To the Graduate Council:

I am submitting herewith a thesis written by Carrie Srnka entitled "The Effects of Sun and Shade on the Early Stages of Human Decomposition." I have examined the final paper copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

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Dr. Murray Marks, Major Professor

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Accepted for the Council:

Vice Provost and Dean of Graduate Studies

The Effects of Sun and Shade on the Early Stages of Human Decomposition

A Thesis
Presented for the
Master of Arts
Degree
The University of Tennessee, Knoxville

Carrie F. Srnka
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Dedication

This accomplishment is dedicated to all the loved ones in my life, most importantly to my parents, Carol and Charles Srnka. Without their unending encouragement and support, I would never have been so successful in all my endeavors. I have learned so much from each of them and found that to teach strength one must practice it every day in their own lives.

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Abstract

Existing literature on human decomposition has noted the importance of sun versus shade locations. To date, no study has focused on this variable exclusively. While the affects of temperature are becoming well recognized, there is conflicting information surrounding direct sunlight or lack thereof. Some researchers note that decomposition progresses faster in the sun, while others note that it is faster in the shade. The only existing study of such information was performed in the state of Washington using two pigs. Therefore, the goal of this study is to bridge the gap between animal and human decomposition and to note the differences that result from sun exposure and shaded locations. From this information, anthropologists will be able to estimate a more accurate postmortem interval based on human as well as animal decomposition studies. This was accomplished by documenting weather data and changes in the bodies of nude subjects as they decomposed in both sun exposed and shaded areas. The individual results were compared to each other using weather data that had been calculated into accumulated degree days.

Over the summer months, the cadavers of five unembalmed, unautopsied individuals were placed at the Anthropology Research Facility to decompose. Subjects were studied and all pertinent information, including all kinds of weather data, was recorded on a daily basis over the course of three months. Accumulated degree days were calculated for each location and compared to each other and the local weather service information. Exposed bodies progressed faster then the shaded bodies through the early stages of decomposition. In addition, they began to dessicate earlier due to extreme heat and sun, and thereafter became stalled to future

progression of decomposition. This study demonstrates that location of decomposition must be appreciated and examined when estimating the time since death.

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Chapter I. Introduction and Statement of Purpose

The field of forensic anthropology was formally recognized about thirty years ago to fulfill a need in medicolegal investigations by providing specialization in skeletal morphology for the purpose of identification. Today, remains that are skeletal or badly decomposed tend to pose an identification and investigative problem for the police and pathologists. Forensic anthropologists can assist on these cases by providing information from the bones and today, the decomposition stage. This analysis can include whether the remains are human, number of individuals present, ancestry, sex, age, bone pathology and stature of the individual(s), as well as the time since death (Stewart, 1979, Krogman and Iscan, 1986). This biological profile greatly increases the chances of establishing positive identification.

Recent forensic anthropology research focuses on the processes and rates of decomposition (see for example Rodriguez and Bass, 1983; Mann et al., 1990; Galloway et al., 1989; Komar, 1998; Haglund and Sorg, 1997). Recognizing patterns of decomposition, time frames, temperatures and other variables that affect the process can help in establishing more accurate post-mortem intervals (PMI). To date, as time since death increases, the accuracy in estimating PMI decreases (Love and Marks, 2003; Rhine, 1998). For this reason, estimating this interval has become a main focus of recent research. This interval is necessary in narrowing possible matches when the remains are compared to missing persons records. In addition, the post-mortem interval may be crucial evidence in criminal investigations because it sets an estimated time that the death may have occurred which can rule out or include suspected persons. As a result, any and all information that forensic anthropologists utilize must be thoroughly tested or well substantiated.

There are two primary pathways that information about decomposition is attained: 1) Through case studies in the field (see Galloway 1997; Komar, 1998; Rhine and Dawson, 1997; Galloway et al., 1989). Researchers in the field are encouraged to contribute all relevant information about their cases to a collective source or database (Rhine and Dawson, 1997). 2) Through experimental studies using strategically controlled circumstances. By isolating variables, a more comprehensive examination and explanation of decomposition can be gleaned. Multiple forms of carrion have been used for such studies, from mice or rats (Micozzi, 1991) to donated human remains (Rodriguez and Bass, 1983).

All the experimental human decomposition studies have been conducted at the outdoor Anthropology Research Facility at the University of Tennessee, Knoxville. The facility was created in 1980 by Dr. William M. Bass. Research has studied rates and processes of decomposition, as well as the multiple variables that affect the process by placing the remains in different circumstances and conditions. The bodies used in these studies have been donated to science by themselves or next of kin, or are unclaimed bodies donated by medical examiners.

From the large list of variables that have been studied including insect activity (Bornemissza, 1957; Campobasso et al., 2001; Goff, 2000; Payne and King, 1968 and Rodriguez and Bass, 1983), buried remains (Rodriguez and Bass, 1985; Mann et al., 1990; Payne and King, 1968; Aturaliya and Lukasewycz, 1999), surface remains (Shean et al., 1993; Mann et al., 1990; Micozzi, 1991; Galloway et al., 1989; Clark et al., 1997; Bass 1997; Komar, 1998), compromised positions (Haden and Marks, 2002), in water (Mellen et al., 1993; O'Brien, 1994), clothed versus unclothed (Cahoon, 1992; Miller, 2002; Aturaliya and Lukasewycz, 1999), all have noted the importance of sun versus shade. To date in the United States, only one study using pigs (*Sus scrofa*) has been conducted on the importance of sun exposure in the decomposition process (Shean et al., 1993).

Subsequently, a study using human remains is warranted to assess this variable. In order to correctly evaluate the outdoor forensic case, multiple variables can be examined to determine differences between bodies left to decompose in the sun versus those left in the shade. The purpose of the current research is to examine more fully the exact results, if any, that sun or shade and the resulting temperature differences have on the process of early decomposition of human remains. By placing subjects in two extremes of the outdoor environment, sun and shade, one can directly compare rates and differences in decomposition as it progresses. From this information it is the further goal of this researcher to establish a baseline of time since death estimate based on the early processes of decomposition. To efficiently utilize the information from the multiple variables that will be studied, a full examination of existing literature is in order.

Chapter II. Literature Review

Forensic anthropology incorporates skeletal biology with the processes of decomposition to understand time since death. Forensic anthropology assists law enforcement agencies in identifying remains from criminal cases, as well as other unidentified remains, which can result from natural causes, fire, mass destruction or military conflicts. This forensic application has some quite important implications.

Originally, physical anthropology assisted with information about the skeletal morphology. Here, the remains had to be reduced to bone via processing. This can eliminate possible evidence of trauma or other important characteristics about antemortem variables such as weight, physique, surgery, etc. By combining bone biology with postmortem decomposition, the forensic anthropologist can examine all the potential evidence, including both soft tissue and bone.

Recently, forensic anthropology has focused on the processes of decomposition since many cases involve remains that are in early to advanced stages of decomposition. Visual identity and fingerprinting become impossible early in the process of decomposition, due to the process of epidermal slippage, bloating and general disfigurement (Fisher, 1980). As the postmortem interval progresses, secondary soft tissue identifiers such as tattoos and scars are also lost. Eventually, all that remains is bone and possibly hair (Clark et al., 1997).

Knowing what happens after death can help answer questions concerning the postmortem interval, variables involved, and perimortem location or movement. Examining these questions can unveil information surrounding the cause and manner of death and possibly the identity of the perpetrator.

Stages of Decomposition

Decomposition occurs in a fairly consistent pattern. Researcher have divided the pattern into stages for the purpose of "scientific convenience" (as Love and Marks, 2003 state) based on the processes that occur as the body decomposes (e.g. Clark et al., 1997; Payne, 1965; Reed, 1958; Rodriguez and Bass, 1983; Galloway et al., 1989; Galloway, 1997; Rhine and Dawson, 1997). The processes occur at different speeds, meaning that they may overlap or occur at the same time. These differences can be attributed to the various environmental conditions of the studies, the types of insects, type of carrion used and even the personal biases of the researchers (Payne, 1965; Clark et al.,1997; Galloway, 1997; Galloway et al., 1989; Micozzi, 1991). Recently, it has been argued that stages do not exist at all and that the sequence of phenomenon overlap and combine in a continuous progression (Campobasso et al., 2001; Mann et al., 1990). Despite the continuing discussion about the possible further qualifications on the order and progression of the processes, the information can be compiled as fresh, bloat, decay and dry (Reed, 1958).

Fresh- Initially, cells die off slowly after a mammal dies. This leads into the process of algor mortis, rigor mortis and eventually livor mortis and the loss of usual skin color in humans. Algor mortis is the process where the body slowly cools to the level of the ambient temperature at a quite variable rate (Love and Marks, 2003; Fisher, 1980). Rigor mortis is the process that results in temporary muscle stiffening that begins within a few hours after death, full stiffness by 12 hours and releases through an additional 12 hours (Love and Marks, 2003; Rhine, 1998, Fisher, 1980). Livor mortis is the settling of blood as it is influenced by gravity, which causes a red to purple coloring that darkens with time (Love and Marks, 2003; Rhine, 1998; Fisher, 1980). If a person is lying down when they pass, the blood will pool in the backside of the appendages and torso. As a result, if a person is sitting up when they pass, the blood will travel to the lowest point and settle there. In addition epidermal fluids tend to pool causing blisters to form. The blisters are then referred to as "bullae" (Clark et al., 1997). These points of settled or pooled liquid and lividity, later become prime targets for insect's larval placement and feeding (Rodriguez and Bass, 1983).

The aforementioned processes known collectively as the "mortises" begin within the first 36 hours following death and can sustain up to the 48 hour mark (Micozzi, 1991; Fisher, 1980; Love and Marks, 2003). Within this timeframe pathologists can most accurately pinpoint the time of death. Pathologists specialize in this information and therefore can be the primary consultant in cases where the individual is recently deceased. Beyond the 48 hour time frame a forensic anthropologist should be invited to examine the remains because as a collective, they specialize in or are more familiar with decomposition stages and processes.

While the mortises progress, a less visible process is occurring internally. Cells begin to breakdown, proliferate and spread, releasing intestinal bacteria and microorganisms throughout the body (Payne, 1965; Rodriguez and Bass, 1985; Micozzi, 1991; Clark et al., 1997; Gill-King, 1997). The eventual result is the decay of organic matter. These changes begin as soon as the individual dies, but do not become evident for some time. Usually the first external sign of decomposition is abdominal greening (Galloway et al., 1989). This greening on the lower right quadrant is caused by the breakdown of intestinal cell membranes by existing enzymes which are triggered by low blood pH that results from lack of circulation and oxygen (Love and Marks, 2003; Gill-King, 1997; Fisher, 1980; Clark et al., 1997; Galloway et al., 1989). Once this discoloration becomes evident the body enters the next phase of decomposition, bloat.

Bloat- The bloat stage involves internal processes that take place on the cellular and extra-cellular level. Cellular autolysis (aforementioned cell breakdown) progresses and gives way to putrefaction, which is endogenous bacterial activity that creates liquids and gases (Love and Marks, 2003), as well as color change and odor (Gill-King, 1997). Bloat consists of the internal build up of gases (byproducts of earlier bacterialization), which have no way to escape the body (Bornemissza, 1957; Love and Marks, 2003). In just a few days, bloat can result in the expansion and swelling of the torso in both sexes, as well as the genitals in males (Rodriguez and Bass, 1983; Love and Marks, 2003; Clark et al., 1997) and may last up to 13 days (Galloway et al., 1989). Many variables can directly affect the extent and length of time that the swelling persists. Heat and humidity have been noted to quickly progress the process, while colder temperatures retard it (Campobasso et al., 2001; Rodriguez and Bass, 1983; Micozzi, 1997; Gill-King, 1997).

In this phase there are many other important changes that occur such as marbling under the skin, skin slippage, hair mass loss and seeping of decomposition and purge-fluids (Galloway et al., 1989; Payne and King, 1968; Payne, 1965).

Marbling (intravascular hemolysis) is a process that occurs internally and involves the bacterialization of blood in veins and arteries (Fisher, 1980; Love and

Marks, 2003). As blood is broken into its separate components (autolysis of red blood cells), it becomes useable material for bacterial growth (Clark et al., 1997). The bacteria prosper and release gases and fluids, which furthers the breakdown of the remain's circulatory system (Love and Marks, 2003). "Marbling" is the eventual result and can be briefly explained as the exposure of superficial veins and arteries visible through the skin (Fisher, 1980; Love and Marks, 2003). Although this process is inevitable, it has been noted to occur more rapidly in hot environments because it is prime conditions for bacteria to thrive (Micozzi, 1997; Micozzi, 1991; Campobasso et al., 2001).

Skin slippage is the cellular breakdown of the junction between the epidermal and dermal layers of the skin (Love and Marks, 2003). The process is a combination of natural separation and bullae that can be further progressed by maggot activity (Rodriguez and Bass, 1983).

As decomposition progresses, an external process involving the scalp and hair occurs. The scalp begins to break down and the hair and possibly skin can become fully disjointed from the cranium which is commonly referred to as the hair mass (Mann et al., 1990). The hair mass can inform investigators of the possible ancestry, age and sex of the individual depending on the texture, color and length, but is overlooked in many cases since it can become disassociated from the remains (Bass, 1997).

Decomposition fluids are the liquid byproduct of compositional breakdown of carbohydrates, proteins and lipids (Campobasso et al., 2001). These fluids are also trapped inside the body but can be forced out by the internal build up of pressure and may cause bubbling or oozing (Clark et al., 1997). Another form of this liquid is termed purge fluid. Purge fluid is gastrointestinal decomposition fluids that may flow from the nose and mouth due to internal pressures of the bloat process (Clark et al., 1997). These fluids remain trapped until the individual proceeds into the next stage of decomposition, decay.

Decay- The decay phase can also be referred to as the post-bloat stage (Galloway et al., 1989). In this stage the gases that have been pent up internally are released through natural orifices or those created by maggot activity (Payne, 1965). This process called 'deflation' marks the exact end of the bloat phase and the beginning of decay (Rodriguez and Bass, 1983; Galloway et al., 1989; Bornemissza, 1957). In this phase there can be skin split, which allows aerobic bacterial activity and speeds the process of decomposition (Rodriguez and Bass, 1983). There is soft tissue deterioration as well as extensive leaking and full release of pent up decomposition fluids. The combination of the two processes can result in the formation of mold, fungi or bacterial colonies (Bornemissza, 1957; Payne and King, 1968). The body remains in the decay stage through the point when remaining skin begins to dry out or dessicate and/or the bones become exposed (Clark et al., 1997). Early exposure of bone is not referred to as skeletonization until more then one half of the body has bony exposure, which usually occurs after five months (Galloway et al., 1989). In hot arid environments, this can become the terminal phase, with dessicated soft tissue remaining present for an extended period of time (Mann et al., 1990; Rhine, 1984).

Dry- The dry state is when the bones are fully exposed and begin to degrease or dry out and become weathered, bleached, etc (Payne, 1965). Continual decomposition occurs and the hair mass can be obliterated (Galloway et al., 1989; Rodriguez and Bass, 1983; Bornemissza, 1957). This stage can last for many years, and may include little to no change in the remains (Mann et al., 1990; Galloway, 1997).

Continuous processes of Decomposition

While the aforementioned phenomena have been placed into specific stages, there are two processes that occur throughout all of the stages. Color change or discoloration of the skin and insect activity continuously progress throughout decomposition. These two processes can expose a vast amount of information surrounding decomposition of the remains such as time of death, location of body post mortem and trauma.

Early forms of discoloration, those occurring in the fresh stage, are the result of chemical reactions (Gill-King, 1997). As decomposition progresses, coloration can be induced by changes in the environment, for example, heat, cold, aridity and humidity, which result in further chemical reactions. Common colors are yellowing or orange coloration after skin slippage and browning or blackening with dessication (Clark et al., 1997). Studies have been attempting to decipher if some colors can denote specific stages or sequences of decomposition.

Insect activity is a part of decomposition that is not part of the body, itself, but is very important none the less. Insects facilitate the elimination of the majority of soft tissue (Mann et al., 1990; Stewart, 1979) and perpetuate bacterial growth and dissemination by introducing oxygen into the internal cavities of the remains (Payne, 1965; Rodriguez and Bass, 1983). Insects can become active on the remains in a matter of minutes after the individual's death and are present until and even after skeletonization is some cases (Rodriguez and Bass, 1983; Rhine, 1998; Mann et al., 1990; Campobasso et al., 2001). Obviously, it depends on where the individual passes on. If the remains are outdoors, the insects have more access and react more quickly then they would to a death that occurs indoors in a 'protected' environment (Mann et al., 1990). Insect data on succession and activity are used, most recently, as the most accurate tool for assessment of the stage of decomposition (Love and Marks, 2003).

Insects involved in decomposition are referred to under four main categories: flies (Diptera), ants, bees and beetles (Coeleptera) (Campbasso et al., 2001). These four can be put into two categories, necrophagus (flesh-eating) and predatory. Bees and ants are known to be a combination of the two categories (termed omnivorous) and feed on other insects and larvae as well as human flesh and decomposition fluids (Payne, 1965; Campobasso et al., 2001). Flies and beetles, on the other hand are both necrophagus species and are present on corpses from the early stages of decomposition (Campobasso et al., 2001; Payne, 1965).

Flies and their larvae are the most active of the insects in the process of decomposition. Initial ovipositioning (egg laying) is noted to occur first in the natural orifices (eyes, nasal openings, mouth, ears, genitals) (Campobasso et al., 2001), then other accessible areas, like the aforementioned bullae or wounds (Goff, 2000; Rodriguez and Bass, 1983). Ovipositioning can be directly affected by sunlight, wherein some flies do not lay eggs in direct sun due to rapid dehydration (Campobasso et al., 2001) while others require direct sun for egg laying (Galloway et al., 1989). In optimal conditions, the eggs hatch within 6 to 40 hours (Campobasso et al., 2001; Rodriguez and Bass, 1983; Goff, 2000). The maggots then enter under the skin and use the overlying layer as protection against the elements and predators (Bass, 1997). In extreme conditions maggot's normal succession can be affected. In cold conditions the maggots may freeze and die (Micozzi, 1997; Goff, 2000), while in extremely hot conditions they may never pupate and will feed continuously until death (Campobasso et al., 2001).

Variables Affecting Decomposition

Many variables can alter the progression of decomposition. Some of the most important variables affecting decomposition are environmental conditions including temperature, humidity and rainfall (Mann et al., 1990; Ubelaker, 1997; Rodriguez and Bass, 1985). In order to properly understand the environmental affects, the origin of the information must be examined.

Sources of Decomposition Data

There are two sources that forensic anthropology uses to study and interpret the progression of decomposition and the variables that affect it. A large amount of the comparative information about decomposition is compiled from actual forensic cases assessed as cross-sectional data from medical examiner reports (e.g. Komar, 1998; Galloway et al., 1989; Rhine, 1984; Snow and Luke, 1984). The rest of the information is from specialized experimental studies referred to as longitudinal case studies (Love and Marks, 2003) that follow decomposition from the time of death to full skeletonization in most cases (e.g. Mann et al, 1990; Payne, 1965; Shean et al., 1993; Rodriguez and Bass, 1983).

Forensic cases- Case work information is compiled by practicing forensic anthropologists and pathologists. They record all pertinent information from forensic cases such as season, location, stage or description of decomposition and estimated weather so that it can be of use to others in the field. In this way, regional differences can be noted and utilized without confounding the investigation.

Case studies have minor limitations for full interpretation of the information. All information is logged at the time of discovery and the rest must be reconstructed (e.g. Galloway, 1997; Galloway et al., 1989; Rhine, 1984; Steadman, 2003). Degree of decomposition, current environmental conditions, insects present and protection of the body (clothed, buried, etc) are descriptions of the current state of the remains upon discovery. Information about long-term environmental conditions must be reconstructed using the closest weather station, by fully comparing current readings and correlating the information backwards through time (Stewart, 1979; Shean et al., 1993). In addition, past insect activity must be assumed, but can never be fully certain as to length and amount of insects and larvae involved.

In addition, geographic differences can also account for a large portion of variability of decomposition examined as forensic cases. There are regional differences in stage progression, basic processes of decomposition and insect or scavenger activity based on climate, altitude, etc (see Rhine, 1998; Rhine, 1984; Komar, 1998; Galloway et al., 1989). For these reasons it is important for practicing forensic anthropologists to compile case information into working databases so that regional differences can be fully recorded, recognized and utilized by others in the profession (compiled by Rhine and Dawson, 1997). Despite minor limitations of forensic data estimation and compilation, the information has become so vastly important to the field since experimental studies are still quite rare.

Experimental studies- Experimental studies record decomposition processes from the time of death of the individual. By creating a scientific study research can isolate the variables and, in effect, study each component separately (e.g. Rodriguez and Bass, 1983; Mann et al., 1990; Shean et al., 1993; Payne, 1965). There are limitations to this method, as well. Most areas do not have access to human remains (see Shean et al., 1993; Payne, 1965; Micozzi, 1991). As a result, research must resort to other forms of carrion for decomposition studies. In addition,variables of decomposition are intricately connected and almost impossible to study as separate entities (Campobasso et al., 2001; Aturaliya and Lukasewycz, 1999). Therefore, it is safe to say that these experimental studies may show significant differences when compared to actual forensic cases.

The most commonly discussed limitation of the experimental studies is based on the type of carrion used. This is because the various species utilized can create differences in the process and length of decomposition. Past studies have utilized baby pigs (Payne and King, 1968), rats/mice, squirrels, rabbits, cows, amphibians, reptiles (Micozzi, 1991), dogs (Reed, 1958), frogs, shrews, chipmunks, cats, as well as chickens and other birds (Payne, 1965). In general, large pigs are most similar to humans in flesh thickness, fat content, skin type, lack of thick fur and overall mass and are therefore used more often in recent or current studies (Shean et al., 1993;

Payne, 1965). Non-human carrion has lead to helpful information on insect and scavenger activity, chemicals affecting decomposition, patterns of the process and environmental affects. The problem is that each species is a little different, so the data is not fully applicable to human forensic cases (Rodriguez and Bass, 1985; Mann et al., 1990).

The Anthropology Research Facility has become a way to bridge the gap of the species that are studied by using human remains. The use of human remains began at the Research Facility in 1980 (Rodriguez and Bass, 1985). The subjects used have been donated to scientific endeavors or are unclaimed by families from the medical examiner. Most experimental studies at the facility examine the daily temperatures, rainfall, humidity, insect activity and bodily changes in relation to stages of decomposition (Mann et al., 1990). Using the human remains, studies on entomological data of succession patterns (Rodriguez and Bass, 1983), degree of deterioration of materials during decomposition (Morse and Stoutamire, 1980; Cahoon, 1992), effects on soil composition (Vass et al, 1992), and above ground decomposition (Haden and Marks, 2002), to name a few, have resulted in vast amounts of information for the field of forensic anthropology surrounding the post mortem interval and variability of decomposition.

Environmental conditions

Information compiled from forensic cases and experimental studies has lead to a well-rounded interpretation of the process of decomposition, especially information regarding the environmental influences and factors. Temperature, alone, has been considered the most important variable influencing time elapsed in each stage and overall speed of the process of decomposition (Gill-King, 1997). Ideal conditions for decomposition consist of high heat combined with high humidity (Mann et al., 1990; Stewart, 1979). In such conditions, human skeletonization has been noted to occur in as short as two to four weeks (Mann et al., 1990; Stewart, 1979; Snow and Luke, 1984). High heat and humidity are important to the process of decomposition because both have been positively correlated with maggot and fly activity (Mann et al., 1990; Reed, 1958; Shean et al., 1993). It has been noted that most of the soft tissue loss can be attributed to larvae feeding and development, maggots to be more precise (Shean et al., 1993; Mann et al., 1990; Stewart, 1979). Conversely, periods of cold temperatures reduce fly and maggot activity and inhibit deposition of eggs (Stewart, 1979; Shean et al., 1993). The fact that skeletonization is reached in one fifth of the time in the summer compared to that of the winter clarifies the importance of heat combined with humidity, as they relate to decomposition and the insects involved (see Galloway et al., 1989).

On the other hand, rain (closely related to high humidity) and direct sunlight (a cause of high heat) can, in some cases, retard the process of decomposition (Komar, 1998; Mann et al., 1990; Galloway, 1997). Rain effects the fly activity, while having little effect on maggot activity (Mann et al., 1990). This means that if the early stages of outdoor decomposition are during a rainy period there will be less chance for flies to lay eggs and therefore there will be a noticeable slowing of the processes of decomposition. In addition, warm summer rains have been noted to cause repetition of succession according to Payne (1965). Under average conditions, maggots attempt to avoid direct rain and sunlight and may "hide" during such times

(Komar, 1998; Bass, 1997) and flies may not even lay eggs in direct sunlight (Galloway, 1997).

There are differing opinions on which causes the fastest recorded decay rates, shaded areas (Mann et al., 1990; Galloway, 1997; Bass, 1997) or sun exposed (Reed, 1958; Rhine, 1998; Shean et al., 1993; Anderson, 2001). Shean et al. (1993) noted that high temperature or *direct sunlight* act as a catalyst in stimulating maggot (as well as bacterial) growth and activity and thus speed decomposition (as Rhine, 1998 also states). Mann et al. (1990) agree, in part, to that point stating that when remains are covered in clothing it protects the soft tissue from sunlight (as well as animals, wind and rain) which in turn retards decay rates (see also Stewart, 1979). On the other hand, many have documented faster decomposition of shaded bodies (e.g. Galloway, 1997; Bass, 1997; Mann et al., 1990). One reason behind this side of the argument is the fact that insects can be highly distressed by sunlight and if they do not act within the first few days of exposure, the body will become dessicated or dehydrated and unusable (Galloway, 1997). The first data directly correlating temperature with decomposition was done by Vass and colleagues in 1992. They calculated accumulated average daily temperatures (sum of consecutive average temperatures or accumulate degree days (ADD)) with the stages of decomposition, but neglected to fully examine the differences that may occur in the sun versus the shade. It is quite obvious that heat is agreed upon as a stimulant of maggot and bacterial growth and activity and thus rates of decomposition, but the topic of direct sunlight seems to be shrouded in disagreement or disregard.

The only existing research in the United States on the topic of sun versus shade was performed by Shean, Messinger and Papworth in 1986 using large, white pigs (published 1993). The study was conducted in the state of Washington between June and August. Two pigs were examined from death (killed on sight) until the point of full skeletonization or arrested dessication. Two weather stations were built and maintained at a shaded site and a sun-exposed site about 300m away. Ambient temperatures, maximum and minimum, and humidity were recorded, as well as internal temperatures using a permanently inserted probe. The two sites were each surrounded by large mesh poultry wire fencing, and the carcasses were further enclosed in wire "caskets" in order to keep birds and carnivores out. From the study, it was concluded that the pig in the sun bloated and began to deflate much faster then the shaded pig (agreeing with data presented in Galloway et al., 1989). Laying of eggs and maggot activity were noted to occur for a longer period of time on the shaded pig, but the exposed (sun) pig was consumed in a shorter time frame. Simply put, the maggots kept working only as long as there was "suitable carrion" (1993)(see also, Payne, 1965). Overall, it was found that the exposed pig decomposed much faster then the shaded pig.

Chapter III. Materials and Methods

Location

The study was conducted at the outdoor Forensic Anthropology Research Facility at the University of Tennessee, Knoxville (see Figures 1 and 2). The facility is a 1.5 acre area on the south side of the Tennessee River in Knox County. The area is fenced to keep out unwanted visitors, scavengers such as dogs and coyotes, as well as raccoons, opossums and skunks to a lesser extent. The predominant tree cover in the facility is maple and oak, with minimal grass coverage except in the cleared area that makes up an approximate 30 meter circle. The climate in eastern Tennessee, approximately 36 latitude and 84 longitude, ranges from highs around 100 degrees F in the summer to lows around 10 degrees F in the winter. The average rainfall for a year is about 47 inches. Throughout the year the area has notably high humidity, averaging from 30 to 80 percent.

Season

The study was conducted in the summer to early fall because of the issue of natural shade. The foliage in the facility includes only deciduous tree species. This means that almost all of the leaf coverage or natural shade is lost during the fall season. In order to include only naturally shaded experimental studies, late fall, winter and spring were disregarded.

General Subject Information

Five unautopsied, unembalmed adult human subjects were used for this research. All bodies were received in July and August (2002) and examined through early October (2002). Each subject was given an identification code number

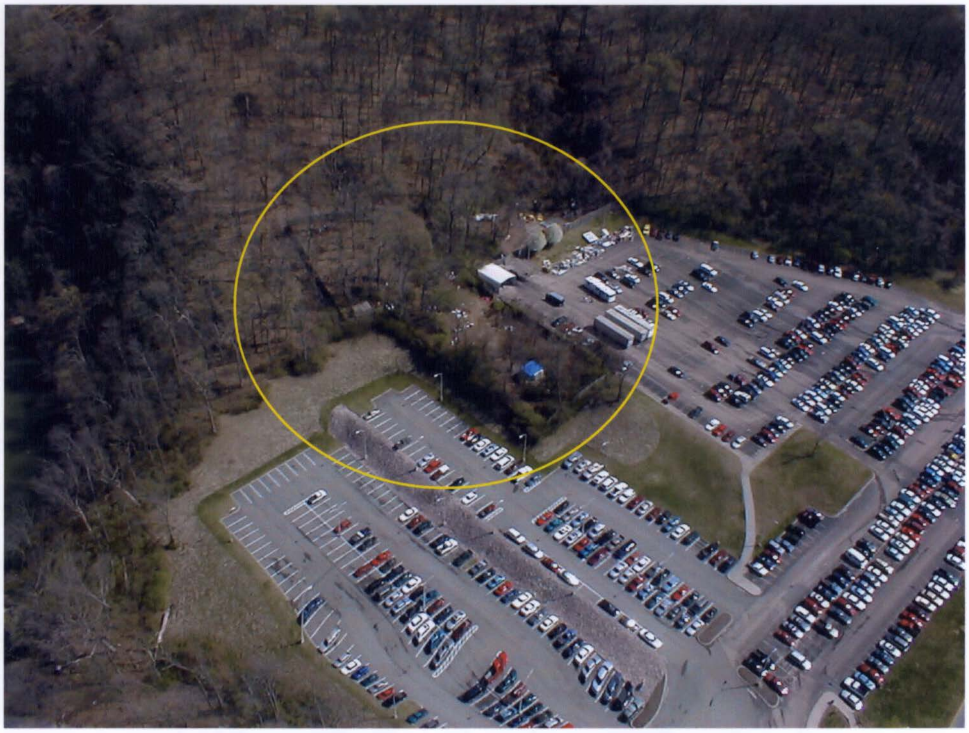

Figure 1. Aerial View of Facility- The 1.5 acre Anthropology Research Facility in Knoxville, Tennessee (circled in yellow). The fencing creates a dark outline of the area and the blue is the roof of the building housing the electronic weather station.

Figure 2. Inside Facility- A portion of the Anthropology Research Facility. Note the clearing that exists and also how dense the tree cover is during the summer time.

representing subject number and year. Upon receipt, all subjects were temporarily held (varied by subject) at 35-38 degrees F, until placement. All information about the condition of the remains was logged at the time of placement. Each subject was placed face-up on relatively flat ground. Arms and hands were not in true anatomical position, but instead placed such that hands were naturally curled and on the side, palms facing toward the torso. The legs were spread slightly apart. In order to accurately record the processes of decomposition, subjects were placed nude. Clothing can drastically mask or even alter the effects and processes of decomposition (Miller, 2002). At placement, a tape measure was positioned under the small of each subject's back as a method to measure bloat. Once placed, the subjects were not disturbed by researcher contact.

Variables Studied

Visual assessments were logged on each individual, every day using a self-created data sheet. The data sheet was broken into separate portions including the head, neck/shoulders, torso, arms, genitals, and legs/feet. Marbling, bullae, skin slippage, color changes, bloat, insects, dessication and skeletonization were recorded for each of the aforementioned regions of the body. In addition to these categories, a general category was logged which included overall processes, insect activity, as well as estimated numbers of each category of insects.

Definitions of Variables

Marbling- (or intravascular hemolysis) Defined as bacterialization of the vascular system that become visible through the skin with the appearance of large "spidering" (see Figure 3). Noted as present or absent.

Figure 3. Intravascular Hemolysis- This is an example on the legs of subject E about two weeks into the study. Notice the obvious marbled affect and the variation in thickness and coloration of the exposed circulatory system during the process.

Bullae- Defined as blisters which are at least an approximate one half inch in width (see Figure 4). Noted as present or absent.

Skin slippage- Defined as the natural process as well as the involved maggot activity, with the eventual result of separation of the epidermis from the dermis (see Figure 5). Noted as present or absent.

Discoloration- Defined as any change of color before or after skin slippage and bloat (see Figure 6 and 7). Colors included are orange, yellow, black, brown, red and drastic whitening or graying after rainfall.

Insect activity- Defined and recorded in terms of numbers or estimated amounts of flies, bees/yellow jackets, ants, maggots and beetles. Maggots present were logged as infesting (large masses), present (medium sized masses) and a few (only minimal amounts present) (see Figures 8 and 9). Ants were reported in a similar manner (many or few). In order to record flies present, a consistent span of 60 seconds was used, wherein number and type of flies landing was visually noted and recorded as accurately as possible. All other insects were counted and recorded as exact amounts when seen.

Dessication- Is a difficult process to determine, but documented for this study to start when the process of dehydration becomes visible including some resulting color change usually brown or black, but always darker then the surrounding soft tissue (see Figure 10). Noted as present or absent.

Figure 4. Bullae- or blisters, which are a pooling of epidermal fluids that separate the dermis from the epidermis. These bullae were noted on subject B only a day into the study.

Figure 5. Skin slippage- a continuation and eventual end to the localized bullae. The areas that are gray (lower torso and arms) are experiencing full skin slippage. This is subject A only a few days into the study.

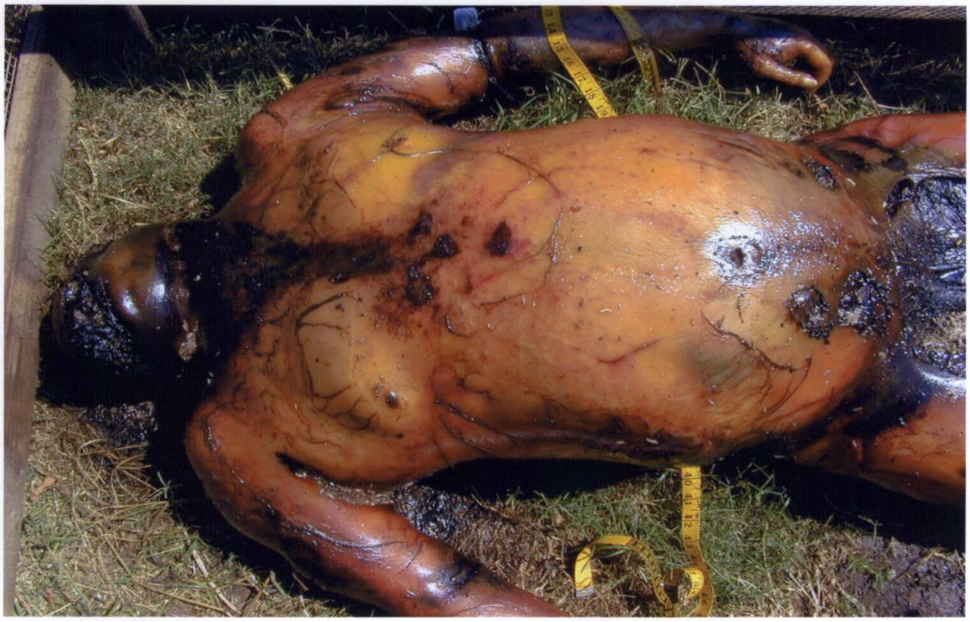

Figure 6. Bloat- The distention and swelling of the abdomen and face is referred to as bloat. The swelling is caused by the internal build up of gases and fluids.

Figure 7. Discoloration- occurs throughout the process of decomposition and is noted to include yellow, orange, red, green, brown and black. This is subject B who is experiencing very prominent red and green discoloration a few weeks into the study.

Figure 8. Few Maggots- This is an example of the level recorded as a few maggots. This is subject D on day 8 of the study.

Figure 9. Maggot Infestation- This is a level of maggots that was recorded as an infestation, where the piles of maggots are obscuring visibility of parts of the subject. This is subject D five days into the study. Any amount that fell between a few and infesting (the two shown above) was listed as present.

Figure 10. Levels of dessication- or the process of dehydration of the soft tissues during decomposition. There are multiple stages of dessication occurring from the very early stages on the lower abdomen to very set dessication on the neck and lower right arm as visible on subject C about six weeks into the study.

Skeletonization- Defined as the process when any amount of bone becomes exposed (see Figure 11), usually beginning with the back of the head, but it was noted as to which area was first recorded. Noted as present or absent.

Once all information was logged a bloat measurement was taken. To accurately gauge bloat, the tape measure (previously mentioned at placement) was pulled snuggly around that area of highest swelling. This point was about two to three centimeters above each subject's navel. The measurement was only taken once each day and then laid back to the sides as not to restrict swelling or disrupt insect activity.

Location of Placements

Multiple locations of the two natural environmental extremes in question, sun and shade, were utilized. The requirement of the sun location was a minimum of five hours of direct sunlight, at least the size of a human body, throughout the day. Conversely, the shaded locations were areas that received minimal, if any, sun spotting (random, intermittent points of small localized sun exposure through the existing foliage).

Individual Conditions Upon Placement

Table 1. Comparison of Subject's Initial Conditions- Data of five subjects, including sex (F=female, M=male), ancestry, age, weight, height (cadaver), date of placement and location.

Subject's Letter	**Subject's Number**	**Sex**	**Ancestry**	**Age (yrs.)**	**Weight (lbs.)**	**Height (cm.)**	**Date of Placement (2002)**	**Location**
A	17-02	F	White	50	105	154.7	5 July	Shade
B	18-02	M	White	62	233	194	8 July	Sun
C	19-02	F	White	85	177	154.4	8 July	Sun
D	21-02	F	White	85	140	155	19 July	Shade
E	26-02	M	White	63	215	175.3	27 August	Sun

Note: The average temperature during the study for all subjects was 75 Degrees (F).

Figure 11. Portion of skeletonization- or the first exposure of bone. This exposure of the tibia and fibula occurred in three days on subject A.

Condition of Subject A-

Day 0 (5 July)- The subject had multiple health conditions including insulin dependant diabetes, heart and breathing problems, drug problems, and was known to be an avid smoker. The subject was not in the hospital at the time of death. Cause of death was listed as atherosclerotic cardiovascular disease. She was discovered on 1 July and then placed on 5 July. At the time of placement the subject was in the late phases of the fresh stage, beyond the mortises. There was green discoloration on the abdomen, large bullae on the ankles, a portion of marbling on the inner knee or thigh, set lividity and some skin slippage on the posterior side. The subject's hands were already beginning to dry out and darken to black at this time. Multiple ants and about 35 flies (all kinds from large blow flies to small gnats) were immediately attracted and two hours later there were maggot masses present on the face and genital areas. Bloat measurement was recorded as 81 cm.

Condition of Subject B-

Day 0 (8 July)- The subject's health conditions consist of heart and stomach problems. The subject was not in the hospital at the time of death. The cause of death was logged only as "heart conditional". The date of death was recorded as 30 June and the subject was placed at the facility on 8 July. Upon placement the subject was in the late phases of the fresh stage, beyond the mortises. The subject was noted to have some moderate swelling, evident in the genitals, green abdominal discoloration, set lividity on the posterior side and no bullae or skin slippage were present. The body showed no signs of drying. After placement only five flies and no other insects were present on the body. Bloat measurement was recorded as 122 cm.

(Note: the body was placed on a grate and had temperature probe inserted in the abdomen (see Excess Equipment))

Condition of Subject C-

Day 0- The subject's health conditions include diabetes (assumed insulin dependant), and heart problems. The subject was admitted as an inpatient at the hospital on 5 July and remained there until the time of death. The cause of death was logged as acute myocardial infarction with underlying coronary artery disease. Date of death was recorded as 7 July and the subject was placed at the facility on 8 July. The subject was in the end of the fresh stage, beyond the mortises. The body already had bullae present on the arms and legs at the time of placement, in addition to posterior lividity and green discoloration of the abdomen, but no skin slippage was present. No dryness was noted. Only ten flies and one ant were present on the body following placement. Bloat measurement was recorded as 115 cm. (Note: the body was placed on a grate and had temperature probe inserted in the abdomen (see Excess Equipment))

Condition of Subject D-

Day 0- The subject had existing health conditions including a brain tumor and was therefore under constant care of a rehabilitation and treatment center. The subject was at the treatment center at the time of death. The cause of death was logged as a brain tumor. The date of death was recorded as 10 July and the subject was placed at the facility on 19 July. The subject was at the late phase of the fresh stage, beyond the mortises. At the time of placement it was noted that lividity was set on the posterior side, there was green discoloration of the abdomen and no bullae or skin slippage were present. The body had no noted dryness. Upon placement about 100 blow flies were immediately present on the body, as well as a few yellow jackets. Bloat measurement was recorded as 74 cm.

Condition of Subject E-

Day 0- The subject had existing health conditions including strokes, renal failure, malaria, cardiomyopathy. The subject was admitted in hospice starting 23 August and remained there until the time of death. The cause of death was noted as the end stages of COPD (chronic obstructive pulmonary disease). The date of death was recorded as 27 August and the body was placed on 27 August. The subject was in the middle of the fresh stage, with remaining rigor mortis present in the appendages. Upon placement, the body was noted to have set lividity on the posterior side and slight green discoloration of the abdomen, with no bullae or skin slippage noted. The body showed no signs of drying. Immediately after placement the ants were attracted to the body, as well as a few gnats, house flies and yellow jackets. Bloat measurement was recorded as 105 cm.

Data Collection

Data was recorded daily on each individual. Information is only reported in the Individual Results section (including Appendix A) if something major had changed, so days where observations were the same as the previous day were not included in this report. The results for each individual only include the time span that it took to begin and end skin slippage, marbling, bloating, major insect successions, and beginning of dessication and skeletonization. Therefore, the number of days reported for each individual will vary. Photographs from additional days are included in Appendix D (Plate 1, in pocket) labeled as to subject number and day since placement. Due to technological difficulty many of the digital images were lost, but all remaining images are present.

Equipment

Weather recordings

Multiple instruments were used to record temperatures, humidity and rainfall. Two digital thermometers were used as site specific temperature recorders (brands noted later in full description). Each thermometer was placed within three feet of the current research subject. The thermometers were indoor/outdoor thermometers, and had to be accommodated accordingly. Two simple structures of concrete blocks covered with plywood were constructed to protect the indoor sensors from the direct rain or sun (see Figure 12). The outdoor sensor was stapled to a long stake and angled out from the structures with a clearance of about one foot from the structure and one foot from the ground. The one foot of ground clearance made the readings more accurate for temperatures at the height of the subject. The thermometers kept track of high and low temperatures for the day, as well as simple current readings for the indoor and outdoor sensors.

Initially, having thermometers in direct sunlight was considered to be a detriment of the study based on information from Haskell et al. (1997). Having a thermometer registering temperature in direct sun is most representative of what the tissues were experiencing. However, a warning on the thermometers stated that extended exposure to sunlight might damage the mechanics of the thermometer and

Figure 12. Thermometer structure- created with cement block and a plywood cover to protect the mechanics of the thermometers from direct sunlight and rain. The outdoor sensor is attached to the small wood stake. Structures were exactly the same at the sun and shade locations.

lead to malfunctioning. This was tested by calibrating and recording the thermometer readings in the exact same location at the start of each experiment. By doing the same process at the end of the experiment and comparing the differences it was assumed that the thermometers were unaffected throughout the length of the study. It can be further noted that the readings from the outdoor and indoor sensors were recorded in case additional comparison was needed (see Appendix A and B).

Another dilemma with the thermometers was that each was not suspended like professional weather stations. This creates less circulation around the probes and had the possibility of skewing the temperature readings. This may have been more of a problem during daylight hours, since most times the night-time lows were quite similar from the indoor and outdoor readings at both the sun and shade locations (see Figure 14 in the Results section). In order to compensate for the possible error, recordings from both the indoor and outdoor portions of the digital thermometers were recorded and compared. The indoor sensors were sheltered from sun but had much less circulation as a result.

There were two times throughout the study that the thermometers had to be switched out because of malfunction, neither of which was due to exposure to direct sunlight. At the start of the study the thermometers were Brookstone ®, no model #, but stock #222976). One malfunction was due to ant infestation and the other resulting from internal moisture in the thermometer. After the first malfunction, a new thermometer, same brand, was used to replace the broken one so that the recordings were known to occur at the same intervals. Each was then calibrated to the working one before placement. Upon the second malfunction, a new brand of thermometers (Oregon Scientific, model #EM899) was used, meaning that both thermometers were switched out at the same time. All functioning thermometers were calibrated together before the final switch to the new brand.

In addition, the permanent weather station (VWR Scientific, Electronic Weather Station) at the facility was used to record exact time of high and low temperature and humidity. This assumes that the humidity within the facility is not variable enough to warrant having site specific humidity readings. The purpose of the weather station was to provide an intermediate reading since it is neither directly in the sun nor full shade throughout the day.

Two site specific rain gauges (Springfield Precision Instruments, model #90107) were located within a three foot range from the study subjects. The rain gauges had permanent ground stakes and a removable collection portion for easier and more accurate reading and consistent ground placement. Each was recorded and emptied daily.

Information on local sky conditions was also recorded each day. Simple visual observations were noted as such: cloudy-no open sky areas, mostly cloudy-spots of sun but the majority of sky is clouds, partly cloudy-majority of sky is sun with one or more clouds, clear-no clouds at all (information included in Appendix A).

In order to record weather data in 24 hour segments, the data had to be logged and all instruments reset each day. Once all weather data was collected, the information was calibrated and correlated to the closest national public weather station. Therefore, the temperature readings from all three locations, the sun, shade and intermediate weather station, as well as the rain gauge readings were compared to the readings acquired from the National Weather Service reports from McGhee-Tyson airport in Knox County, Tennessee about 15 miles from the facility. A regression formula was used as a mathematical way of comparing two known data sets and determining the relationship between the two. From this information a more accurate prediction of site specific weather data can be attained by future researchers.

All weather data was put into spreadsheets and tables using Excel for further analysis and calculation of accumulated degree days (see Appendix B and C). The data was analyzed using graphing in Excel ®. Using the graphs, the maximum and minimum temperatures, as well as rainfall from the sun and shade were compared (see Figures 13 and 14). In addition, time of onset and end of each variable (in Combined Analysis) was compared using ADD (accumulated degree days). All other data was not fully analyzed, but is included in the Appendix (B and C) for additional analysis.

Accumulated degree days are a quantitative way to record decomposition data. ADD is calculated by averaging the high and low temperatures for each day. The averages are then summed together for the time period in question. A full description can be referenced in Vass, 1991. The process is used most often by entomologists because of the predictable nature of the developmental and life progression of insects. For this study, it was used as a common baseline for comparison to determine the affects, if any, that slight temperature differences have on the early stages of decomposition. This was the only reason for using ADD since there are flaws when it is misused in decomposition studies. It has been known to mask information since so many more variables are involved in decomposition then in entomological studies (Wells and Lamotte, 2001). Other flaws include information surrounding geographical, seasonal, as well as biotic factors (discussed in depth in Wells and Lamotte, 2001; Goff, 2000). These are issues discussed by entomologists, which are accentuated when used improperly in decomposition research. To further strengthen the use of ADD in this study, days were reported, as well as accumulated degrees, in the graphs of each variable.

Photography equipment

Data on the subjects was documented in written form as well as photographically. Three cameras were used throughout the study. All were Nikon brand digital cameras. One was a Coolpix 750, another was a Coolpix 950, and the last was a Coolpix 990. Due to technological difficulties, many images were lost. All remaining pictures taken throughout the study (labeled by subject number and day) are included in Appendix D (Plate 1, in pocket).

Measuring equipment

Tape measures (Sullivans ®, model #12249 and #12058) were used to measure bloat and were therefore permanently placed under each subject (visible in many of the preceding Figures). The tape measures were made of fiberglass so that it would not stretch, shrink, tear or become otherwise deformed. The tapes were double sided, with metric measures on the one side and english measures on the other.

Protection from Scavengers

Wire "caskets", as Shean et al. (1986) referred to them, were used in the study to reduce predation by scavengers. The cages were made of one-half inch wire mesh attached to 2x4 wooden framework. Each cage was removable in one of two forms. One of the cages was a single piece and had to be fully removed each day. All other cages had separate lids that were laid over the main structure and could be removed each day.

Excess Equipment

It should be noted that two of the subjects used in this study were shared with a colleague doing other forms of decomposition research. The equipment used for that research consisted of metal grates placed under the body and temperature probes placed internally using a small incision on the abdomen.

Chapter IV. Results

Individual Results

***Note:** All individual data is in tabular format for quick reference. The full narrative, including additional day descriptions is included in Appendix A.

The individual tabular results include information on six processes, intravascular hemolysis (marbling), skin slippage, maggot presence, maximum bloat measurement, dessication and skeletonization. Each of the first four processes are recorded as to day of onset and last day that the process was noted. Dessication and skeletonization were recorded only at the day of onset since they are both continual processes. This information was utilized in multiple ways. The data expresses what state of decomposition the individuals were at in the beginning of the study when processes were already present at day 0 (day of placement). In addition, the data was used to compare how each subject progressed through decomposition, for example whether dessication began before or after maximum bloat girth was reached. In this way the order of processes can be analyzed for each subject. The data was also used to establish which subjects reached each process first or last. This portion of the analysis was further investigated by creating graphs, which are included in the combined results section to follow.

Table 2. Subject A- Daily Results- including intravascular hemolysis, skin slippage, maximum bloat measurement, dessication, skeletonization and maggot presence.

Day	*Description of Processes*
0	Marbling/Intravascular hemolysis began
2	Maggot infestation began Skin Slippage began
3	Dessication noted on the hands Skeletonization of the posterior cranium Last day that marbling was present
4	Last day that skin slippage was present
5	Maximum bloat girth was recorded (91 cm), followed by rapid deflation
14	Last day that maggots were present

Table 3. Subject B- Daily Results- including intravascular hemolysis, skin slippage, maximum bloat measurement, dessication, skeletonization and maggot presence.

Day	*Description of Processes*
1	Marbling/Intravascular hemolysis began Skin slippage began
2	Maggots first present
3	Maximum bloat girth was recorded (128 cm), remained until deflation on Day 6
4	Dessication noted on the shoulders and hands
5	Last day that skin slippage was present Skeletonization of the facial bones
16	Last day that maggots were present
28	Last day the marbling was present

Table 4. Subject C- Daily Results- including intravascular hemolysis, skin slippage, maximum bloat measurement, dessication, skeletonization and maggot presence.

Day	*Description of Processes*
1	Marbling/Intravascular hemolysis first noted
2	Skin slippage began Maggots first present Dessication noted on hands and feet
4	Maximum bloat girth recorded (142 cm), full deflation was a few days later
5	Last day that skin slippage was present Skeletonization of the posterior cranium
6	Last day that marbling was present
12	Last day that maggots were present

Table 5. Subject D- Daily Results- including intravascular hemolysis, skin slippage, maximum bloat measurement, dessication, skeletonization and maggot presence.

Day	*Description of Processes*
1	Skin slippage began
2	Maggots first present
3	Marbling/Intravascular hemolysis began
4	Last day that skin slippage was present
5	Maximum bloat girth recorded (117 cm), followed by fairly rapid deflation Dessication noted on the hands
6	Skeletonization of the posterior cranium and facial bones
8	Last day that marbling was present
17	Last day that maggots were present

Table 6. Subject E- Daily Results- including intravascular hemolysis, skin slippage, maximum bloat measurement, dessication, skeletonization and maggot presence.

Day	*Description of Processes*
2	Marbling/Intravascular hemolysis began Maggots first present
4	Skin slippage began
8	Last day skin slippage was present
9	Maximum bloat girth was recorded (125 cm), same girth through Day 17, deflate on 18 Maggots first infest natural orifices (noted because comparatively delayed) Last day skin slippage was present
13	Dessication noted on the hands
19	Skeletonization of the facial bones
30	Last day that marbling was present
32	Last day that maggots were present

Combined Analysis

Weather Data Analysis

Weather data that was recorded includes high and low temperatures and rainfall. The data analyzed in this section includes only the outdoor readings recorded daily from the digital thermometers placed near the subject in the sun and the subject in the shade.

Notice (in Figure 13) that the rainfall is considerably higher in the sun exposed location. The natural canopy of the shaded site, likely blocks and redistributes rainfall resulting in a lower rain gauge reading. This was a consistent pattern throughout the entire study. Such information was very important for the site-specific data because this was not expected to vary so obviously and the effects may need to be carefully considered in future cases and research.

As would be expected, the sun subjects were exposed to higher temperatures during the day, while having similar low temperature readings when compared to the shaded subjects (see Figure 14). As a result, there was greater temperature fluctuation experienced by those in the sun. In addition, the sun high temperatures averaged about 10 degrees (Celsius) above the shaded high temperature readings (exact temperatures available in Appendix C). The temperature data was also calculated into accumulated degrees for the single variable comparison, which follows, in order to create a consistent baseline for comparison for all individuals.

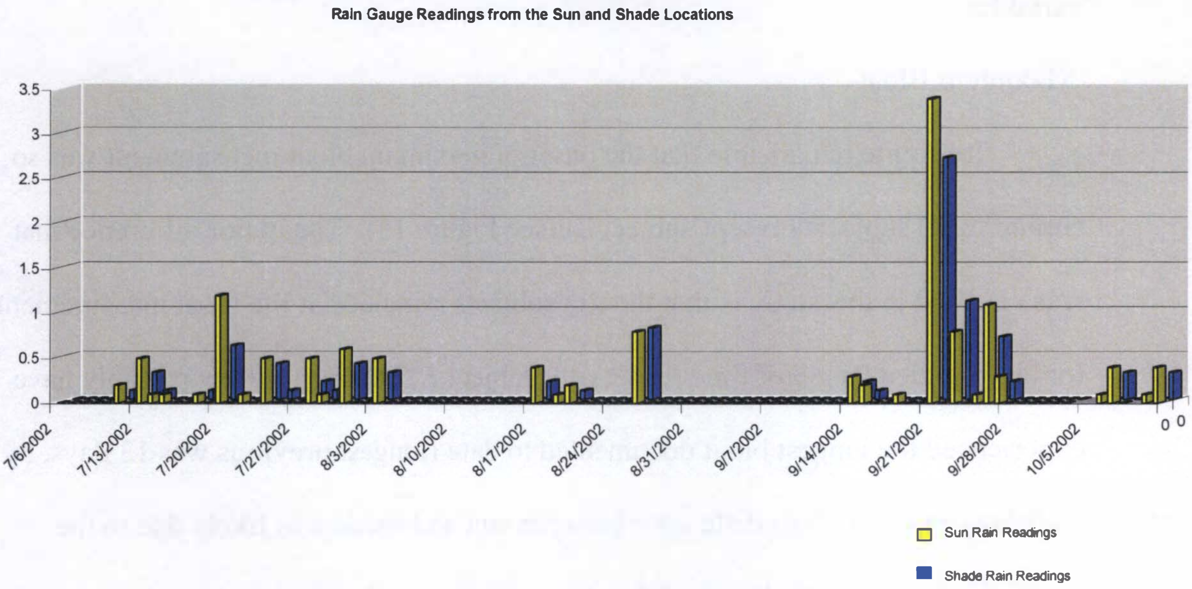

Figure 13. Daily rain gauge readings- (in inches), comparing the sun and shade over the course of the study.

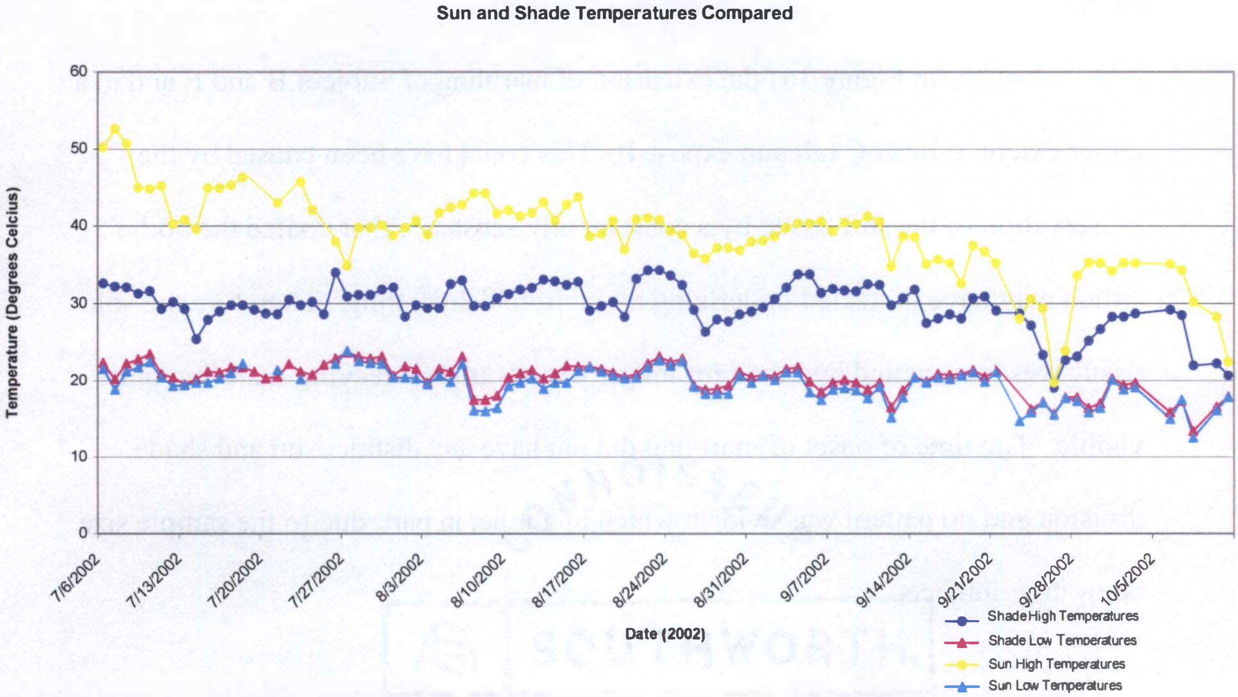

Figure 14. High and low temperatures- of the sun and shade compared. Notice that the sun and shade lows are overlapping while the highs are quite distinct from one another.

Variables Analysis

Note: Different scales were used for each graph to more accurately analyze single variables.

Maximum Bloat-

It is quite remarkable that the onset of maximum bloat measurement was so similar in all subjects (except subject E) (see Figure 15). The major difference that was clarified in this study is that the sun subjects remained at the bloat measurement for an extended length of time (especially subject E). Subject E may possibly have experienced the longest bloat documented to date (longest previous was 13 days, by Galloway (1997)). This difference between sun and shade was likely due to the hardening or almost "baking" of the outer soft tissue, wherein it was very hard and hot to the touch for an extended period of time.

Marbling-

Notice (in Figure 16) the extension of marbling of Subject B and E and to a lesser extent Subject C (all sun exposed). This could have been caused by the preservation of the soft tissue by a constant oily substance that coated the body, which may have protected underlying tissue from dehydrating. Therefore the soft tissue was present and hydrated for longer periods of time leaving marbling quite visible. The time of onset of marbling did not have any distinct sun and shade division and no pattern was evident which might be, in part, due to the sample size being five subjects.

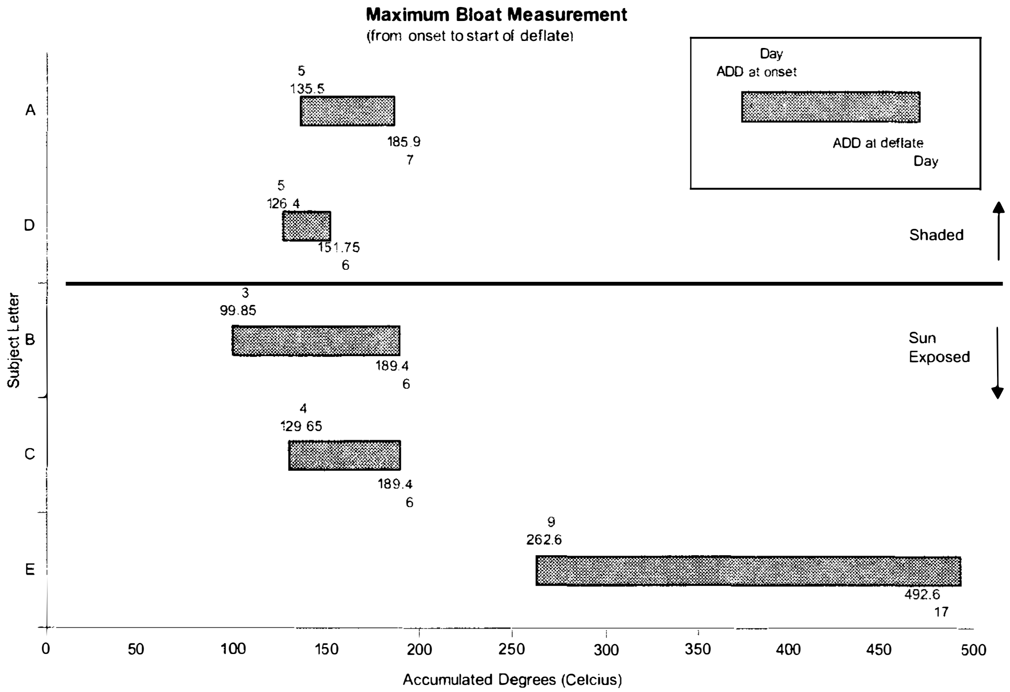

Figure 15. Recorded onset and length that maximum bloat measurements were recorded for each individual using accumulated degrees for comparison.

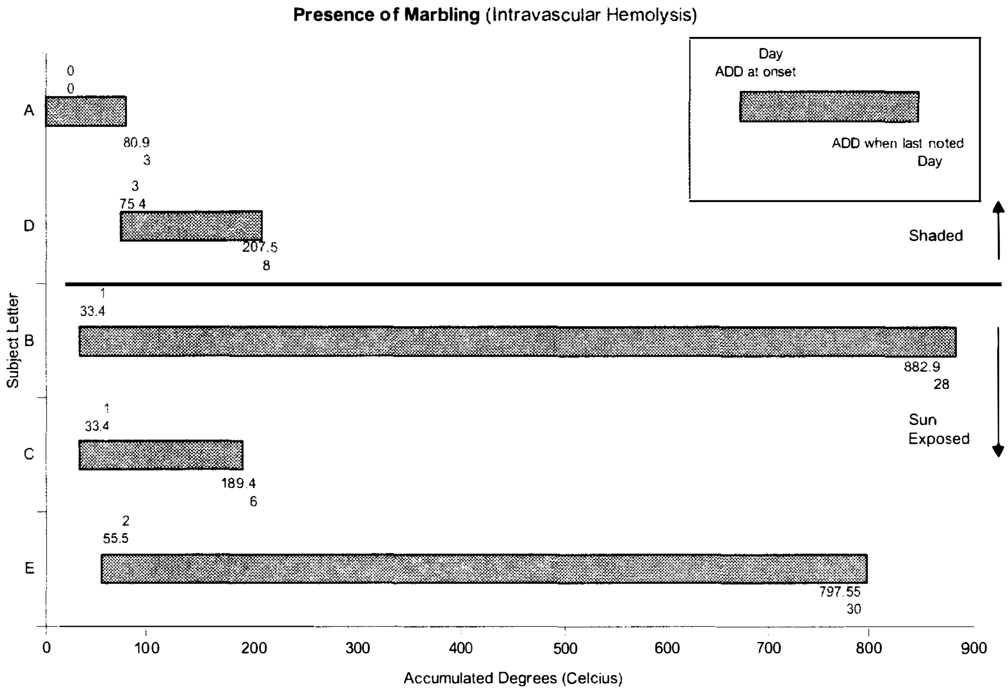

Figure 16. Recorded onset and length that intravascular hemolysis (marbling) was present on each individual using accumulated degrees as a comparison.

Skin Slippage-

There is a slight delay in the onset of skin slippage on the subjects in the sun (refer to Figure 17). This can also be discussed using information from Appendix A. As noted in Appendix A, the sun bodies were much slower to progress to full skin slippage (covering the majority of the body), while we can see in Figure 17 that the initial onset of a single portion of skin being slipped is quite variable. There are no directional affects of initial skin slippage or duration that were caused by exposure to sun or shade. As previously noted, bullae were examined separately from skin slippage for this analysis since many times bullae are used in the field to estimate PMI when full skin slippage has not occurred. Dividing the two makes this portion of the study quite subjective, but with reasonable cause for doing so.

Bullae-

There is an extension in the length of time that bullae are present and visible on the subjects in the sun (see Figure 18). This can be explained by the delay of full body skin slippage as discussed in Appendix A. Once full skin slippage occurs, the bullae become obliterated. Therefore, as there is a longer period of time before full skin slippage occurs, there is also a longer period of time that bullae remain apparent. Generally, the presence of bullae is quite variable, if they occur at all and how long they last on each individual. As previously mentioned the main purpose of including bullae was because of their use in the field when full skin slippage has not occurred. In addition, bullae were used for this study as a way to compare the state of decomposition of the subjects upon placement. As shown, two subjects (A and C)

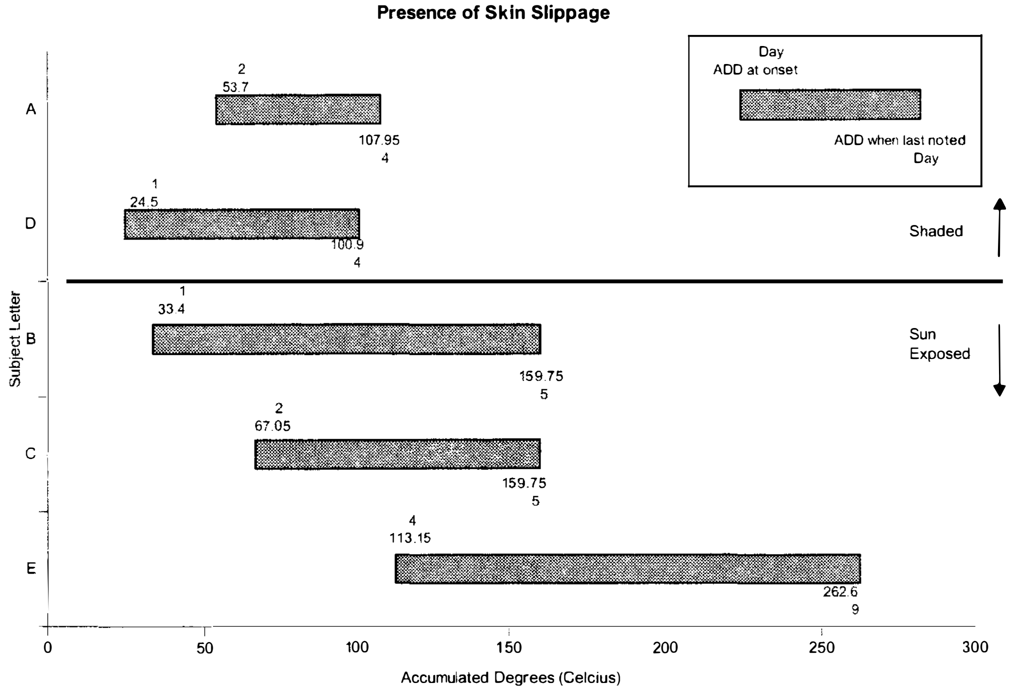

Figure 17. Recorded onset (of any portion) and length that skin slippage was present on each individual using accumulated degrees as a comparison.

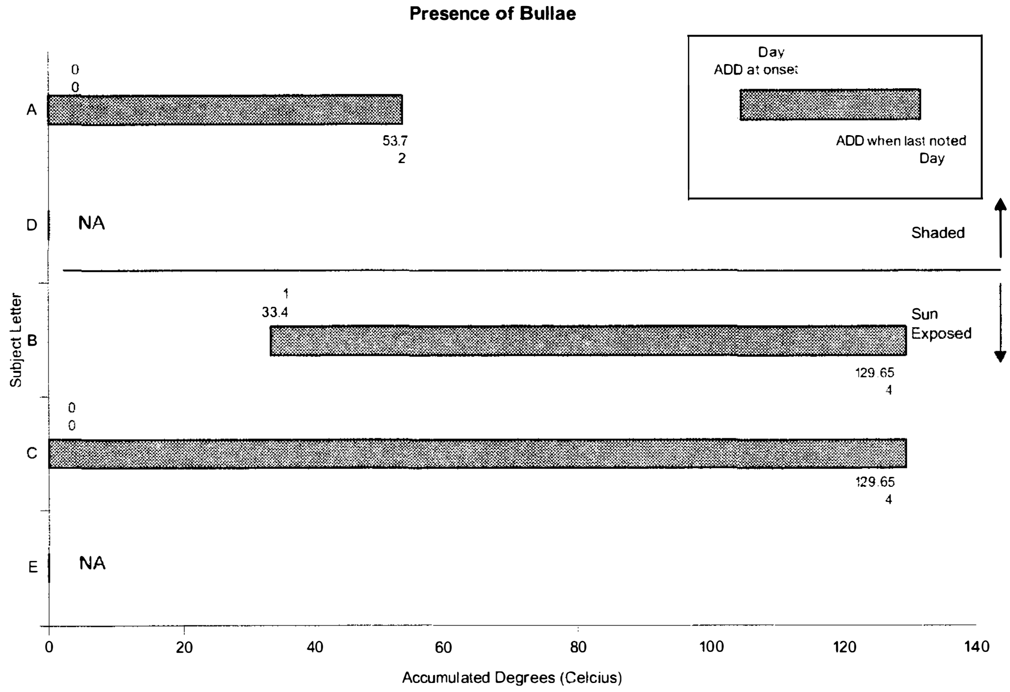

Figure 18. The presence of bullae from the time of onset until the blisters were no longer apparent.

came to the research facility with large bullae already present meaning they may have been further along in the decomposition process then the other subjects.

Dessication-

There was seemingly early dessication of all bodies except Subject E who remained hydrated and oily for a long period of time (see Figure 19). Dessication was quite variable on length of time that it took each subject to go from a single part dessicated to the whole body as was noted in the narrative portion of the results (Appendix A). The results on dessication may be skewed because of the subjectivity in recognizing dessication. It is complicated to define and even more difficult to assess since the study extended over a period of months, but the definition used was noted in Methods and Materials as dehydration accompanied by dark discoloration.

Maggot Activity-

Overall, the presence of maggots was quite similar in all subjects (see Figure 20). All subjects experienced at least a few maggots by Day 2. As noted in the narrative results (Appendix A), length of time to full maggot infestation varied amongst the subjects. In addition, all subjects experienced continued maggot presence for approximately two weeks (except subject E who had extended presence). Therefore, maggot activity compared by first sightings and duration of presence shows no clear division between those in the sun and those in the shade.

Skeletonization-

The first sighting of skeletonization is quite variable in this study (refer to Figure 21). There were three (subject B, C and D) that occurred at almost the exact same ADD. No information surrounding timing of skeletonization presents a clear

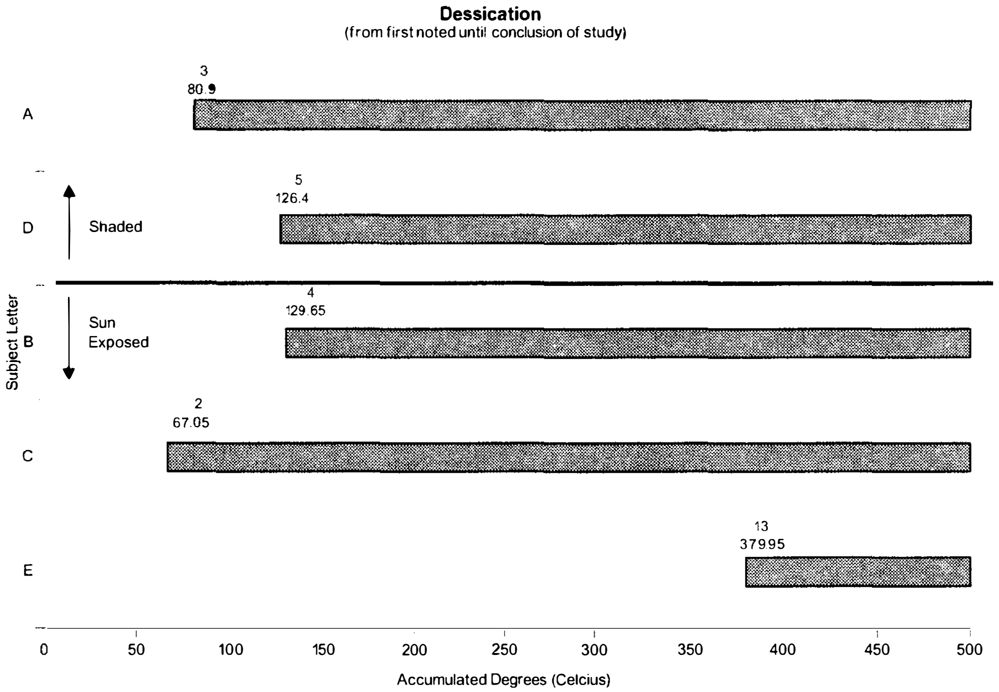

Figure 19. Recorded onset of dehydrated, darkened portion of skin (dessication) for each individual using accumulated degrees as a comparison. Days are listed above ADD on each subject's results.

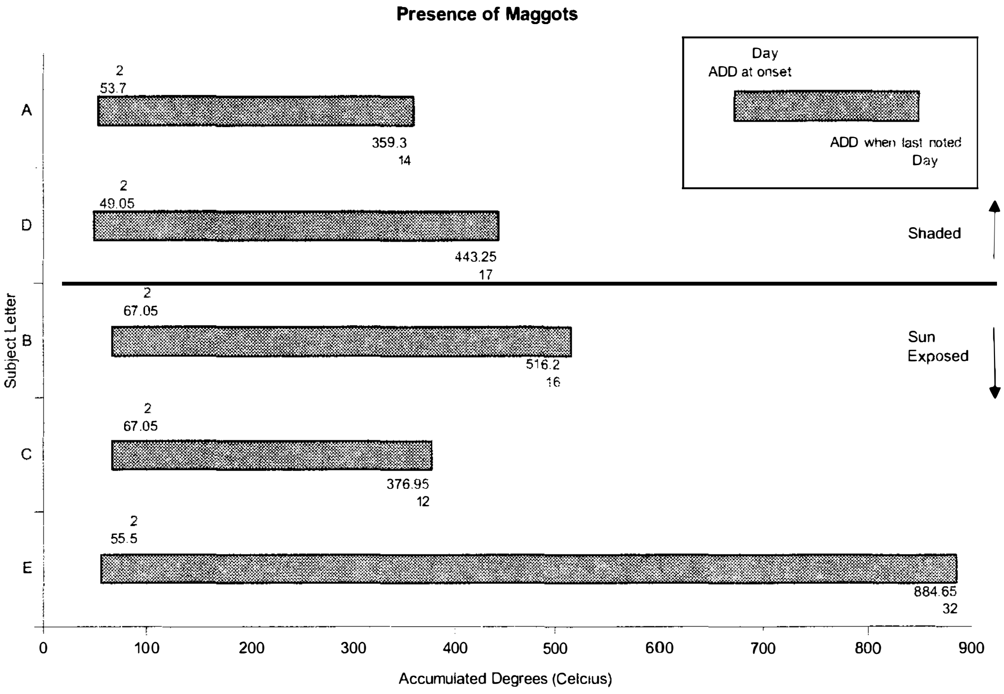

Figure 20. The presence of maggots recorded from first sighting on the bodies to when maggots were last noted on each subject using accumulated degrees as a comparison.

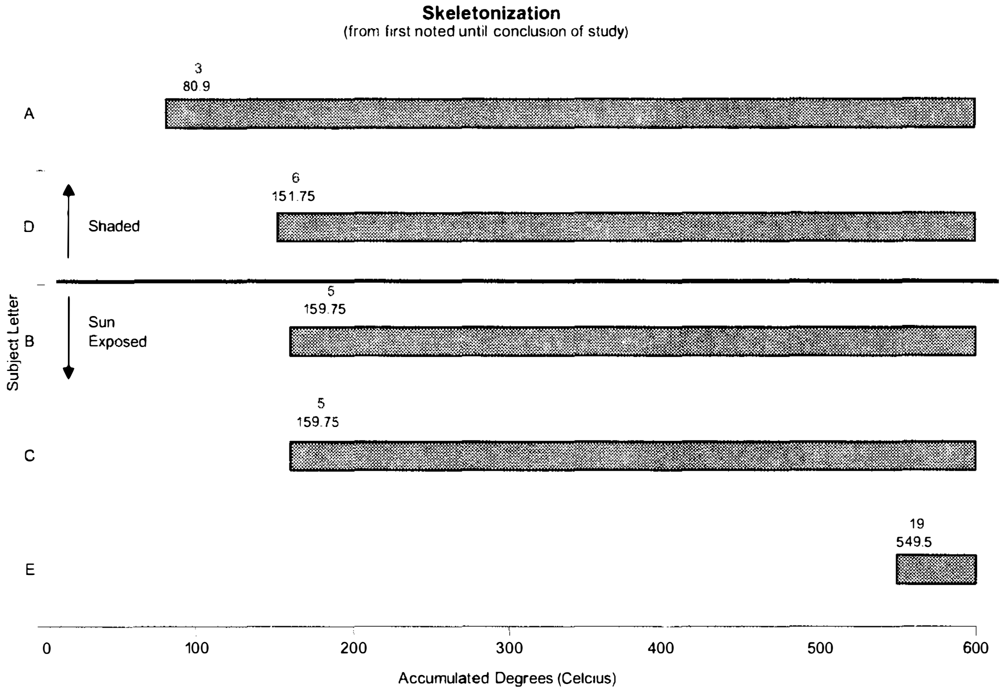

Figure 21. The recorded first exposure of bony elements on each subject using accumulated degrees as a comparison. Number of days are also listed above the ADD for each individual.

distinction when comparing sun and shade subjects. It should be noted that skeletonization was reported when any bony element became exposed. In some subjects it was the face and cranium that was first exposed, while on others it was fingers, arms or legs. The variability can be further examined from the narrative portion of the results (Appendix A).

General-

As can be quickly noted from the preceding seven graphs, no obvious divisions can be connected to the differences between bodies exposed to full sun or full shade. There was extreme variation between subjects in some of the variables such as skeletonization and initial presence of skin slippage, slight variability of marbling and bloating, while maggot activity showed very minimal variability amongst all subjects. Further analysis on progression of these variables is in order since the present study compared only the initial stages of each process. A distinct division may become more obvious if variables are broken down by progression, not just onset.

Chapter V. Discussion

Comparisons with existing information

The results can be compared to the findings of Shean et al. (1993) with pigs. In their study, it was noted that sun exposed bodies decomposed faster, bloated faster, had larvae (maggots) present on them for a shorter period of time and were exposed to greater temperature fluctuation then the shaded bodies. This study had somewhat differing results. The sun exposed bodies progressed through the early stages of decomposition faster, but then stalled. This halt in progression was caused by continuous hydration of the soft tissue from the protection of an oily substance, leading to extended visibility of marbling and soft tissue discoloration. As for the speed of bloating, two of the sun bodies (subjects B and C) bloated at least a day faster (then shaded subjects A and D), while subject E had extremely delayed bloat even when compared to the shaded subjects. The presence of maggots was quite similar on both the sun and shade subjects, lasting about two weeks (much longer on subject E). This information is very different from the previous study (Shean et al, 1993) since the sun bodies had maggots for an equal, if not extended length of time when compared to the shaded bodies. Sun exposed bodies do experience greater temperature fluctuations (see Figure 14) as Shean et al. (1993) noted. In that study, the difference in high temperature readings was only about 2 degrees (Celsius). This range was greatly surpassed in the current study, as the difference was almost 10 degrees (Celsius). The difference was accentuated in this study because of the thermometer readings in direct sunlight, rather then semi-protected in a weather station structure.

Overall, the variables that were most greatly affected by the exposure to direct sun or shade were marbling and length of bloat. Each variable was greatly extended on the sun subjects. Both variables seemed to be directly affected by the constant hydration of the inner layers of soft tissue on the sun subjects once the outer layer created a shield to the sun. Further analyses on current and future studies may create a more accurate comparison by utilizing more subjects, as well as different comparative techniques of the current variables.

Possible Limitations of the Study

There are many things that could affect the rate of decomposition of sun or shade bodies and in turn, the conclusions of this study. An assessment of differences between the two locations was attained but there are additional variables that could be involved and will be quickly examined.

The inclusion of grates created questions but cannot be assumed as the cause of the observed variability of decomposition. The grates intermittently interrupted the ground-body interface, which Micozzi (1997) states is the location of most rapid decomposition, on two of the sun bodies (subjects B and C). In turn, this would be assumed to slow the process of deflation since most of the maggots would be working on decomposition fluids that had leaked onto the ground rather then directly on the back side of the subject due to gravity. This would tend to slow the rate of deflation because the time it takes for internalization of maggots would be extended. In addition, on subject C, the decomposition fluids tended to leak out and run down hill, while on subject B, the decomposition fluids remained pooled underneath the body due to the slight depression of the ground surface. In reality, the bodies on the grates deflated faster then the body that was on the ground (subject E). So although the ground-body interface was intermittently interrupted and decomposition fluids could seep away from the immediate proximity of at least one of the bodies, the resulting affects of the grates on the process of decomposition were unexpected, and unexplained in this report.

A temperature probe was added to two of the bodies that were located in the sun as part of a colleague's study. A small incision was made on the lateral abdominal surface wherein a small temperature probe was taped into place. Immediate reactions were that this would alter the results of the study but according to Burger (1965) flies are less attracted to postmortem incisions then natural orifices because there is little or no blood present on such areas. This assumption has been questioned, but held true throughout the current study since maggots would infest the incision a day or two after infesting the natural orifices. Based on the similar processes of decomposition amongst all of the sun bodies, it seems that the probes had little affect. These can be useful to more case specific explorations by developing further information surrounding possible trauma in forensic cases. Therefore, it was important to include all the cases observed in this study.

Once the bodies had been placed, the body type and biological differences that existed were noted. The three sun bodies had larger body mass then the two subjects in the shade. There were no males subjects in the shade. In addition, the causes and circumstances of death were quite different amongst all of the subjects based on hospitalization, care, and health conditions. It should be noted that studies have shown that obese corpses decompose faster due to liquid percentages which favor bacterialization (Campobasso et al., 2001; Hewadikaran and Goff, 1991). The direct affects of the differences could not be fully assessed in the span of this study, but were noted as additional variables. Such differences could not have been corrected for based on the process of subject procurement.

Possibly the most important stage of this study was in comparing the recorded temperatures. Law enforcement investigators use local weather information, which they are able to correlate to the site-specific data. From this study, it can be seen how much difference was recorded between the sun and shade locations, including not only temperature but also amounts of rainfall. In addition, the sun location experienced much higher temperatures then the National Weather Service, while the lows were quite similar. So although all the bodies in this study were within approximately thirty yards of one another, there was remarkable temperature variability between the sites, and from the sites to the National Weather Service. Such information should be thoroughly examined and properly interpreted by forensic investigators.

Chapter VI. Conclusion

Throughout the summer of 2002, five unautopsied, unembalmed individuals were placed at the outdoor Anthropology Research Facility at the University of Tennessee, Knoxville. Processes of early decomposition, as well as important weather recordings were assessed daily. The site-specific temperatures were calculated in order to accurately assess differences that exist between the bodies in the sun versus those in the shade.

To date, there has been debate in the field whether direct sun and shade have either qualitative or quantitative affects on the process of decomposition. The results of this study show that there are some noted differences that occur on nude bodies in the direct sun during the hot summer months. Marbling and bloating tend to be extended on subjects exposed to direct sunlight. It was also noted on sun bodies that the stages of decomposition become further entangled, when marbling extends for longer periods of time and dessication occurs before full bloat is even reached.

Possibly the most interesting findings of the study were based around the site-specific weather recordings. The vast temperature and rainfall differences of bodies placed only 30 yards apart shows the importance of appropriate assessment of local weather by forensic professionals. Properly comparing or calibrating the temperature and rainfall readings can drastically alter the initial assessment of decomposed remains. Those in direct sun are subject to much higher temperatures, more rainfall and larger temperature fluctuation then those in full shade.

Overall, it can be said that sun bodies progress through the early stages of decomposition slightly faster then shaded bodies. Once a sun exposed body has been outside longer then a few weeks the length of decomposition is much more likely to be misinterpreted due to the extreme halt in progression that occurs during or soon after bloat. Therefore, shade bodies reach the late stages of decomposition including full dessication or skeletonization faster then sun exposed bodies.

This study is compiled as a baseline for estimating time since death on cases involving environmental extremes of sun and shade. A need for further research on this subject is seen from the variability that was recorded. The individuals were placed at the facility throughout a period of the three summer months, and were therefore subject to different weather patterns despite the fairly consistent high temperature and humidity. There were differences amongst the individuals that may have affected the results. The circumstances of subject procurement could not be arranged to meet such study needs. Therefore, the individuals used in the study were placed at different times, and were of different ages, sizes and causes of death. The sun bodies were also notably larger in body mass then the shaded bodies. This was not by choice but could not be accommodated for based on the direction and needs of the study.

The hope is that continued efforts will be made to assess the affects of sun and shade on decomposition. The process of decomposition is known to be quite variable, but as more experiments are attempted, the accuracy of the assessments in the field increases. Making steps towards evaluating variables that affect decomposition requires isolation and understanding of those variables. It is from such studies that more knowledge can be generated.

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Appendices

Appendix A.

Narrative results, including day to day descriptions of individual changes evident on each subject.

Subject A-

Day 1 (6 July)- There were egg sacks present in the mouth and major ant infestation. There were about 130 large flies per minute.

Day 2 (7 July)- There was noted facial discoloration to orange. The egg sacks from Day 1 had hatched and created a maggot infestation which lasted until Day 6. The subject was experiencing skin slippage and was still increasing in bloat size. Since the skin was slipping, the bullae became deflated and indistinguishable from the rest of the skin. Discoloration was caused by the skin slippage making the whole body appear gray and the head and neck/shoulders appear yellow to orange. Marbling was still visible through parts of the skin slippage. There were well over 300 large flies per minute.

Day 3 (8 July)- There was noted dessication (increased dehydration from Day 0, with further discoloration) of the subject's hands and initial skeletonization of the posterior portion of the head. This was the last day that marbling was present. There was discoloration of the torso, neck/shoulders and head to orange and yellow and the legs turned to black and reddish.

Day 4 (9 July)- Skin slippage was in the final phases on this day and the body was left an orangey color. This was the last day that abdominal greening was evident. The soft tissue on the face was turning to dark brown and black. The right leg began skeletonization but was preceded by exposure of the cranium on Day 3. Ants and gnats became the most predominant insects.

Day 5 (10 July)- Maximum bloat girth of 91 cm. was recorded. Rapid deflation was noted after this day. First exposure of facial bones was noted. The number of flies finally decreased down to about 30 large flies per minute.

Day 6 (11 July)- This was the last day that ants were present on the subject. Maggots still present after this day (until Day 15) but no longer infesting. Only a few gnats and no other flies were present for the remainder of the study. This was the first day that beetles were present. They remained and became the most predominant insect for the duration of the decomposition process. Most soft tissue present is orange or dark brown.

Day 7 (12 July)- Toe nails began to fall off.

Day 8 (13 July)- Arms fully skeletonized. Current rain so no flies or insects, but maggots still present. From the rain the soft tissue turns to grayish-white color.

Day 9 (14 July)- All soft tissue turned to dark brown. Femoral head disarticulated from pelvis. Limited insects, with only a few flies of all sizes and beetles.

Day 14 (19 July)- The last day that maggots were noted. The flesh turned a gray color because of the rain, but quickly turned back to dark brown and dessicated.

Subject A was studied through 28 September.

Subject B-

Day 1 (9 July)- The subject had developed bullae on the appendages, and was beginning phases of skin slippage. Marbling was noted for the first time and visible through Day 28. Ants were only present for this day with noted ant bites on the body. Genitals very swollen. There were about 100 large flies per minute.

Day 2 (10 July)- Maggots were noted for the first time on this day but were not infesting, only present. There was an increase in the number of bullae present. Still about 100 large flies per minute.

Day 3 (11 July)- Skin slippage all over arms and legs. Maggots began infestation. Orange to yellow discoloration on neck/shoulder and legs. Maximum bloat girth was measured on this day as being 128 cm. Instead of immediately deflating after maximum bloat was reached, the measurement remained the same until Day 6. Genitals were mostly deflated. There were only about 60 large flies per minute.

Day 4 (12 July)- The last day that any bullae were evident. The full destruction of bullae was due to skin slippage. The skin on the bottom of the feet slipped off. Initial stages of dessication were noted on the shoulder and hands.

Day 5 (13 July)- This was the last day that skin slippage was noted. The left side of the face skeletonized. Still at maximum bloat measurement. Maggots decreased down to present and there were no flies because of current rain. There was extreme graying of the flesh due to the rain.

Day 6 (14 July)- Beetles were noted for the first time. Last day of maximum bloat measurement, followed by fairly rapid deflation. Maggots reinfested again after rain. Finger nails had fallen off. The bones in the pelvis became exposed. There were only about 25 large flies per minute. All soft tissue turned to yellow or orange to brown.

Day 7 (15 July)- The back side of the head was skeletonized as well as the upper arms. Maggots reduced back down to present and remained that way until Day

16. Legs changing color from reddish-purple to green and continue as such through Day 28. There were only about 40 large flies per minute.

Day 9 (17 July)- Head and neck beginning to dessicate, rest of body still yellow to orange.

Day 10 (18 July)- Large flies are no longer present around the body, but little gnats become most prevalent along with beetles from this day on.

Day 14 (22 July)- Fingers all skeletonized.

Day 16 (24 July)- Last day that maggots were noted on the subject. Torso was still yellow or orange to brown, but distal appendages turned to dark brown and dessicated.

Day 20 (28 July)- The flesh turned to a gray color because of the rain. Quickly returned back to yellow to brown that lasted until Day 49, when torso finally turned to dark brown and dessicated.

Day 28 (5 Aug)- Marbling still noted on the subject's legs.

Subject B was studied through 25 September.

Subject C-

Day 1 (9 July)- Ants were the only insects present on this day leaving visible bite marks. Marbling was first noted on the arms. Only about 30 large flies per minute were present.

Day 2 (10 July)- There was beginning stages of skin slippage, as well as marbling all over the subject. This was the first day that maggots were present on the body. Ant activity was not noted after this day. Early dessication was noted on the hands and feet which turned a purple color. Head and face were a black color, but rest of body was still light brown and yellow.

Day 3 (11 July)- The maggots began to truly infest, which lasted through Day 5. Skin slipping but bullae still present on the ankles. About 150 large flies per minute were present.

Day 4 (12 July)- The aforementioned bullae from Day 0 were no longer distinguishable due to full body skin slippage. The maximum bloat measurement of 142 cm. was recorded on this day followed by full deflation by a few days later. About 150 large flies per minute were present. Distal appendages became dark brown and dessicated, while torso area remained yellow to light brown.

Day 5 (13 July)- This was the last day that skin slippage was noted. The first stages of skeletonization began this day by the dropping of the hair mass. As a result the back of the cranium was exposed. Maggot activity was reduced to present. There were no flies at this point because of current rain. There was extreme graying of the flesh due to the rain.

Day 6 (14 July)- This was the last day that marbling was noted. This was the first day that arms were partially skeletonized. Maggots reinfested the body through Day 9.

Day 7 (15 July)- Beetles were noted for the first time on this day and continued throughout the remainder of assessments. There was noted dessication on the feet and hands, followed soon after by the face. All soft tissue was turning from yellow to dark brown and dessicated. Gnats became the most prevalent flies. Facial bones became exposed.

Day 9 (17 July)- Maggots were no longer infesting but were present through Day 12.

Day 14 (22 July)- Since the body was on the grass, it can be an added note that it was not until this day that all of the surrounding vegetation was blackened and dead because of seepage of volatile fatty acids.

Subject C was studied through 26 September.

Subject D-

Day 1 (20 July)- The early stages of skin slippage were recorded (note: no bullae were ever recorded on this individual). Ants and massive egg sacks were present on this day. There were only about 100 large flies per minute. There was no discoloration noted.

Day 2 (21 July)- One single American Carrion beetle was noted under the subject's leg. The head, neck/shoulders and legs were turning to an orange color. Ants and about 150 large flies per minute were present. Maggots began a full infestation (until Day 7), as did the ants.

Day 3 (22 July)- Green discoloration on the abdomen was no longer present or noticeable. Marbling was in the early phases and was evident until Day 8.

Day 4 (23 July)- The process of skin slippage was last noticed on this day. Ants were no longer active. The skin on the bottom of the feet slipped off.

Day 5 (24 July)- The first wave of beetles was noted on the subject and were present for the duration. Maximum bloat of 117 cm. was recorded followed by rapid deflation. In addition, the first signs of dessication on the hands were recorded. The legs began to turn a greenish color and the rest of body was orange to yellow. .

Day 6 (25 July)- The back of skull skeletonized with the dropping of the hair mass. Appendages became dark brown and dessicated but torso still yellow to orange.

Day 7 (26 July)- Legs discolored to red and green. Maggots decreased down to only present. Gnats became the most prevalent fly type for the duration of the study.

Day 8 (27 July)- This was the last day that marbling was present.

Day 9 (28 July)- Flesh color turned to gray because of rain.

Day 10 (29 July)- All soft tissues turning to brown and dessicating.

Day 17 (5 August)- This was the last day that maggots were noted.

Subject D was studied though 6 October.

Subject E-

Day 1 (28 August)- There was major purpling of the face, increasing from Day 0. About 30 small flies per minute were present.

Day 2 (29 August)- Marbling was noted for the first time, which was evident until Day 30. A few maggots were recorded on this day. Ants as well as ant bites were noted. Skin color began to change to yellow and light brown. About 20 large flies per minute were present.

Day 4 (31 August)- The early stages of skin slippage were recorded, still with minimal maggot activity (note: no bullae were ever recorded on this individual). This was the last day that ants were recorded on the subject. Abdominal discoloration changed from green to brown but still present. There were about 150 large flies per minute present (through Day 9).

Day 5 (1 September)- Maggots finally began to infest which progressed skin slippage quite rapidly from this day. The maggots did not become active on the orifices until Day 9.

Day 6 (2 September)- The head changed to a reddish-black color. The rest of the soft tissue turned an orange to yellow color.

Day 7 (3 September)- A few beetles were noted on this day, but then disappeared until day 15.

Day 8 (4 September)- This was the last day that the process of skin slippage was recorded.

Day 9 (5 September)- Maximum bloat measurement of 125 cm. began on this day. The measurement remained constant until Day 17. This was the first day that the maggots were infesting the natural orifices of the body (remained until Day 14). Note: this subject was on the grass and it was not until this day that there was a full black outline of dead grass.

Day 12 (9 September)- Legs began to turn to a greenish color.

Day 13 (10 September)- Early stages of dessication on the hands and feet were noted. Most of the hair mass was dropped on this day, but the skin remained connected to the cranium with no resulting noticeable skeletonization.

Day 14 (11 September)- This was the last day that abdominal discoloration was visible. Flesh still yellow to orange in color until Day 32.

Day 15 (12 September)- Major beetle infestation began on this day and continued for the remainder of decomposition.

Day 17 (14 September)- This was the last day that the maximum bloat measurement of 125 cm was recorded, followed by slow deflation, with full deflate on Day 25.

Day 19 (16 September)- Facial bones became exposed, so skeletonization had begun.

Day 22 (19 September)- The maggots began to reinfest the body. Yellow jackets and beetles became the most prevalent insects for the duration of the study.

Day 24 (21 September)- Skeletonization of the arms was first noted, but preceded by facial skeletonization on Day 19.

Day 27 (24 September)- The skin on the bottom of the feet slipped off.

Day 30 (27 September)- The last day that marbling was present.

Day 32 (29 September)- The last day of constant maggot presence. All soft tissue turned to a dark brown and dessicated.

Subject E was studied through 11 October.

Appendix B.

Weather data from the National Weather Service and the Anthropology Research Facility electronic weather station.

date	time	wstatcurre	humidity	wstathigh	time	date	humhigh	time	date	wstatlow	time	date	humlow	time	date	NWShigh	NWSlow	NWSavg	NWSprecip
06-Jul	3:00	32.4	38	NA	NA	NA	87	8:49	06-Jul	23.1	7:09	06-Jul	34	17:13	05-Jul	32.8	22.8	27.8	0
07-Jul	15:42	33.5	36	34.9	18:33	06-Jul	71	8:48	07-Jul	21	7:25	07-Jul	20	18:40	06-Jul	32.8	19.4	26.1	0
08-Jul	16:02	32.4	43	34.8	18:36	07-Jul	81	7:33	08-Jul	23	7:02	08-Jul	31	18:39	07-Jul	31.7	22.8	27.2	0
09-Jul	16:10	32.4	34	33.4	17:29	08-Jul	79	8:56	09-Jul	23.3	7:02	09-Jul	32	14:58	09-Jul	31.7	20.6	26.1	0
10-Jul	15:58	31.2	49	32.8	15:08	10-Jul	74	9:26	10-Jul	24	6:14	10-Jul	34	18:56	09-Jul	31.1	22.8	27.2	T
11-Jul	16:02	31	58	31.1	16:01	10-Jul	97	11:36	11-Jul	21.4	5:01	11-Jul	43	16:14	10-Jul	31.1	20.6	26.1	T
12-Jul	17:05	30.3	55	32.3	17:28	11-Jul	90	7:12	12-Jul	20.6	6:02	12-Jul	48	18:22	11-Jul	29.4	20.6	25	0.26
13-Jul	16:08	20.9	97	30.7	17:43	12-Jul	97	16:08	13-Jul	20	8:38	13-Jul	54	18:02	12-Jul	22.2	20	21.1	1.47
14-Jul	15:43	24.3	97	27.3	13:54	14-Jul	97	15:43	14-Jul	20.5	4:26	14-Jul	96	14:42	14-Jul	27.8	20.6	24.4	0.38
15-Jul	16:04	26.7	74	30.1	15:12	15-Jul	97	11:53	15-Jul	21.5	6:23	15-Jul	68	15:53	15-Jul	30	21.7	26.1	0
16-Jul	15:41	29.9	57	30.6	15:13	16-Jul	97	9:49	16-Jul	21.4	7:34	16-Jul	55	15:19	16-Jul	31.7	20.6	26.1	0
17-Jul	15:36	27.4	73	31.7	14:00	17-Jul	94	9:04	17-Jul	22.1	7:07	17-Jul	49	16:32	16-Jul	31.7	21.1	26.7	0
16-Jul	15:43	30.7	51	31.2	14:54	18-Jul	96	3:31	18-Jul	23.3	6:41	18-Jul	49	15:29	18-Jul	31.1	22.2	26.7	0
19-Jul	15:57	30	64	30.7	15:37	18-Jul	92	8:59	19-Jul	21.6	6:59	19-Jul	50	15:39	16-Jul	29.4	21.1	25.6	0.16
20-Jul	15:43	23.9	97	30.3	17:46	19-Jul	97	11:50	20-Jul	20.8	22:27	19-Jul	57	19:08	19-Jul	28.9	20.6	25	0.25
21-Jul	15:50	30.9	59	31.3	15:09	21-Jul	97	11:08	21-Jul	21.2	7:20	21-Jul	57	14:22	21-Jul	32.2	20.6	26.7	0
22-Jul	15:45	30.4	59	33.1	14:51	22-Jul	93	10:02	22-Jul	22.6	6:56	22-Jul	51	15:01	22-Jul	32.2	21.7	27.2	0
23-Jul	15:40	31.7	58	32.2	15:05	23-Jul	90	8:59	23-Jul	21.8	6:57	23-Jul	57	15:15	23-Jul	31.7	20.6	26.1	0.68
24-Jul	15:32	29.4	64	31.7	15:59	23-Jul	97	11:43	24-Jul	21.3	7:30	24-Jul	55	17:17	23-Jul	31.1	21.1	26.1	0
25-Jul	15:47	29	68	29.8	17:20	24-Jul	NA	NA	NA	22.6	7:08	25-Jul	62	17:29	24-Jul	28.9	22.2	25.6	0.13
26-Jul	15:49	30.9	81	31.2	14:55	26-Jul	91	8:03	26-Jul	23.5	6:59	26-Jul	61	15:49	26-Jul	30.6	22.2	26.7	0
27-Jul	15:46	31.8	57	32	15:06	27-Jul	91	8:13	27-Jul	24	7:18	27-Jul	56	15:37	27-Jul	32.2	22.8	27.8	T
28-Jul	15:34	25.7	91	32	12:53	28-Jul	92	15:29	28-Jul	23.9	5:39	28-Jul	54	18:53	27-Jul	31.1	23.3	27.2	0.72
29-Jul	15:41	32.3	55	32.7	14:58	29-Jul	97	8:43	29-Jul	23.4	6:08	29-Jul	52	15:16	29-Jul	32.2	22.8	27.7	0
30-Jul	15:33	32.6	61	33	15:24	30-Jul	89	8:39	30-Jul	23.8	7:40	30-Jul	50	15:42	29-Jul	32.8	20.6	26.7	0.49
31-Jul	15:52	29.4	70	33.1	16:46	30-Jul	97	11:36	31-Jul	21	1:18	31-Jul	51	16:27	30-Jul	30.6	20.6	25.6	0
01-Aug	15:38	31.1	57	31.2	15:35	01-Aug	97	9:23	01-Aug	22.1	7:07	01-Aug	49	15:31	01-Aug	32.6	21.1	27.2	0
02-Aug	15:34	31.9	54	32.2	15:14	02-Aug	91	9:24	02-Aug	21.8	7:15	02-Aug	47	19:09	01-Aug	33.9	20.6	27.2	0.3
03-Aug	15:28	31.3	57	32.6	18:10	02-Aug	97	11:23	03-Aug	20.3	3:22	03-Aug	45	15:50	02-Aug	33.9	20	27.2	0
04-Aug	15:35	32.8	38	32.8	15:35	04-Aug	91	9:19	04-Aug	22	7:21	04-Aug	38	15:35	04-Aug	33.9	20.6	27.2	0
05-Aug	15:35	33.7	47	33.8	15:34	05-Aug	89	9:37	05-Aug	21.5	7:11	05-Aug	35	16:32	04-Aug	34.4	20.6	27.8	0
06-Aug	16:30	30.7	30	33.9	17:00	05-Aug	90	8:52	06-Aug	23.5	5:55	06-Aug	29	16:28	06-Aug	32.2	20.6	26.7	0
07-Aug	15:29	29.6	33	31.1	18:07	06-Aug	72	9:06	07-Aug	18.7	7:12	07-Aug	24	17:23	06-Aug	30.6	17.2	23.9	0
08-Aug	15:20	30.1	32	30.6	18:19	07-Aug	70	9:29	08-Aug	18	7:42	08-Aug	28	16:44	07-Aug	31.1	17.2	24.4	0
09-Aug	15:37	31.5	40	31.5	15:37	09-Aug	74	9:31	09-Aug	18.6	7:11	09-Aug	29	18:23	08-Aug	31.7	16.7	24.4	0
10-Aug	15:41	30.6	41	31.7	17:19	09-Aug	85	8:04	10-Aug	20.7	7:36	10-Aug	34	16:08	09-Aug	31.1	20	25.6	0
11-Aug	15:31	32.8	37	32.8	15:31	11-Aug	82	6:59	11-Aug	21.3	7:27	11-Aug	38	15:30	11-Aug	32.8	20	26.7	0
12-Aug	15:35	32.7	37	33	15:06	12-Aug	85	6:54	12-Aug	21.7	7:03	12-Aug	34	18:34	11-Aug	33.3	20	26.7	0
13-Aug	15:40	33.6	32	33.6	15:40	13-Aug	87	8:36	13-Aug	20.6	7:38	13-Aug	31	16:09	12-Aug	33.3	18.3	26.1	0
14-Aug	15:55	31.7	44	33.5	15:42	13-Aug	81	8:38	14-Aug	21.3	7:08	14-Aug	30	17:11	13-Aug	33.9	19.4	26.7	T
15-Aug	15:34	32.4	44	33.6	15:01	15-Aug	90	7:49	15-Aug	22.2	7:15	15-Aug	39	16:34	14-Aug	33.3	21.1	27.2	0.04
16-Aug	15:24	31.2	53	33.1	16:13	15-Aug	91	8:05	16-Aug	22.1	6:55	18-Aug	43	16:18	15-Aug	31.1	21.1	26.1	0.37
17-Aug	15:29	24.6	78	31.1	15:25	16-Aug	97	11:35	17-Aug	22.2	6:08	17-Aug	53	15:31	16-Aug	29.4	21.7	25.6	0.01
18-Aug	15:26	30.2	64	31.2	13:46	18-Aug	96	16:56	17-Aug	21.8	5:45	18-Aug	58	14:15	18-Aug	31.7	20.6	26.1	T
19-Aug	15:22	22.1	91	31.8	14:21	19-Aug	97	9:31	19-Aug	21.3	7:24	19-Aug	44	14:25	19-Aug	30.6	20.6	25.6	0.11
20-Aug	15:31	31	46	31	15:31	20-Aug	97	10:49	20-Aug	20.8	6:20	20-Aug	43	15:27	20-Aug	32.8	20	26.7	0
21-Aug	15:45	34.2	35	34.2	15:45	21-Aug	89	9:10	21-Aug	21.2	7:22	21-Aug	35	15:45	21-Aug	34.4	20.6	27.8	0
22-Aug	15:51	34.9	38	35.1	15:42	22-Aug	89	9:18	22-Aug	22.7	7:26	22-Aug	32	17:54	21-Aug	35	22.2	28.9	0
23-Aug	15:28	33.9	42	34.9	16:19	22-Aug	89	8:14	23-Aug	23.4	7:10	23-Aug	35	17:17	22-Aug	34.4	22.8	28.9	T
24-Aug	16:00	32.1	55	34	17:31	23-Aug	96	4:15	24-Aug	23.2	2:50	24-Aug	41	17:56	23-Aug	32.2	23.3	27.8	0.05
25-Aug	15:15	29.6	84	32.7	17:12	24-Aug	97	11:49	25-Aug	23	8:43	25-Aug	49	17:23	24-Aug	30	20.6	25.6	0.1

date	time	wstatcurre	humidity	wstathigh	time	date	humhigh	time	date	wstatlow	time	date	humlow	time	date	NWShigh	NWSlow	NWSavg	NWSprecip
26-Aug	15:23	27.6	60	29.9	16:17	25-Aug	97	9:58	26-Aug	20	7:27	26-Aug	59	15:22	26-Aug	30	18.3	24.4	0.43
27-Aug	15:46	29	51	29.1	17:21	26-Aug	97	10:31	27-Aug	19.1	5:57	27-Aug	49	15:25	27-Aug	29.4	18.3	23.9	0
28-Aug	15:39	29.3	47	29.4	17:08	27-Aug	95	9:05	28-Aug	19.3	6:03	28-Aug	44	15:33	28-Aug	30	17.2	23.9	0
29-Aug	15:36	29.1	47	29.4	16:46	28-Aug	90	9:15	29-Aug	19.8	7:58	29-Aug	43	16:18	28-Aug	30	18.3	24.4	T
30-Aug	15:32	29.8	53	29.8	15:32	30-Aug	91	8:54	30-Aug	21.4	8:34	30-Aug	43	16:36	29-Aug	31.1	20.6	26.1	T
31-Aug	15:27	30.3	45	30.3	15:27	31-Aug	89	9:08	31-Aug	20.7	8:03	31-Aug	44	15:25	31-Aug	31.1	20	25.6	T
01-Sep	15:31	30.2	45	30.7	16:58	31-Aug	83	8:00	01-Sep	21.1	7:58	01-Sep	43	18:41	31-Aug	31.1	20	25.6	0
02-Sep	15:38	31.1	41	31.2	15:32	02-Sep	93	8:43	02-Sep	20.8	7:54	02-Sep	40	15:38	02-Sep	31.7	19.4	25.6	0
03-Sep	15:41	32.8	40	33	15:31	03-Sep	87	8:33	03-Sep	21.9	6:08	03-Sep	38	16:39	02-Sep	33.3	20.6	27.2	0
04-Sep	15:27	34	38	34	15:27	04-Sep	90	9:05	04-Sep	22	7:55	04-Sep	37	15:25	04-Sep	35	20.6	27.8	0
05-Sep	15:38	32.8	17	34.1	15:40	04-Sep	65	9:04	05-Sep	20.3	7:52	05-Sep	17	15:38	05-Sep	33.9	18.3	26.1	0
06-Sep	15:51	32.3	32	33.1	17:12	05-Sep	71	6:55	06-Sep	19	7:37	06-Sep	17	18:11	05-Sep	33.3	15.6	24.4	0
07-Sep	14:27	31.3	34	32.6	16:43	06-Sep	82	9:23	07-Sep	20.2	6:15	07-Sep	26	16:46	06-Sep	33.9	16.3	26.1	0
08-Sep	15:30	30.8	41	32.8	17:28	07-Sep	78	9:52	08-Sep	21.4	7:54	08-Sep	28	17:36	07-Sep	33.9	18.3	26.1	0
09-Sep	15:18	31.2	38	31.4	15:13	09-Sep	77	9:39	09-Sep	21.3	8:01	09-Sep	36	18:10	08-Sep	34.4	18.3	26.7	0
10-Sep	15:50	31.7	23	32.4	15:12	10-Sep	76	9:47	10-Sep	20.7	8:37	10-Sep	22	15:38	10-Sep	35	16.7	26.1	0
11-Sep	15:27	28.8	49	31.7	16:35	10-Sep	67	10:18	11-Sep	21.5	7:58	11-Sep	21	16:57	10-Sep	31.1	18.9	25	0
12-Sep	15:36	28.1	39	28.8	15:31	11-Sep	63	0:02	12-Sep	19	8:14	12-Sep	36	14:17	12-Sep	30.6	15.6	23.3	0
13-Sep	15:34	31.1	39	31.1	15:34	13-Sep	70	7:19	13-Sep	20.4	7:37	13-Sep	36	16:25	12-Sep	32.6	17.2	25	0.09
14-Sep	15:25	27.3	77	32.3	16:32	13-Sep	97	12:35	14-Sep	20.6	7:12	14-Sep	32	16:29	13-Sep	30	20.6	25.6	0.23
15-Sep	15:31	25.3	79	28.6	16:11	14-Sep	97	12:39	15-Sep	20.2	7:42	15-Sep	66	17:11	14-Sep	26.7	20	23.3	0.07
16-Sep	15:26	28.9	59	30.1	14:48	16-Sep	97	8:14	16-Sep	21	5:02	16-Sep	54	14:49	16-Sep	30	20	25	0
17-Sep	15:41	29.1	64	29.7	16:18	16-Sep	94	8:58	17-Sep	21	7:57	17-Sep	54	16:23	16-Sep	28.9	20	24.4	0.1
18-Sep	15:32	25.2	91	29.1	15:44	17-Sep	97	12:38	18-Sep	21	6:42	17-Sep	61	16:44	17-Sep	26.1	20	23.3	T
19-Sep	15:28	31.6	52	31.6	15:28	19-Sep	97	8:57	19-Sep	21.5	7:24	19-Sep	52	15:27	19-Sep	31.7	20.6	26.1	T
20-Sep	15:37	29.2	55	31.6	15:32	19-Sep	95	8:38	20-Sep	20.6	7:52	20-Sep	46	15:00	20-Sep	30.6	18.9	25	0.4
21-Sep	15:26	22.3	97	29.8	17:23	20-Sep	97	15:26	21-Sep	21.3	8:17	21-Sep	53	17:39	20-Sep	23.3	20.6	22.2	2.41
22-Sep	15:28	22.8	97	23.3	15:16	22-Sep	97	15:28	22-Sep	21.2	4:37	22-Sep	97	15:26	22-Sep	24.4	18.9	21.7	0.66
23-Sep	15:32	23.6	57	24	15:08	23-Sep	97	8:45	23-Sep	15.8	7:57	23-Sep	52	15:09	23-Sep	25	15.8	20.6	0
24-Sep	15:27	25.7	50	25.7	15:27	24-Sep	81	9:41	24-Sep	17	8:37	24-Sep	49	15:26	24-Sep	26.1	16.1	21.1	0
25-Sep	15:32	19.3	97	25.7	15:38	24-Sep	97	15:32	25-Sep	17.6	8:03	25-Sep	49	15:39	24-Sep	19.4	16.7	18.3	0.44
26-Sep	15:21	18.3	97	19.4	16:15	25-Sep	97	15:20	26-Sep	15.9	3:38	26-Sep	97	15:20	26-Sep	18.9	15.6	17.2	0.73
27-Sep	15:38	22.8	90	23.3	13:43	27-Sep	97	11:37	27-Sep	18	18:00	26-Sep	88	14:38	27-Sep	28.7	18.3	22.8	0.04
28-Sep	15:33	25.5	54	25.7	15:09	28-Sep	97	19:27	27-Sep	18.6	9:07	28-Sep	50	14:37	28-Sep	28.7	18.3	22.8	0
29-Sep	15:37	27.3	55	27.7	15:06	29-Sep	96	10:15	29-Sep	16.8	8:15	29-Sep	51	15:07	29-Sep	28.3	15	21.7	0
30-Sep	15:06	26.3	56	28.3	15:06	30-Sep	96	10:04	30-Sep	17.5	8:21	30-Sep	52	16:33	29-Sep	27.2	16.1	21.7	0
01-Oct	15:23	29	54	29.8	14:35	01-Oct	90	9:49	01-Oct	20.6	7:52	01-Oct	52	14:42	01-Oct	28.9	19.4	24.4	0
02-Oct	15:34	29.2	60	30	14:11	02-Oct	97	10:04	02-Oct	19.7	7:53	02-Oct	54	15:23	01-Oct	29.4	17.8	23.9	0
03-Oct	15:28	29.4	56	30.2	15:11	03-Oct	97	9:33	03-Oct	20	8:04	03-Oct	54	15:27	03-Oct	30	18.3	24.4	0
06-Oct	15:19	29.3	44	29.8	16:13	03-Oct	97	11:23	05-Oct	16.2	8:20	06-Oct	43	15:19	06-Oct	28.3	18.3	23.3	0.02
07-Oct	15:29	20.6	76	29.3	15:19	06-Oct	97	12:27	07-Oct	18	11:35	07-Oct	43	15:32	06-Oct	28.3	17.8	23.3	0.05
08-Oct	15:19	23.3	62	23.3	15:19	08-Oct	89	9:03	08-Oct	14	8:14	08-Oct	61	14:50	08-Oct	28.9	13.9	21.7	0
10-Oct	15:18	19.9	97	23.4	15:48	08-Oct	97	15:18	10-Oct	16.9	7:49	09-Oct	82	15:54	08-Oct	20.6	13.9	17.2	0.79
11-Oct	15:18	21.4	97	21.4	15:18	11-Oct	97	15:18	11-Oct	18.3	7:52	11-Oct	97	15:18	11-Oct	23.9	12.8	18.3	0

Appendix C.
Weather data from the two digital thermometers, one placed in the sun and one placed in the shade.

date	shcurrout	shhighout	shlowout	shavgout	shcurrin	shhighin	shlowin	shade rain	suncurrout	sunhighout	sunlowout	sunavgout	suncurrin	sunhighin	sunlowin	sun rain
06-Jul	30.4	32.6	22.4	27.5	NA	NA	NA	0	46.6	50.2	21.6	35.9	NA	NA	NA	0
07-Jul	31.3	32.2	20.2	26.2	30.5	31.6	22.4	0	48.2	52.6	18.8	35.7	42.7	43	21.6	0
08-Jul	30.4	32.1	22.3	27.2	30.4	31.5	24.3	0	43.2	50.7	21.2	35.95	37.5	44	23.8	0
09-Jul	30.2	31.3	22.8	27.05	29.7	31	24.2	0	35.2	45	21.8	33.4	37.2	40.3	23.7	0
10-Jul	29.4	31.6	23.5	27.55	29.4	30.2	24.9	0	30.6	44.8	22.5	33.65	35.6	39.9	24.2	0
11-Jul	28.8	29.3	20.9	25.1	28	29.4	22.5	0.1	41.9	45.2	20.4	32.8	37.4	37.9	22.3	0.2
12-Jul	29.2	30.2	20.4	25.3	28.2	29.4	21.9	0	40	40.3	19.3	29.8	37.9	38.3	21.9	0
13-Jul	20.6	29.3	19.5	24.4	21.4	28.3	21.2	0.3	21.1	40.8	19.4	30.1	22.3	38.8	21.9	0.5
14-Jul	23	25.4	20.2	22.8	24	24.5	21.4	0.1	22.9	39.6	19.7	29.65	25.7	30.9	21.7	0.1
15-Jul	26.2	27.9	21.2	24.55	26.2	26.4	22.5	<.1	27.4	44.9	19.7	32.3	33.4	35.2	21.7	0.1
16-Jul	28.6	29	21.1	25.05	27.6	28	22.1	0	35.8	44.9	20.3	32.6	37.2	37.2	22.3	0
17-Jul	25.2	29.8	21.8	25.8	26.6	28.4	23.3	0	25.8	45.3	21	33.15	31.7	38.8	23.2	0
18-Jul	21.8	29.8	21.8	25.8	23.3	28.7	23.3	0.1	44.9	46.3	22.3	34.3	37.1	37.1	23.1	0.1
19-Jul	36	NA	NA	NA	34.3	37.1	22.5	0	27.8	29.2	21.2	25.2	27.3	28.7	22.9	0
20-Jul	23.6	28.7	20.3	24.5	24.2	27.6	22	0.6	33.2	NA	NA	30	30.5	NA	NA	1.2
21-Jul	28.1	28.6	20.5	24.55	27.2	27.7	22.3	0	43	43	21.4	32.2	40.2	40.2	22.6	0
22-Jul	28.2	30.5	22.2	26.35	28.1	28.6	23.7	0	29.9	NA	NA	32	34.7	41.3	23.7	0.1
23-Jul	29.7	29.8	21.2	25.5	28.2	28.2	22.9	0	43.2	45.7	20.2	32.95	39.9	39.9	22.8	0
24-Jul	27.9	30.2	20.8	25.5	27.5	28.7	22.4	0.4	39.3	42.1	NA	42.1	39.4	40.9	23	0.5
25-Jul	27.5	28.6	22.1	25.35	27	27.6	23.7	0.1	32.5	NA	NA	32	35	39.7	23.9	<.1
26-Jul	29.4	34	22.9	28.45	27	34.7	23.6	0	35.3	38	22.2	30.1	37.6	37.7	24.9	0
27-Jul	30.1	30.9	23.7	27.3	27.6	27.7	24.3	0	34.6	34.9	23.9	29.4	37.1	37.7	25.2	0
28-Jul	24.6	31.1	23.2	27.15	26	28.1	24.4	0.2	24.9	39.8	22.6	31.2	31.4	39.3	25.4	0.5
29-Jul	30.2	31.1	22.9	27	27.3	27.3	23.8	0.1	35.2	39.8	22.4	31.1	38.7	38.7	25	0.1
30-Jul	31	31.8	23.2	27.5	28.3	28.5	23.9	0	33	40.1	22.3	31.2	38.5	39.6	25.1	0
31-Jul	26.7	32.1	20.7	26.4	25.2	28.8	22.1	0.4	37.6	38.8	20.4	29.6	38.7	39.1	23.2	0.6
01-Aug	27.8	28.3	21.9	25.1	25.8	25.8	22.7	0	38	39.8	20.4	30.1	40.7	41.2	23.2	<.1
02-Aug	29.1	29.8	21.6	25.7	26.6	26.6	22.6	0	33.7	40.7	20.3	30.5	39.8	41.5	23.4	0
03-Aug	27.3	29.4	19.7	24.55	25.5	26.7	21.6	0.3	36.7	38.9	19.5	29.2	39.6	39.9	22.6	0.5
04-Aug	29.3	29.4	21.6	25.5	26.4	26.4	22.5	0	40.2	41.7	20.7	31.2	40.5	40.9	23.5	0
05-Aug	31.8	32.5	21.2	26.85	27.9	27.9	22.4	0	40.6	42.4	19.8	31.1	40.7	41.1	23.2	0
06-Aug	29.3	33	23.2	28.1	26.9	28.4	24.2	0	40.7	42.8	22.2	32.5	39	41.4	24.9	0
07-Aug	28.4	29.7	17.5	23.6	25.2	25.9	19.2	0	42.8	44.3	16.1	30.2	39.3	39.7	19.1	0
08-Aug	28.4	29.7	17.5	23.6	25.2	25.9	19.2	0	38.2	44.3	16	30.15	39.9	40.5	18.6	0
09-Aug	30.6	30.7	18	24.35	26.7	26.7	19.4	0	38.6	41.6	16.4	29	40.3	41.1	19.6	0
10-Aug	30	31.2	20.4	25.8	27.1	27.8	21.5	0	37.6	42.1	19.3	30.7	39.6	41	22.1	0
11-Aug	31.6	31.8	21	26.4	28.3	28.3	22	0	38.7	41.3	19.7	30.5	39.6	39.8	22.1	0
12-Aug	31.7	32	21.4	26.7	28.3	29.1	22.4	0	39.3	41.7	20.3	31	39.3	40.7	22.9	0
13-Aug	31.5	33.1	20.3	26.7	28.3	29.1	21.5	0	37.8	43.1	18.9	31	38.4	40.2	21.7	0
14-Aug	31.8	32.9	21	26.95	28.8	29	22.2	0	37.4	40.7	19.7	30.2	38.2	40	22.4	0
15-Aug	31.5	32.4	22	27.2	28.8	29.1	23.1	0	35	42.8	19.7	31.25	38.2	40	22.4	0
16-Aug	28.9	32.8	21.9	27.35	27.9	29.3	23	0	33.2	43.8	21.3	32.55	36	39.4	23.9	0
17-Aug	22.5	29.1	21.9	25.5	24.6	27.9	23	0.2	22.6	38.7	21.8	30.25	29.1	35.9	23.9	0.4
18-Aug	28.7	29.7	21.6	25.65	26.4	26.4	22.4	<.1	29.8	39	21.2	30.1	33.4	36	23.2	<.1
19-Aug	21.7	30.2	21.1	25.65	24.2	27	22.2	<.1	23.2	40.7	20.6	30.65	28.9	37.1	23	0.1
20-Aug	27.6	28.3	20.5	24.4	25.5	25.5	21.7	0.1	36.5	37	20.3	28.65	38.7	39.2	22.4	0.2
21-Aug	32	33.2	20.9	27.05	28	28	22	0	39.2	40.9	20.4	30.65	42.6	42.6	22.3	0
22-Aug	33.3	34.3	22.3	28.3	30	30.1	23.4	0	39.8	41.1	21.8	31.45	43.3	43.9	23.7	0

date	shcurrout	shhighout	shlowout	shavgout	shcurrin	shhighin	shlowin	shade rain	suncurrout	sunhighout	sunlowout	sunavgout	suncurrin	sunhighin	sunlowin	sun rain
23-Aug	32.4	34.3	23.2	28.75	30	30.8	24.3	0	35.3	40.8	22.7	31.75	40.4	44.2	24.6	0
24-Aug	31.6	33.6	22.5	28.05	29.3	30.6	24.5	0	36.8	39.4	22	30.7	40.4	43.4	25	<.1
25-Aug	28.3	32.4	22.9	27.65	26.7	29.9	24.1	<.1	33.8	38.9	22.6	30.75	36.1	41.4	24.6	<.1
26-Aug	25	29.2	19.4	24.3	24.4	26.9	21	0.8	33.9	36.5	19.2	27.85	33.9	37.2	21.3	0.8
27-Aug	29.2	26.4	18.8	22.6	26.9	24.4	20.4	<.1	35	35.8	18.3	27.05	37	37.8	20.9	0
28-Aug	26.9	28	18.9	23.45	24.4	24.7	20.3	0	35.8	37.2	18.3	27.75	37.5	38.8	20.9	0
29-Aug	27	27.7	19.4	23.55	25.2	25.2	20.9	0	35.2	37.2	18.3	27.75	36.2	39.3	20.9	0
30-Aug	27.6	28.6	21.2	24.9	25.3	25.5	22	0	30.3	36.9	20.7	28.8	33.1	38	22.5	0
31-Aug	28.8	29	20.5	24.75	26.4	26.4	21.5	0	36.4	38	19.7	28.85	37.7	38.1	21.7	0
01-Sep	28.7	29.5	20.8	25.15	26.9	26.9	21.8	0	33.2	38.1	20.7	29.4	36.4	38.7	22.3	0
02-Sep	29.3	30.6	20.6	25.6	27.8	27.8	21.9	0	37.4	38.7	20.1	29.4	37.1	39.1	22.1	0
03-Sep	31.7	32.1	21.6	26.85	29.1	29.1	22.9	0	37.8	39.8	21.1	30.45	38.5	38.7	23	0
04-Sep	32.7	33.8	21.8	27.8	29	29.4	23.2	0	38.6	40.4	21.1	30.75	38.7	39.2	23.1	0
05-Sep	30.4	33.8	19.9	26.85	28	30.1	21.6	0	39.1	40.4	18.5	29.45	39.5	39.5	21.3	0
06-Sep	30.9	31.4	18.5	24.95	28.6	28.7	19.7	0	38.7	40.6	17.5	29.05	38.7	41.2	20.1	0
07-Sep	29.8	31.9	19.7	25.8	27	29.1	21.1	0	38.6	39.3	18.8	29.05	36.1	39	21.4	0
08-Sep	30.9	31.7	20.1	25.9	28.7	28.9	21.2	0	38.3	40.5	19	29.75	38.8	40.1	21.5	0
09-Sep	31.3	31.6	19.7	25.65	28.7	29.2	21.2	0	39.5	40.3	18.7	29.5	38.6	40.5	21.4	0
10-Sep	32.1	32.5	18.8	25.65	30.1	30.2	20.3	0	39.1	41.3	17.7	29.5	39.7	40.8	20.6	0
11-Sep	28.8	32.4	19.7	26.05	28.4	30.1	21.1	0	35.7	40.6	19.2	29.9	35.3	40.8	21.5	0
12-Sep	29.6	29.8	16.5	23.15	26.5	28.7	18.1	0	35.7	34.8	15.2	25	34.9	35.1	17.6	0
13-Sep	30.3	30.7	18.7	24.7	28.2	28.2	19.9	0	36.5	38.7	17.8	28.25	36.4	37.4	20.2	0
14-Sep	25.8	31.8	20.5	26.15	24.8	29.4	21.7	0.2	32.5	38.6	20.4	29.5	30.7	37.2	22.5	0.3
15-Sep	23.9	27.5	19.9	23.7	23.3	25.4	21.1	0.1	28	35.1	19.7	27.4	28.2	32.5	22.1	0.2
16-Sep	27.8	28.1	20.9	24.5	25.6	25.5	21.6	<.1	33.3	35.7	20.4	28.05	33	33.2	22.4	0
17-Sep	27.5	28.6	20.8	24.7	25.7	25.9	21.8	0	30	35.2	20.2	27.7	30.6	34.2	22.3	0
18-Sep	25	28.1	20.9	24.5	23.8	25.9	21.8	<.1	27.3	32.6	20.6	26.6	26.4	30.9	22.6	0.1
19-Sep	29.7	30.7	21.4	26.05	27.7	27.8	22.1	0	35	37.5	21.1	29.3	35.1	35.2	22.8	0
20-Sep	28	30.9	20.5	25.7	27.4	28.1	21.6	0	31.6	36.7	19.8	28.25	31.7	35.7	22	0
21-Sep	22	29.1	21.2	25.15	22.4	27.7	21.8	2.7	22.3	35.2	21.1	28.15	23.9	32.4	22.8	3.4
22-Sep	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	28	NA	NA	NA	NA
23-Sep	17.9	28.7	NA	28.7	27.3	NA	NA	1.1	28.6	28.1	29.5	28.8	NA	30.4	14.7	0.8
24-Sep	22.9	27.2	16.2	21.7	21.4	29	17.2	0	29.2	30.6	15.8	23.2	29.1	37.3	18.6	0
25-Sep	18.9	23.4	17.2	20.3	19.7	21.5	18.6	<.1	19.3	29.4	17.1	23.25	22.1	29	20	0.1
26-Sep	17.9	19	15.6	17.3	18.6	19.8	17.1	0.7	18	19.7	15.5	17.6	20.6	22.2	18.3	1.1
27-Sep	21.9	22.7	17.8	20.25	21.5	21.9	18.6	0.2	22.8	23.9	17.7	20.8	22.7	22.8	20	0.3
28-Sep	22.7	23.2	17.8	20.5	21.5	21.5	19.1	<.1	32.4	33.6	17.3	25.45	32.2	32.4	19.9	0
29-Sep	24.8	25.2	16.4	20.8	22.4	22.5	18	0	32.8	35.3	15.8	25.55	33.1	33.1	18.7	0
30-Sep	26.4	26.7	17	21.85	22.4	22.7	18.7	0	32.1	35.3	16.4	25.85	31.7	33	19.4	0
01-Oct	26.9	28.3	20.3	24.3	24.2	24.2	20.9	0	32.5	34.2	20.1	27.15	32.9	33.1	22.2	0
02-Oct	27.4	28.3	19.4	23.85	25.2	25.2	20.9	0	34.1	35.3	18.8	27.05	33	33.2	21.4	0
03-Oct	26.9	28.7	19.7	24.2	25	25.4	21.2	0	32.9	35.2	19.1	27.15	33.2	33.6	21.6	0
06-Oct	27.9	29.2	15.8	22.5	25.5	25.5	17.8	<.1	32.5	35.1	15	25.05	33.3	33.5	18.3	0.1
07-Oct	18.4	28.5	17.3	22.9	19.8	25.6	19.4	0.3	21.5	34.3	17.5	25.9	23.3	33	20.7	0.4
08-Oct	21.5	22	13.4	17.7	19.9	19.9	15.6	0	26.6	30.2	12.5	21.35	27.1	27.1	16	0
10-Oct	19.4	22.3	16.5	19.4	20.2	20.7	18	<.1	20.1	28.3	16.1	22.2	22.5	27.3	18.8	0.1
11-Oct	20.7	20.7	17.9	19.3	20.9	20.9	19.1	0.3	21.2	22.5	17.8	20.15	22.8	23.1	20	0.4

Appendix D.

Description of Plate 1 (in Pocket)
Photographs taken on all four subjects including those not displayed in the report. Pictures are in Jpeg format. Each picture is labeled by subject number and day. Multiple pictures taken on one day are recorded by a letter following the day. Note: Pictures may be out of order due to technological reordering.

Vita

Carrie Srnka was born in Ithaca, NY on 21 November 1979. She grew up in Trumansburg, NY and attended Trumansburg Central School District. She received her Bachelor of Arts degree with honors in Sociology with a minor in Anthropology from the State University of New York at Geneseo in the spring of 2001. She received her Master of Arts degree in Anthropology from the University of Tennessee, Knoxville in May 2003.