water temperatures of the individual pigs in comparison to one another can be seen in Figure 20. The study carried on for approximately three and a half months, commencing August 30, 2006 and terminating December 12, 2006.

Table 6. Partial Correlation of Water Chlorination and Stages of Decomposition.

Control Variables			Water Chlorination	Stages of Decomposition
Treatment & Day	Water Chlorination	Correlation	1.000	-.254
		Significance (1-tailed)	.	.003
		df	0	116
	Stages of Decomposition	Correlation	-.254	1.000
		Significance (1-tailed)	.003	.
		df	116	0

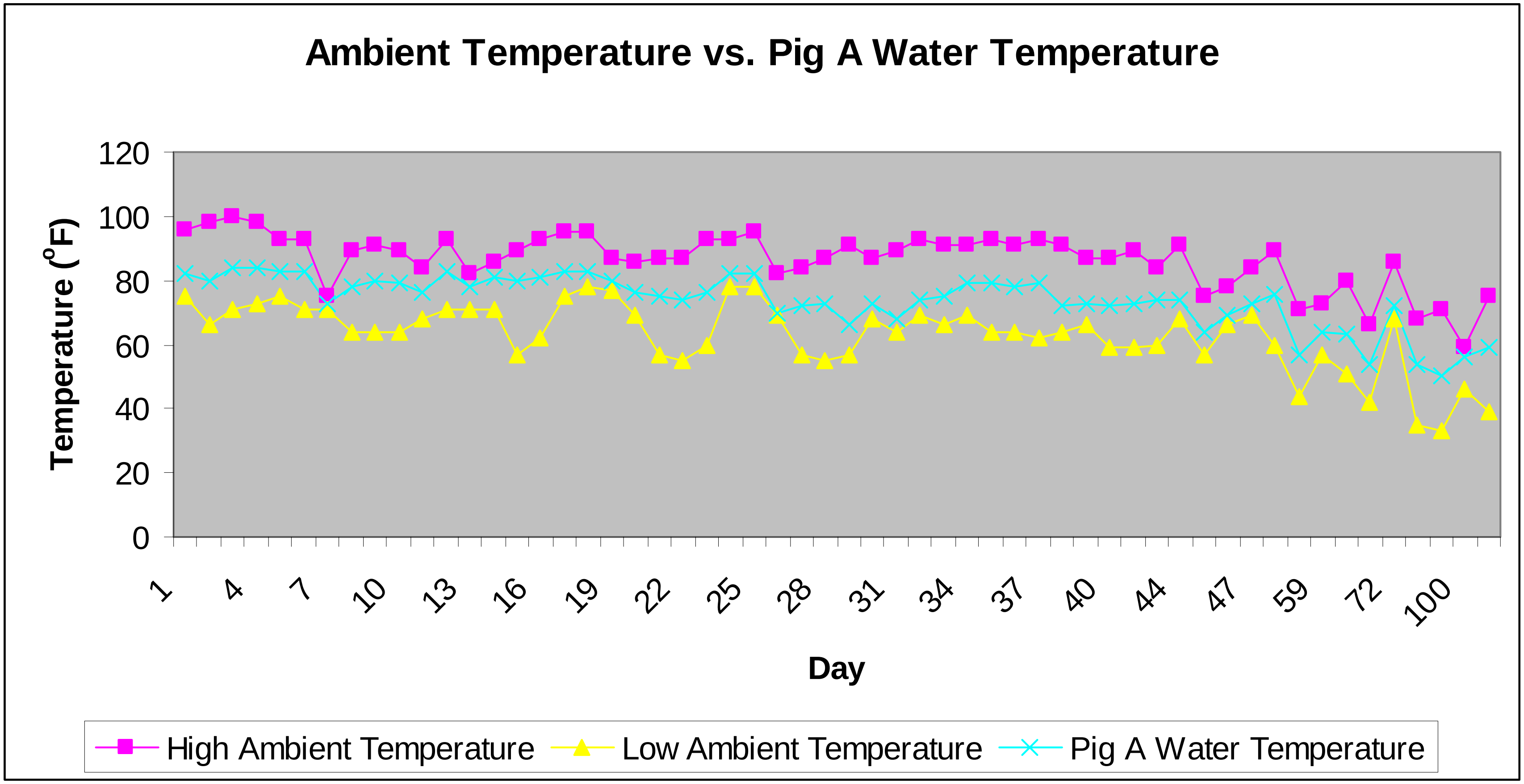

Figure 16. **Ambient Temperature vs. Pig A Water Temperature.** This graph compares the high and low ambient temperature to the water temperature recorded from Pig A.

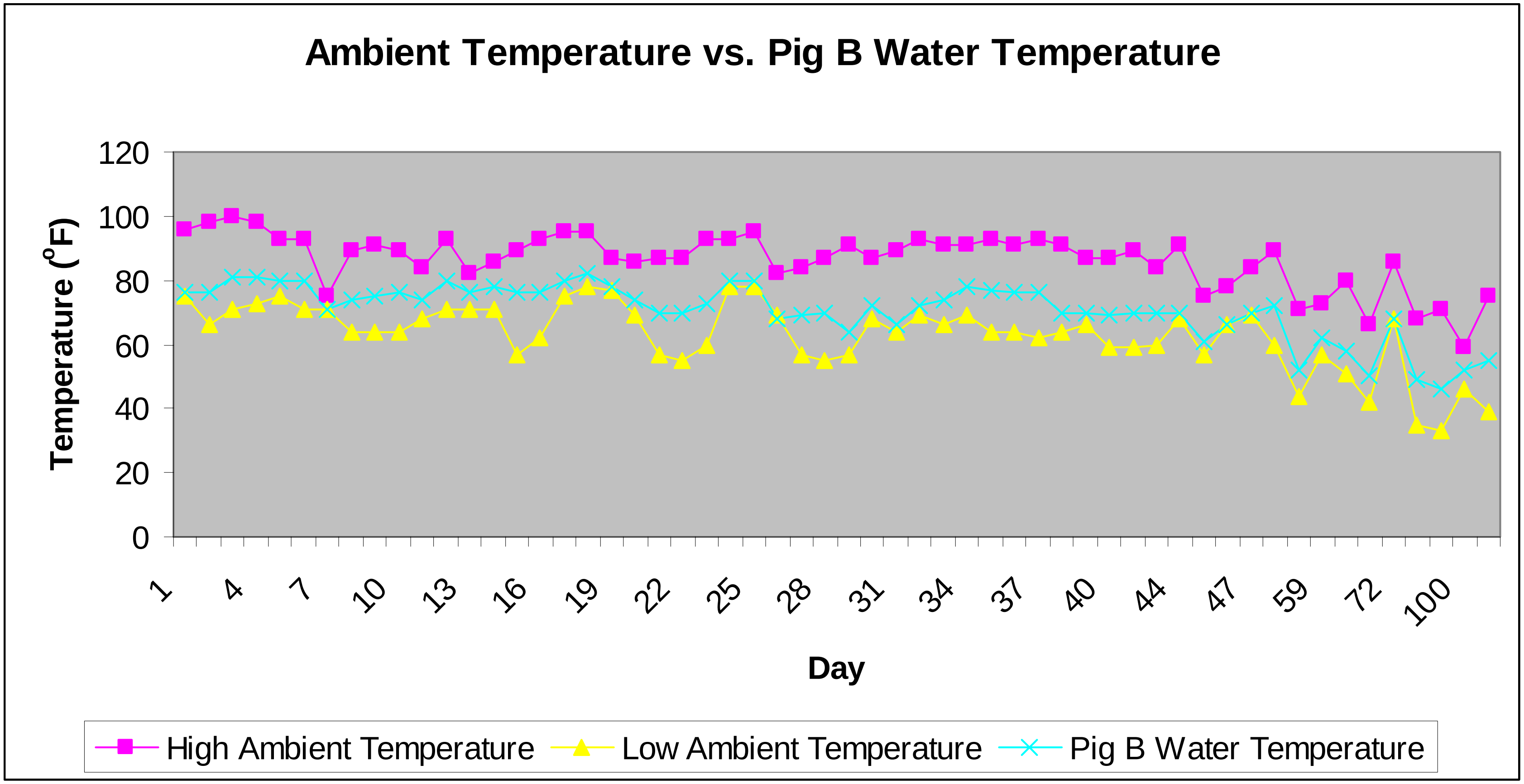

Figure 17. Ambient Temperature vs. Pig B Water Temperature. This graph compares the high and low ambient temperature to the water temperature recorded from Pig B.

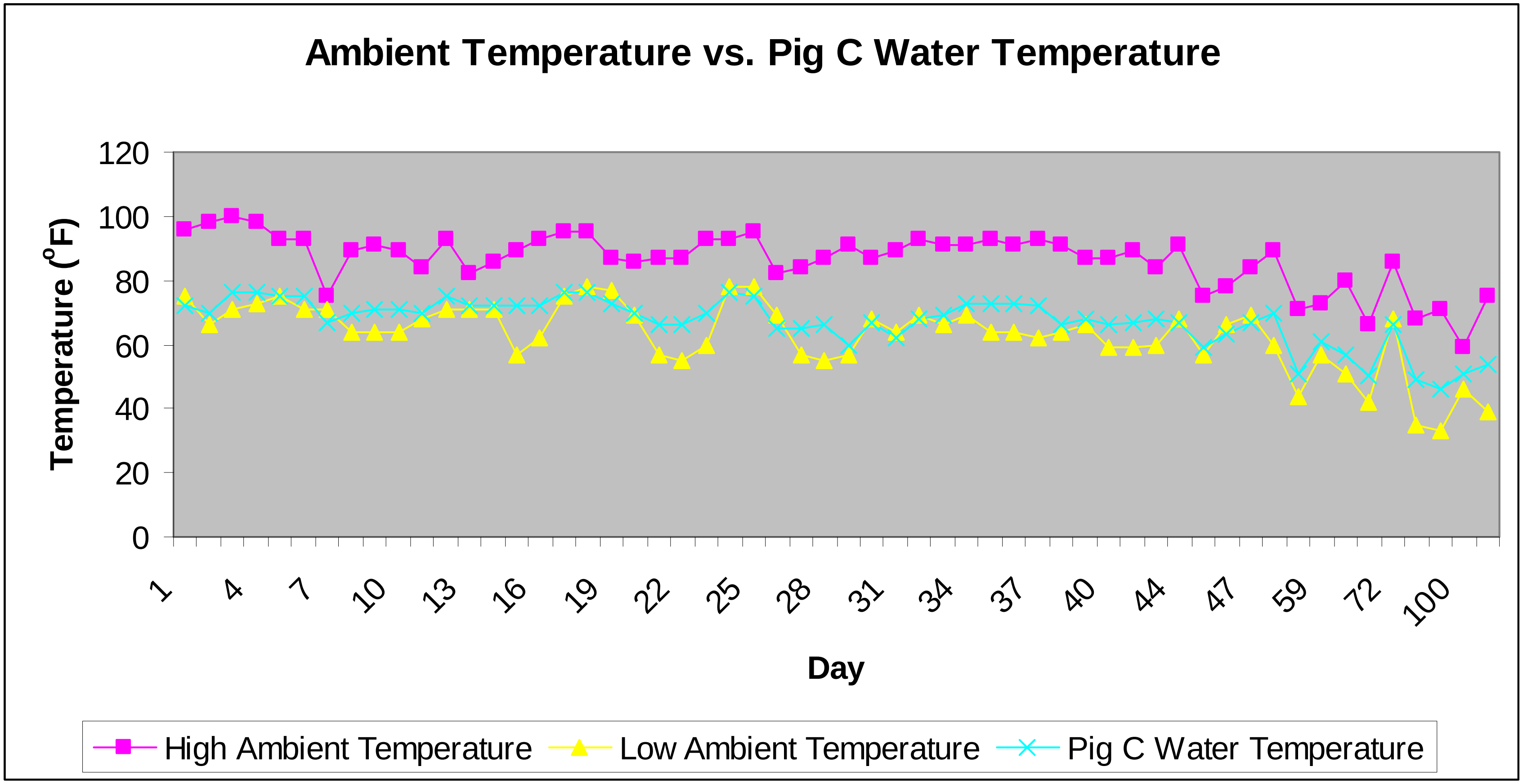

Figure 18. Ambient Temperature vs. Pig C Water Temperature. This graph compares the high and low ambient temperatures to the water temperature recorded from Pig C.

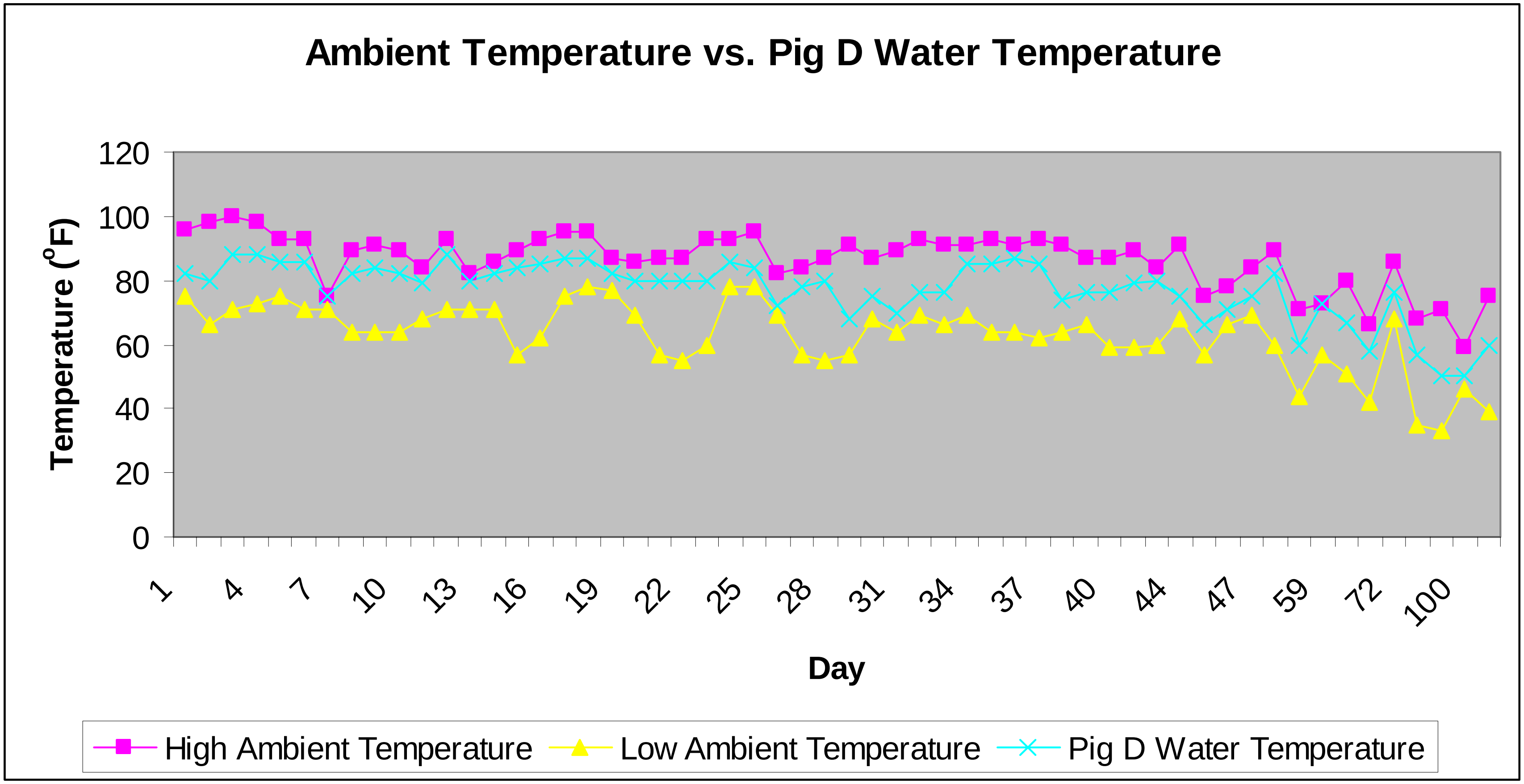

Figure 19. Ambient Temperature vs. Pig D Water Temperature. This graph compares the high and low ambient temperature to the water temperature recorded from Pig D.

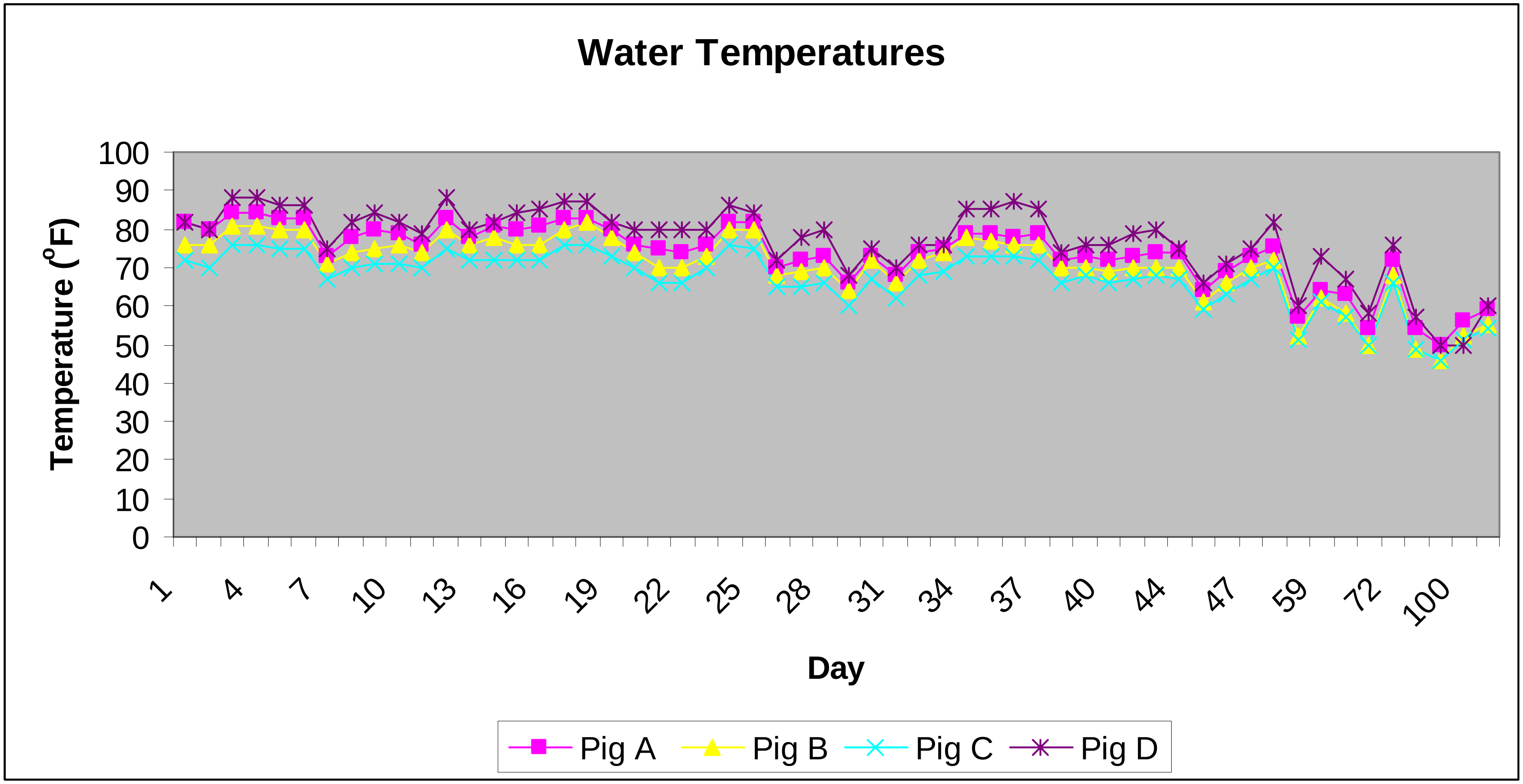

Figure 20. Water Temperatures. This graph compares the water temperatures of each of the subjects in the study.

V. DISCUSSION AND CONCLUSIONS

Three and a half months had elapsed since the pig carcasses were placed into the four tubs of water. During this time of placement, various morphological and taphonomical changes occurred (see Appendices B and C). This chapter will begin by revisiting the initial questions posed for resolution by the research. These questions consisted of: 1) Does the presence of chlorine in a water decomposition situation have an effect on the postmortem interval? 2) What additional factors could contribute to the rate of decomposition in these environments? 3) Does the addition of superficial trauma have an effect on the rate of decomposition in these environments? 4) How could this be valuable information? In order to conclusively answer these questions, a brief synopsis of each subject shall be presented here:

PIG A (Chlorinated/ Void of Trauma)

The carcass in this tub floated throughout the duration of the project, which was unexpected, but not an uncommon occurrence. As a result of the carcass' persistent flotation, aquatic decomposition stages were unable to be used completely as a gauge. When bloat stage began (Day 4), the intestines of the carcass protruded from the abdomen. Periods of mummification of the carcass exposed above the water were peppered throughout the three and a half month period. Adipocere formation and *cutis anserina* were also noted at the waterline of the carcass. Periodical milky skin was noted on the surface of the water throughout the study. Insect activity on the carcass above the surface of the water was standard cycle of ovapositioning and maggot activity. Many dead 3rd instar maggots were noted in the tub. No pupae were observed during the study.

Fire ants were also noted and will be discussed later. As the carcass proceeded into more advanced decay, the body disarticulated and aspects of the carcass submerged beneath the water. This pig was slow to completely decompose and a portion of the carcass remained floating at the termination of the project (December 12). Complete skeletonization of the carcass never occurred.

PIG B (Chlorinated/ Stab Wound)

The carcass in this tub was the most illustrative of the impact of chlorinated water on the rate of decomposition. The initiation of bloat stage was delayed approximately twenty-four hours as compared to the rest of the specimens in the study. Once bloat stage was achieved (Day 6), and the chlorine in the water had dissipated, the carcass decomposed at a standard interval with the rest of the specimens in the study. The intestines of the carcass protruded from the abdomen as the bloat stage developed. Even with the application of a stab wound to the abdomen, the carcass floated throughout the decomposition process and only sank when full skeletonization had occurred. The continued flotation of the carcass allowed for differential decomposition above and below the waterline. *Cutis anserina* was noted around the perimeter of the carcass at the waterline. The water in the tub had a milky film on the surface periodically through the study. The exterior of the carcass exposed above the surface of the water experienced insect ovapositioning and subsequent maggot activity. The pupa stage of development was not observed due to the high sides of the tub preventing the third instar maggots from leaving to pupate. Fire ants were observed traversing the length of the carcass. The impact of the fire ants will be discussed later. The carcass experienced multiple periods of mummification and re-hydration. Exfoliation of the hair and epidermis was also noted. While in advanced decay, only portions of the carcass remained floating and consisted of sporadic vertebrae and other bones floating on “pillow-like” pieces of adipocere. As a result of a rain storm, these adipocere pieces of the carcass were obliterated and all that remained were minute pieces of adipocere peppered throughout the tub.

PIG C (Freshwater/ Void of Trauma)

The carcass in this tub had the slowest initial decomposition of the four subjects. Reasons for this will be discussed later. The carcass floated for the duration of the project and the intestines protruded from the abdomen at the inception of bloat stage (Day 5). A standard cycle of insect activity was noted. Pupae were not observed in the vicinity of the carcass or tub. Heavy fire ant activity was noted and the impact will be discussed later. The carcass experienced disarticulation and submergence of some aspects of the carcass. The water in the tub turned a rust color and frequently had a milky film on the surface. *Cutis anserina* was observed at the water line around the perimeter of the carcass. Discoloration of the flesh (white and rust color) was noted at the waterline of the carcass. Frequent mummification and rehydration of the carcass exposed to the surface of the water was noted throughout the span of the project.

PIG D (Freshwater/ Stab Wound)

The carcass in this tub had the most rapid decomposition compared to the other tubs in the study. The carcass quickly advanced through the process of decay. The carcass was stabbed and yet maintained its’ buoyancy throughout the study. The intestines of the carcass protruded from the abdomen in the onset of bloat stage (Day 4). The standard cycle of insect activity was noted and fire ants were also observed scattered throughout the carcass. *Cutis anserina* was noted around the parameter of the carcass at the waterline where the carcass meets the water. By the conclusion of the study, the carcass had completely sunk under the water.

The primary question of this study was: Does the presence of chlorine in a water decomposition situation have an effect on the postmortem interval? Additionally, the question of what variables could be present that could effect decomposition was also posed. To fully explore these questions, the variables that were present during the research must be noted and explained.

VARIABLES

Fly and Maggot Activity

Previous research on decomposition noted that in warm environments, flies could arrive at a dead individual almost immediately after placement (Mann et al. 1990:109). The initial presence of flies at or on the carcass was not noted on any of the subjects until Day 3 of this study (Pig D). The chlorinated Pigs A and B did not have any insect activity observed until approximately twenty-four hours after the initial fly activity was noted on freshwater Pig D (Day 4). Pig C, which was also freshwater, did not have any insect activity until approximately twenty-four hours after the chlorinated Pigs A and B (Day 5). One possible reason for the absence of fly activity in Pig C was the relatively low water temperature and that the tub was in the shade out of direct sunlight for the entirety of the day.

Water Temperature

As mentioned above, water temperature had an observed effect on the initial presence of insect activity. Low water temperatures seemed to slow the arrival of flies to the carcass, whereas higher temperature water seemed to expedite fly arrival. Water temperature also seemed to have an effect on the decomposition process. Lower water temperature appeared to slow the decomposition process, whereas high temperatures accelerated the process. For instance, Pig C, which was the slowest to decompose, had consistently the lowest water temperature of all the subjects in the study. Additionally, Pig D, which was the quickest to decay, consistently had the highest temperature of the subjects. Pig A also had high water temperature, second only to Pig D. Pig A experienced frequent and prolonged periods of mummification that delayed the skeletonization of the carcass. In the realm of the study, Pig B had moderate water temperatures throughout the study. Even with the presence of moderate water temperatures, Pig B did not reach bloat stage until Day 6, forty-eight hours after Pigs A and D and twenty-four hours after Pig C (which consistently had the lowest water temperature). The before mentioned events indicate that the presence of chlorine could be the catalyst for the retardation of decomposition of Pig B.

Exposure to Sunlight

Exposure to direct sunlight also seems a likely reason for the succession of the stages of decomposition of Pigs A, C, and D. Pigs A and D attained the most exposure to direct sunlight throughout the day. The exposure to direct sunlight made the water temperatures warmer than the other tubs and most probably caused the onset of bloat stage to occur on Day 4 for Pigs A and D. In contrast, the lack of exposure to sunlight for Pig C allowed for the coolest water temperature and was most probably the cause of the onset of the initial bloat stage to be Day 5. Pig B, which was chlorinated, and exposed to a moderate amount of direct sunlight, did not start the bloat stage until Day 6. The absence of an excess of sunlight exposure and moderate water temperatures could indicate that the slowing of decay is a result of the presence of chlorine.

Fire Ants

As mentioned previously, fire ant activity was noted on all of the subjects of the project. The fire ants were disruptive to the decomposition process by harvesting maggot eggs and 1st and 2nd instar maggots from the carcasses. Fire ant activity had the largest impact on freshwater Pig C. Pig C experienced heavy fire ant activity, which seems likely to be one of the factors which slowed its' rate of decomposition. With the fire ants harvesting the maggot eggs, the eggs did not get the opportunity to hatch and the subsequent maggots to feed on the carcass. A large aspect of the decomposition process and soft-tissue destruction is the result of insect larva consumption (Mann et al. 1990: 106). Additionally, the harvesting of the 1st and 2nd instar maggots also eliminated the maggots from feeding on the carcass and as a result slowed the natural process of ovapositioning and ensuing insect activity. In the event that the maggots escaped to the soil surrounding the tubs, fire ants attacked and killed them preventing them from pupating and reaching the adult fly stage.

Buoyancy

The buoyancy of the subjects in this study effected their overall decomposition. One theory on body buoyancy concludes that the proximity of the specific gravity of a body to that of water has an effect on the buoyancy of a body (Donoghue and Minnigerode, 1977: 577). As an effect of the continual floating of all of the subjects in the study, the aquatic decomposition stage of “sinking” never occurred. The absence of the early sinking of the subjects during the process of decomposition resulted in a prolonged stage of differential decomposition that persisted until remains disarticulated and sank in the tubs. Additionally, the subjects of the study were not weighed to determine the loss of body mass throughout the study because “weight loss measurements would be confounded by water taken up by the carcass” (Hobischak and Anderson 2002:147).

Aquatic Predators

Though this experiment attempted to find differences in decomposition in a pool environment, aquatic predators would play a role in the decomposition of the freshwater aspect of the project. The presence of aquatic predators and their subsequent contribution to the decomposition process was absent in this study. In a natural freshwater milieu, aquatic predators (e.g. fish and crustaceans) would take part in the decomposition process by feeding and disarticulating the subject. The damage that aquatic creatures inflict on a water decomposition body increase the difficulty of assessing cause of death or determining identification of the individual. For example, fish could consume a vast amount of the soft tissue of the facial region, which would make identification arduous (Mottonen and Nuutila 1977:1097). Smaller fish inflict damage that appear as erosions of the soft tissue to mostly to the fingers, toes, lips and ears. Turtles and crabs have been observed to be more destructive than fish with the intensity of the damage dependent on the size of the species. For example, large species of turtles have been known to have the ability to crush facial bones while feeding on a body (Rodriguez 1997:465). Turtle predation is characterized by “large scalloped pits” that can be present on exposed areas of the body (Rodriguez 1997:465). The damage that crabs inflict could be mistaken for sharp force trauma due to the sharp or “clean-edge” of the wound (Rodriguez 1997:465). Additionally, it has been estimated that within two weeks fish and crustaceans could almost fully skeletonize a body (Mottonen and Nuutila 1977:1097). Most published research available pertaining to aquatic predation focuses on marine aquatic predation, which can give an indication of what freshwater predation could entail but is not exact. By assessing the damage that marine aquatic predators wreak on remains, one could safely assume that the presence of freshwater aquatic creatures would exact similar results and that they would expedite the decomposition process. Aquatic predators would not be present in a chlorinated water environment, and therefore were not a variable for Pigs A and B.

Superficial Abdominal Trauma

The additional superficial abdominal trauma inflicted on Pigs B and D was not observed as having an impact on the rate of decomposition. The absence of an impact could be for two reasons: 1) when the subject was placed in the tub, the area of the abdominal trauma was below the waterline, 2) the subsequent protrusion of the intestines blocked access of insects to the interior of the subjects.

Chlorine

After isolating the variables that could contribute to decomposition as seen above, the results indicate that the presence of chlorine has a retarding effect on the process of decomposition.

The program SPSS 14.0 was used to analyze data record from daily observations. When the partial correlation for this project was enacted, the result was a significance of

0.003. Since the realm of significance in this statistical analysis is 0.05, a result of 0.003 shows significance. The results indicate that there is a significant connection between the presence of chlorine and the stages of decomposition.

Lastly, how could the information of the study be valuable information? The information in this study could be valuable on a number of levels. The data collected in this research indicate that chlorinated water appears to have a retarding effect during the initial stages of decomposition when the chlorine was still present in the water environments. If this is actually the case, the PMI of bodies discovered in chlorinated water environments should be distinguished from that of freshwater. The ability for an investigator to determine the PMI of a body is crucial to any death investigation. The further study of the effects of chlorine on aquatic decomposition could result in a more accurate estimation of the progression of decay of individuals found in such environments.

The ideal situation in conducting this research will now be addressed. Ideally, research that is conducted to simulate human decay should utilize human subjects. Human subjects would necessitate the use of a larger pool tub in order to accommodate the size of the individuals. The use of larger tubs would allow for the utilization for time-release chlorinate tablets. The benefit of using time-release chlorinated tablets is that the chlorine will not dissipate as quickly, and therefore, a longer period of chlorine exposure could be observed by the researcher. Additionally, the freshwater subjects should be placed in a natural freshwater environment so that they could be exposed to aquatic creatures and naturally occurring microbes that are typically present in these environments. One subject from both environments could be intentionally submerged in order to account for bodies that stay submerged when they sink in the water. Lastly, a greater number of study subjects should be utilized in order to denote patterns that emerge and evaluate if the initial observations noted here are accurate.

In conclusion, it seems apparent that the presence of chlorine in an aqueous environment retards the process of decomposition. This study provides preliminary insight into the impact of chlorine on decomposition. The research conducted in this study should be used as a catalyst for further study into chlorinated aquatic decomposition and its comparison to freshwater decomposition.

VI. SUMMARY

This study focused on the presence of chlorine in an aquatic decomposition situation and its effect on the process of decomposition as compared to a freshwater decomposition situation. Previous aquatic decomposition research lack studies pertaining to chlorinated water environments and tend to focus more on freshwater and sea water environments. A research model was constructed using *Sus scrofa* L. as a substitute for human remains. Four tubs were utilized, two of which contained chlorinated water and the other two containing freshwater. Superficial sharp force trauma was applied to one pig from each milieu. The four subjects were placed in the tubs and observed for approximately three and a half months. The focus of the study was centered on the period before and immediately after the chlorine dissipated in the water.

Meteorological conditions remained relatively constant throughout the study perpetuating a warm, dry environment. Throughout the study, water temperature, ambient temperature, humidity, water pH, and chlorination levels were measured and recorded. Additionally, gross morphological changes in the subjects were noted through the duration of the decay process.

All the subjects of this study remained floating throughout the project and did not advance through the aquatic decomposition stages of initial sinking and re-floatation. As a result, all of the subjects experienced differential decomposition for the length of the

project until the remains disarticulated and sank. Insect activity was not noted on any of the subjects until Day 3 of the project (Pig D). Chlorinated Pigs A and B were not observed having fly activity until approximately twenty-four hours after activity was noted on Pig D. Insect activity was not noted on Pig C until Day 5 of the study. The low water temperature of Pig C is theorized as a possible reason for the extended absence of flies. Additionally, Pig C was situated in a more shaded area than that of the rest of the subjects and experienced shade for the majority of the day. High water temperature is theorized to be a large contributing factor to the accelerated decay of Pig D. Pig B, which was in chlorinated water, had moderate water temperature and exposure to sun radiation but was still the last to reach bloat stage on Day 6 of the study (Pig A and D = Day 4 and Pig C = Day 5). Therefore, even though Pig B had sharp force trauma, moderate shade, and moderate water temperature, it was still the last subject to reach bloat stage. This statement is significant because it indicates that there must have been an additional factor to explain why Pig B was that last subject to reach bloat stage. The only additional factor present for Pig B was the presence of chlorine in the water.

Fire ants also played an interesting and unforeseen role in this research project. The fire ants present during this research disrupted the fly succession and its involvement in the decomposition process. By harvesting maggot eggs, 1st instar maggots, 2nd instar maggots, and killing pre pupae maggots that escaped the tubs, the fire ants retarded and limited the large impact that fly larva typically contribute to the process of decay.

The small sample size of four subjects restricts this research from making any concrete statements on the effect of chlorine on the decomposition process. This research, however, is a strong indicator that the presence of chlorine in an aquatic decomposition milieu will slow decomposition by twenty-four to forty-eight hours. Further research will be conducted on a larger scale to confirm or refute the previously mentioned observations.

APPENDIX A

EDWARDS AQUIFER WATER QUALITY REPORT

EDWARDS AQUIFER WATER QUALITY
(all data from Edwards Aquifer Authority 2000)

Metals.

Metal	**Current Maximum Contaminant Level (ug/L)**	**Typical Range of Concentrations for Freshwater Edwards Aquifer (ug/L)**
Antimony (Sb)	6	BMDL*: 1.18
Arsenic (As)	50	BMDL: 2.0
Barium (Ba)	2,000	BMDL: 100
Beryllium (Be)	4	BMDL
Cadmium (Cd)	5	BMDL: 1.0
Chromium (Cr)	100	BMDL: 15
Mercury (Hg)	2	BMDL: 1.5
Selenium (Se)	50	BMDL
Silver (Ag)	183	BMDL
Thallium (Tl)	2	BMDL
Metal	**Current Secondary Standard (ug/L)**	**Typical Range of Concentrations for Freshwater Edwards Aquifer (ug/L)**
Aluminum (Al)	50-200	BMDL: 210
Iron (Fe)	300	BMDL: 500
Manganese (Mn)	50	BMDL: 50
Zinc (Zn)	5,000	BMDL: 2,000
Metal	**Current Action Level (ug/L)**	**Typical Range of Concentrations for Freshwater Edwards Aquifer (ug/L)**
Copper (Cu)	1300	BMDL: 40
Lead (Pb)	15	BMDL: 10

*Below Method Detection Limits

Fecal Coliform Bacteria.

Bacteria	**Maximum Contaminant Level (cfu/100ml)**	**Typical Range of Concentration for Freshwater Edwards Aquifer (cfu/ml)**
Fecal Coliform Bacteria	2,000	0-150

Nutrients.

Nutrient	**Current Maximum Contaminant Level (mg/L)**	**Typical Range of Concentration for Freshwater Edwards Aquifer (mg/L)**
Nitrate as Nitrogen	10	BMDL*: 3.0
Total Nitrate Nitrogen	1.0	BMDL: 0.02
Total Phosphorous	n/a	BMDL: 0.1

***Below Method Detection Limits**

Major Ions.

Major Ion	**Typical Range of Concentrations for the Freshwater Edwards Aquifer (mg/L)**
Calcium (Ca)	80-120
Magnesium (Mg)	10-20
Sodium (Na)	3-10
Potassium (K)	1-2
Bicarbonate (CO_3)	250-400
Sulfate (SO_4)	10-30
Chloride (Cl)	10-30
Fluoride (F)	0.1-0.5
Silica (SiO_2)	10-20

Pesticides, Herbicides, and Volatile Organic Compounds.

- Freshwater Edwards Aquifer levels are below the detection limits of testing.

APPENDIX B

RESULTS AND OBSERVATION TABLES

Pig A Results.

Day	Water Temperature (°F)	pH	Chlorine (ppm)	Flies	Maggot Eggs	Maggots	Beetles	Fire Ants	Float	Bloat/ Putrefaction	Differential Decomposition	Sink
1	82	7.6	1.0						X			
2	80	7.8	1.0						X			
3	84	7.8	0.5						X			
4	84	7.6	0.5	X					X	X		
5	83	7.6	0.5	X	X			X	X	X		
6	83	7.6	0	X	X	X		X	X	X		
7	73	7.6	0	X		X			X	X		
8	78	7.2	0	X	X	X			X	X		
9	80	7.2	0	X		X	X	X	X	X		
10	79	7.2	0			X		X	X	X		
11	76	7.2	0	X		X	X		X	X		
12	83	7.2	0	X		X	X		X	X		
13	78	7.2	0	X		X			X	X		
14	81	7.6	0	X	X				X	X		
15	80	7.2	0	X	X		X		X	X		
16	81	7.6	0	X	X	X			X	X		
17	83	7.6	0	X	X	X			X		X	
18	83	7.6	0	X		X			X		X	
19	80	7.6	0	X		X			X		X	
20	76	7.6	0	X		X	X		X		X	
21	75	7.6	0	X		X	X		X		X	
22	74	7.6	0	X		X	X		X		X	
23	76	7.6	0	X					X		X	
24	82	7.6	0	X					X		X	
25	82	7.6	0	X			X		X		X	
26	70	7.6	0	X			X		X		X	
27	72	7.6	0	X			X		X		X	
28	73	7.6	0	X					X		X	
29	66	7.6	0	X		X	X		X		X	
30	73	7.6	0	X		X			X		X	
31	68	7.6	0	X		X	X		X		X	

Pig A Results. (continued)

Day	Water Temperature (^oF)	pH	Chlorine (ppm)	Flies	Maggot Eggs	Maggots	Beetles	Fire Ants	Float	Bloat/ Putrefaction	Differential Decomposition	Sink
32	74	7.6	0	X			X		X		X	
33	75	7.6	0	X			X		X		X	
34	79	7.6	0	X			X		X		X	
35	79	7.6	0	X	X		X		X		X	
36	78	7.6	0	X		X	X		X		X	
37	79	7.6	0	X		X	X		X		X	
38	72	7.6	0	X		X	X		X		X	
39	73	7.6	0	X		X	X		X		X	
40	72	7.6	0	X			X		X		X	
41	73	7.6	0	X		X	X		X		X	
43	74	7.6	0	X		X	X		X		X	
44	74	7.6	0	X		X	X		X		X	
45	64	7.6	0	X			X		X		X	
46	69	7.6	0	X		X	X		X		X	
47	73	7.6	0	X		X	X		X		X	
49	76	7.6	0	X			X		X		X	
55	57	7.6	0			X	X		X		X	
59	64	7.6	0	X			X		X		X	
62	63	7.6	0	X			X		X		X	
66	54	7.6	0	X		X			X		X	
72	72	7.6	0	X		X			X		X	
79	54	7.6	0						X		X	
93	50	n/a	0						X		X	
100	56	n/a	0						X		X	
105	59	n/a	0						X		X	

Pig B Results.

Day	Water Temperature (^{o}F)	pH	Chlorine (ppm)	Flies	Maggot Eggs	Maggots	Beetles	Fire Ants	Float	Bloat/ Putrefaction	Differential Decomposition	Sink
1	76	7.6	1						X			
2	76	8.2	0.5						X			
3	81	7.6	0.5						X			
4	81	7.8	0.5	X				X	X			
5	80	7.6	0.5	X	X			X	X			
6	80	7.8	0.5	X	X	X		X	X	X		
7	71	7.6	0	X		X			X	X		
8	74	7.6	0	X	X	X		X	X	X		
9	75	7.6	0	X		X	X		X	X		
10	76	7.2	0		X	X	X	X	X	X		
11	74	7.2	0	X		X	X	X	X	X		
12	80	7.2	0	X		X	X		X	X		
13	76	7.2	0	X		X	X		X		X	
14	78	7.6	0	X		X	X		X		X	
15	76	7.2	0	X		X	X		X		X	
16	76	7.6	0	X		X	X		X		X	
17	80	7.6	0	X		X			X		X	
18	82	7.6	0	X		X	X		X		X	
19	78	7.6	0	X		X			X		X	
20	74	7.6	0	X		X			X		X	
21	70	7.6	0	X		X			X		X	
22	70	7.6	0	X		X			X		X	
23	73	7.6	0	X		X	X		X		X	
24	80	7.6	0	X					X		X	
25	80	7.6	0	X					X		X	
26	68	7.6	0	X					X		X	
27	69	7.6	0	X					X		X	
28	70	7.6	0	X					X		X	
29	64	7.6	0	X		X	X		X		X	
30	72	7.6	0	X			X		X		X	

Pig B Results. (continued)												
Day	**Water Temperature (^oF)**	**pH**	**Chlorine (ppm)**	**Flies**	**Maggot Eggs**	**Maggots**	**Beetles**	**Fire Ants**	**Float**	**Bloat/ Putrefaction**	**Differential Decomposition**	**Sink**
31	66	7.6	0	X		X	X		X		X	
32	72	7.6	0	X		X	X		X		X	
33	74	7.6	0	X			X		X		X	
34	78	7.2	0	X					X		X	
35	77	7.2	0	X			X		X		X	
36	76	7.6	0	X			X	X	X		X	
37	76	7.6	0	X			X		X		X	
38	70	7.6	0	X			X		X		X	
39	70	7.6	0	X			X		X		X	
40	69	7.6	0	X			X		X		X	
41	70	7.6	0	X			X		X		X	
43	70	7.6	0	X					X		X	
44	70	7.2	0	X					X		X	
45	61	7.2	0						X		X	
46	66	7.2	0						X		X	
47	70	7.2	0						X		X	
49	72	7.2	0				X		X		X	
55	52	7.2	0						X		X	
59	62	7.2	0						X		X	
62	58	7.2	0						X		X	
66	50	7.2	0						X		X	
72	68	7.2	0						X		X	
79	49	7.2	0									X
93	46	n/a	0									X
100	52	n/a	0									X
105	55	n/a	0									X

Pig C Results.

Day	Water Temperature (°F)	pH	Chlorine (ppm)	Flies	Maggot Eggs	Maggots	Beetles	Fire Ants	Float	Bloat/ Putrefaction	Differential Decomposition	Sink
1	72	7.6	0						X			
2	70	7.8	0						X			
3	76	8.2	0						X			
4	76	8.2	0						X			
5	75	7.6	0	X				X	X			
6	75	7.2	0	X	X			X	X			
7	67	7.2	0	X					X	X		
8	70	7.2	0	X				X	X	X		
9	71	7.2	0	X				X	X	X		
10	71	7.2	0		X			X	X	X		
11	70	7.6	0	X	X	X	X	X	X	X		
12	75	7.6	0	X	X	X		X	X	X		
13	72	7.6	0	X	X	X		X	X	X		
14	72	7.6	0	X	X	X		X	X	X		
15	72	7.6	0	X	X	X	X	X	X	X		
16	72	7.6	0	X	X	X	X		X	X		
17	76	7.6	0	X	X	X	X		X		X	
18	76	7.6	0	X		X			X		X	
19	73	7.6	0	X		X			X		X	
20	70	7.6	0	X		X			X		X	
21	66	7.6	0	X		X			X		X	
22	66	7.6	0	X		X	X		X		X	
23	70	7.6	0	X		X			X		X	
24	76	7.6	0	X					X		X	
25	75	7.6	0	X					X		X	
26	65	7.6	0	X		X			X		X	
27	65	7.6	0	X		X			X		X	
28	66	7.6	0	X		X			X		X	
29	60	7.6	0	X		X	X		X		X	
30	67	7.6	0	X		X	X		X		X	
31	62	7.6	0			X			X		X	

Pig C Results. (continued)												
Day	**Water Temperature (^{o}F)**	**pH**	**Chlorine (ppm)**	**Flies**	**Maggot Eggs**	**Maggots**	**Beetles**	**Fire Ants**	**Float**	**Bloat/ Putrefaction**	**Differential Decomposition**	**Sink**
32	68	7.6	0	X		X			X		X	
33	69	7.6	0	X		X	X		X		X	
34	73	7.2	0	X					X		X	
35	73	7.2	0	X					X		X	
36	73	7.6	0	X			X		X		X	
37	72	7.6	0	X			X		X		X	
38	66	7.6	0	X					X		X	
39	68	7.6	0	X				X	X		X	
40	66	7.6	0	X			X	X	X		X	
41	67	7.6	0				X	X	X		X	
43	68	7.6	0	X			X		X		X	
44	67	7.6	0	X		X	X		X		X	
45	59	7.6	0	X					X		X	
46	63	7.6	0	X		X	X		X		X	
47	67	7.6	0	X		X	X		X		X	
49	70	7.6	0	X			X		X		X	
55	51	7.6	0	X			X		X		X	
59	61	7.6	0						X		X	
62	57	7.6	0			X			X		X	
66	50	7.6	0			X			X		X	
72	66	7.2	0	X		X			X		X	
79	49	7.6	0								X	
93	46	n/a	0								X	
100	51	n/a	0								X	
105	54	n/a	0								X	

Pig D Results.

Day	Water Temperature (°F)	pH	Chlorine (ppm)	Flies	Maggot Eggs	Maggots	Beetles	Fire Ants	Float	Bloat/ Putrefaction	Differential Decomposition	Sink
1	82	7.2	0						X			
2	80	7.8	0						X			
3	88	7.6	0	X					X			
4	88	7.2	0	X					X			
5	86	7.2	0	X	X	X			X			
6	86	7.2	0	X		X			X	X		
7	75	7.2	0	X		X			X	X		
8	82	7.2	0	X		X	X	X	X	X		
9	84	7.2	0	X		X	X		X	X		
10	82	7.2	0			X		X	X	X		
11	79	7.2	0	X		X		X	X	X		
12	88	7.2	0	X		X			X	X		
13	80	7.2	0	X		X	X		X		X	
14	82	7.2	0	X		X			X		X	
15	84	7.2	0	X		X			X		X	
16	85	7.2	0	X		X			X		X	
17	87	7.2	0	X		X			X		X	
18	87	7.2	0	X		X			X		X	
19	82	7.2	0	X		X			X		X	
20	80	7.2	0	X		X			X		X	
21	80	7.2	0	X		X			X		X	
22	80	7.2	0	X		X			X		X	
23	80	7.2	0	X					X		X	
24	86	7.2	0	X					X		X	
25	84	7.2	0	X					X		X	
26	72	7.2	0	X					X		X	
27	78	7.2	0	X					X		X	
28	80	7.2	0	X					X		X	
29	68	7.2	0	X					X		X	
30	75	7.2	0	X					X		X	
31	70	7.2	0						X		X	

Pig D Results. (continued)												
Day	**Water Temperature (^oF)**	**pH**	**Chlorine (ppm)**	**Flies**	**Maggot Eggs**	**Maggots**	**Beetles**	**Fire Ants**	**Float**	**Bloat/ Putrefaction**	**Differential Decomposition**	**Sink**
32	76	7.2	0	X					X		X	
33	76	7.2	0	X					X		X	
34	85	7.2	0						X		X	
35	85	7.2	0						X		X	
36	87	7.2	0						X		X	
37	85	7.2	0						X		X	
38	74	7.2	0						X		X	
39	76	7.2	0						X		X	
40	76	7.2	0						X		X	
41	79	7.2	0						X		X	
43	80	7.2	0						X		X	
44	75	7.2	0						X		X	
45	66	7.2	0						X		X	
46	71	7.2	0						X		X	
47	75	7.2	0						X		X	
49	82	7.2	0						X		X	
55	60	7.2	0						X		X	
59	73	7.2	0						X		X	
62	67	7.2	0						X		X	
66	58	7.2	0						X		X	
72	76	7.2	0									X
79	57	7.2	0									X
93	50	n/a	0									X
100	50	n/a	0									X
105	60	n/a	0									X

APPENDIX C.

OBSERVATION PHOTOGRAPHS

Compact Disc and plastic sleeve
will be attached here.

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VITA

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