A LONGITUDINAL STUDY ON THE OUTDOOR

HUMAN DECOMPOSITION SEQUENCE

IN CENTRAL TEXAS

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ABSTRACT

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Estimating the postmortem interval (PMI), or how much time has passed since an individual died, is an important aspect of investigating a death. Traditionally, forensic anthropologists have relied on non-standardized decomposition stages, anecdotal evidence, and personal experience to make an estimation of the PMI (Love and Marks 2003). Decomposition sequences have been proposed for specific geographic regions (Mann et al. 1990; Galloway 1997; Komar 1998; Rhine and Dawson 1998; Love and Marks 2003), but these stages may not be applicable to different climates and most were developed from cross-sectional data (Galloway et al. 1989; Komar 1998; Rhine and Dawson 1998; Rhine and Dawson 1998).

Recently, Megyesi et al. (2005) developed a quantitative method of estimating the PMI using accumulated degree-days (ADD), temperature data, and total body score (TBS), a system of numerically ranked qualitative observations of decomposition. This method was developed from cross-sectional data and has never been tested in a longitudinal experimental study using human cadavers. In addition, scavenging and its effect on using ADD to estimate the PMI has not been addressed (Simmons et al. 2010a).

The present study tested Megyesi et al.'s (2005) model of scoring decomposition and its relationship to ADD using human cadavers. The goals of this study were to test the system outlined by Megyesi et al. (2005) using longitudinal data and examining the decomposition process directly. This study examined the assumption that all of the stages and decomposition characteristics used by Megyesi et al. (2005) and based on Galloway et al.'s (1989) decomposition stages follow a sequential order. The degree in which scavenging animals in this environment affect the decomposition rate and the estimation of ADD from TBS was incorporated.

From November 2009 to July 2010, 10 donated human cadavers were placed outdoors at the Forensic Anthropology Research Facility (FARF) at Texas State University-San Marcos. Decomposition was ranked using the TBS system for each day of observation over time. Observations support the general decomposition stages found in high temperature and high humidity environments (Galloway et al. 1989; Galloway 1997) with accelerated autolysis, high rates of maggot activity when scavengers are controlled for, and rapid skeletonization. TBS, however, is not linear, with changes in certain decomposition characteristics able to influence the observer's recorded TBS.

Statistically significant differences were found between the estimated ADD and the actual mean ADD for each major decomposition stage. The differences were still significant after cadavers that were scavenged were removed from analysis, meaning that these differences were not caused by scavengers alone.

In this study, longitudinal data collection allowed for a comparison between scavenged and non-scavenged human bodies. Scavenged bodies had significantly lower ADD (i.e. faster rates) to reach major decomposition stages than protected cadavers. This study shows in a quantitative manner that scavenging animals can have a significant impact on the estimation of the PMI from ADD.

Exact binomial tests tested the rate of the equation produced by Megyesi et al. (2005) to successfully predict ADD against an expected success rate. The method had 100% accuracy rates for decomposition scores less than 22, but this was found to be indicative of a lack of precision stemming from a large standard error. Bodies skeletonized much faster than what was estimated with the equation, and the low success rates for scores 22 and above make the equation not recommended for severely decomposed remains. Only score 23 effectively predicted ADD from TBS (~90%), but all successes were recorded from one donation.

The results of this study demonstrate that different environments may contain significant variables that the Megyesi et al. (2005) decomposition scoring system does not specifically address. In addition, low success rates for the Megyesi et al. (2005) equation to predict ADD from TBS above 22 and the wide standard error ranges provided demonstrate the need to reevaluate the equation for PMI estimation from TBS.

I. INTRODUCTION

Forensic anthropologists may be consulted in the estimation of the postmortem interval, or PMI, also known as time since death. In this estimation, forensic anthropologists traditionally rely on decomposition stages, anecdotal evidence, and personal experience (Love and Marks 2003). An accurate assessment of the PMI can assist with the reconstruction of events surrounding a suspicious death, the determination of the identity of a victim, or identifying the perpetrator of the crime (Rodriguez and Bass 1983; Rhine and Dawson 1998; Knight 2002; Love and Marks 2003; Geberth 2007). The PMI is considered to be one of the most vital factors in a forensic investigation of a suspicious death (Geberth 2007), making research on estimating the PMI of significant importance. The PMI for outdoor scenes is dependent on local climate conditions involving several variables (Mann et al. 1990), and among those variables temperature is considered to be the most important variable influencing decomposition (Mann et al. 1990; Love and Marks 2003).

Decomposition sequences have been proposed for specific geographic regions including Tennessee (Mann et al. 1990; Vass et al. 1992; Love and Marks 2003), New Mexico (Rhine and Dawson 1998), Alberta (Komar 1998), and Arizona (Galloway et al. 1989; Galloway 1997), but these sequences may not be applicable for use in other regions of the country, such as Central Texas. The Forensic Anthropology Research Facility (FARF) at Texas State University-San Marcos is located in an area subject to various weather conditions characteristic of a sub-tropical climate, in which the humid climate may be punctuated by periods of drought leading to semi-arid conditions (Dixson 2000).

Megyesi et al. (2005) developed a quantitative method of estimating the PMI using accumulated degree-days (ADD) and a total body score (TBS), a form of numerically ranking qualitative observations of decomposition, from cross-sectional data collected from crime scenes from several regions across the United States. Recently, this use of ADD to predict the PMI has gained prevalence as the preferred variable for research in forensic anthropology focusing on decomposition (Adlam and Simmons 2007; Bachmann and Simmons 2010; Cross and Simmons 2010; Dabbs 2010; Simmons et al. 2010a; Simmons et al. 2010b). Understanding the rate of decomposition in Central Texas is important for forensic anthropologists in similar regions by presenting observations of decomposition for that specific climate and evaluating a method of estimating the PMI.

The following study tests the Megyesi et al. (2005) system of scoring decomposition and its relationship to ADD. The purpose of this study is to test the system outlined by Megyesi et al. (2005) using longitudinal data. In addition, examining the decomposition process directly in a longitudinal manner will test the assumption that all of the stages and decomposition characteristics used by Megyesi et al. (2005) follow a sequential order, an assumption that contradicts Galloway's (1997) assertion that only the four general categories of fresh, early decomposition, advanced decomposition, and skeletonization entail a sequence. Finally, how scavenging affects the estimation of ADD from TBS is tested.

Previous studies (Galloway et al. 1989; Rhine and Dawson 1998; Megyesi et al. 2005) could also not control for scavengers in a natural environment because of the use of cross-sectional data from police reports and forensic cases. As Simmons et al. (2010a) state, all the experimental studies published in the literature have not included scavenging nor the potential influence this factor may have on data in decomposition rate and ADD studies. In this study, longitudinal data collection allowed for a comparison between scavenged and non-scavenged human bodies and included these subjects into the dataset in order to fill this gap in current research. This comparison also addressed the debated issue over what taphonomic forces most accelerate the decomposition of a body. Simmons et al. (2010b) claimed that insects had the most significant influence on decomposition rate. However, scavenging animals were not included as a variable in their study. Accounting for the behavior and effects of scavengers will provide anthropologists and future researchers data on how to properly evaluate the postmortem interval when scavengers have access to a body (Reeves 2009).

The first objective of this thesis was to monitor each donated cadaver upon arrival at the Forensic Anthropology Research Facility (FARF) at Texas State by using the decomposition scoring method developed by Megyesi et al. (2005) based on Galloway's (1997) arid environment decomposition stages. These observations provided a preliminary step toward a discussion of confounding variables that may influence the estimation of the PMI. The stages developed by Megyesi et al. (2005) were useful for this research project due to the fact that mummification was addressed in the authors' outline of decomposition. Desiccation of tissue is the most common form of spontaneous mummification and has been known to occur in the American Southwest (Aufderheide 2003). Spontaneous natural mummification can also occur in humid climates if certain microclimate conditions are met (Aufderheide 2003). Because Central Texas experiences a variety of weather conditions (Dixson 2000), including semi-arid conditions that may produce desiccation of soft tissues, decomposition stages that included mummification were deemed most appropriate.

The second objective of this research study was to determine whether or not the methodology of estimating ADD from decomposition scoring as outlined by Megyesi et al. (2005) was an effective and appropriate method of estimating the PMI. The Megyesi et al. (2005) method built upon previously published forensic anthropological studies utilizing ADD (Vass et al. 1992) and later inspired the recent popular use of decomposition scoring and ADD in research environments (Adlam and Simmons 2007; Bachmann and Simmons 2010; Cross and Simmons 2010; Simmons et al. 2010a; Simmons et al. 2010b). Simmons and colleagues assert that recording ADD alongside decomposition scores provides the ability to compare data from other studies of decomposition occurring under different conditions (Adlam and Simmons 2007) and they state that the future of taphonomic research depends on the standardization provided by measuring decomposition rate against ADD (Simmons et al. 2010a). However, the utility of predicting ADD from TBS has not been tested in a longitudinal study using human cadavers. The current study tests this method of estimating the PMI longitudinally in a new environment with human cadavers.

II. LITERATURE REVIEW

One of the first researchers to describe the concept of defined stages of decomposition was Reed (1958) in a study that focused on the insects associated with decaying dog carcasses. The stages the author described were fresh, bloated, decay, and dry (Reed 1958). Of relevance to the current research, Reed (1958) described how the dog carcasses were frequently disturbed by scavengers before his initial study began. The author used cages to prevent access to the dogs, and thus the study continued to describe decomposition without the influence of scavengers (Reed 1958). Even in Reed's (1958) early study describing the decomposition sequence, scavengers and their influence was noted. A following study on the role of scavenging in ecosystems remarked that the appearance of skeletonization in the decomposition sequence may appear much earlier through the actions of vultures (McKinnerney 1978).

General decomposition stages outlined by various researchers have typically included the categories fresh, discoloration, bloating, and skeletonization (Love and Marks 2003) similar to what was described by Reed (1958). The first decomposition stage is fresh. A body is categorized as fresh when there is no visible trace of insect activity or discoloration other than coloration due to lividity (Galloway et al. 1989). Autolysis, the process in which normal intracellular enzymes begin to self-digest the body cells, occurs next and leads to tissue degradation (Micozzi 1991; Gill-King 1997). The loss of cellular structure from autolysis leads to putrefaction (Gill-King 1997).

Putrefaction is the proliferation of bacteria in decomposing tissue (Micozzi 1991; Gill-King 1997). Early decomposition is marked by discoloration caused by this proliferation of bacteria, and includes bloating and post-bloating (Galloway et al. 1989). Advanced decomposition occurs after bloating has receded and tissue begins to sag. This stage can involve a large amount of insect activity, exposure of bone, adipocere development, and mummification (Galloway et al. 1989). Mummification is a state of arrested decay, in which body tissue resembles its living appearance but is resistant to further decomposition (Aufderheide 2003). Human remains are defined as skeletonized by Galloway after half of the skeleton is exposed (Galloway 1997). The last stage described by Galloway is extreme decomposition, in which bone begins to break down and exhibit bleaching, exfoliation, and decay of the cortical surface (Galloway et al. 1989).

One of the first reports to connect decomposition stages with estimating time since death using outdoor taphonomic research in a laboratory setting was written by Rodriguez and Bass (1983). Rodriguez and Bass attempted to create a reliable method for determining the time interval since death of a human body using entomological and seasonal evidence. Most research concerning decay rates has employed an entomological approach (Rodriguez and Bass 1983). The authors describe their study in which they collected observations on the specific insects found in association with human decomposition. The study observed four unclothed human cadavers that were each placed, at various times of the year, within the University of Tennessee's Anthropological Research Facility located in an open wooded area. The authors collected samples daily throughout the entire decay cycle on the various insect populations that frequented each cadaver. Observations on the daily decomposition state of each cadaver were recorded by means of photographs and written documentation. Rodriguez and Bass (1983) used the decomposition stages observed by Reed (1958). The authors stated that the stages are successional. While this study has the advantage of being longitudinal, the authors used a small sample size of four and the study was mainly descriptive. The decomposition stages are also vague (e.g. the word "decay" seems to be an umbrella term to encompass multiple changes observed after bloating) and the study focuses specifically on using entomological observations to estimate the postmortem interval.

To summarize the research conducted at the University of Tennessee, Mann et al. (1990) compiled observations of decomposition collected over eight years of study. This synthesis of information was longitudinal and provided useful information on the impact of carrion insect activity, ambient temperature, rainfall, clothing, burial and depth, carnivores, bodily trauma, body weight, and the surface with which the body is in contact on decomposition rates. The authors distinguished the factors they believed have the most effect on the decomposition process. In addition, general observations of events and anomalies were provided. Unfortunately, much of the information described in the article was based on singular events and was anecdotal in nature. A single observation cannot be expanded to provide a general explanation of the decomposition process. However, the paper is useful in that it recognized that much of the difficulty in determining the time since death stems from the lack of systematic observation and research on the decomposition rate of the human body, establishing the need for more systematic studies.

Vass et al. (1992) conducted a systematic study that collected data on specific volatile fatty acids produced from soft tissue decomposition that were deposited in soil from decomposing human cadavers. The purpose of the study was to develop a method of determining the time since death of an individual from soil solution. The sample size of the study consisted of seven nude cadavers placed within the University of Tennessee's decomposition research facility at various times of the year. The researchers collected samples of the soil every three days in the spring and summer, and weekly in the fall and winter. Their analysis of the data showed distinct patterns in the soil solution decomposition when based on ADD. Decay rates were obtained based on the decomposition stages of fresh, bloating, decay, and dry. This study is significant in that it is a longitudinal study addressing human decomposition in order to refine time since death estimation. Vass et al. (1992) also introduce the concept of using ADD to predict decomposition stage into the forensic anthropological literature. ADD are calculated as the average of the maximum and minimum air temperatures per day and are an accepted measurement of ambient temperature (Vass et al. 1992; Megyesi et al. 2005; Adlam and Simmons 2007). Ambient temperature has a strong relationship with bacterial growth, insect activity, and decay rates (Mann et al. 1990; Micozzi 1991; Vass et al. 1992; Gill-King 1997; Knight 2002; Krompecher 2002; Love and Marks 2003; Megyesi et al. 2005). Accumulated degree days act as a measurement of energy produced by heat that accelerates biological processes such as bacterial growth or fly larvae development (Micozzi 1991; Megyesi et al. 2005). Vass and colleagues (1992) were the first to correlate ADD with decay. However, this study focused on the analysis of soil solution rather than evaluating the use of ADD or the systematic process of decomposition.

Galloway et al. (1989) augmented studies conducted at the University of Tennessee by researching decomposition in arid climates. Previous research in human body decomposition mostly originated from the Anthropological Research Facility in Tennessee and therefore only examined rates of decomposition in one climate region (Mann et al. 1990). Galloway et al. (1989) complemented this research by studying decomposition in a completely different area of the United States. The researchers conducted a cross-sectional study of forensic case reports in southern Arizona to outline a timeline for the sequence of human decay (Galloway et al. 1989). Galloway (1997) followed this study by describing decomposition in the Arizona-Sonoran desert. The model uses the Galloway et al. (1989) retrospective study of 189 cases to generate a qualitative assessment of human decomposition customized to the environmental surroundings of the remains. Galloway (1997) divided the decomposition process into five general sequential categories: fresh, early decomposition, advanced decomposition, skeletonization, and extreme decomposition. In addition to these general categories, she described secondary characteristics that are associated with each stage but did not imply a sequence of events. A contribution of this research was to acknowledge the process of natural mummification of human remains and the effects different environments have on decomposition. However, the study is cross-sectional and retrospective, meaning that an accurate sequence of events is difficult to obtain because the researchers are only viewing the end result of decomposition (the discovered remains) rather than systematic observations of the same body.

Rhine and Dawson (1998) replicate the Galloway et al. (1989) study by collecting a series of cases with known times of exposure to infer a decomposition sequence for a specific region. Rhine and Dawson used case reports to develop a sequence of stages for environments in New Mexico, producing a comparable description of decomposition to what was developed by Galloway et al. (1989), but modified to what the authors observed. Rhine and Dawson note that while longitudinal observations are preferable to cross-sectional data, longitudinal research requires the acquisition of a large sample size of human cadavers and a research facility in which to conduct observations. Such requirements are difficult for many researchers to fulfill in multiple regions, thus making cross-sectional data a sensible alternative. In that study, 270 cases were examined by the authors to test the assumption that the degree of decomposition and time of exposure have a linear relationship. Decomposition was scored on a 1-15 point scale based on soft tissue presence, color, and bone exposure, and plotted against time since death. Rhine and Dawson (1998) acknowledged that the first attempt to correlate decomposition produced poor results. The authors increased the sample size and accounted for environmental diversity and found that the relationship between time since death and decomposition score was curvilinear. A curvilinear relationship showed a large amount of variability and that earlier stages of decomposition occurred fairly rapidly in comparison to skeletonization and disintegration of bone. Skeletonized cases with exposure of over a year did not differ greatly from cases skeletonized within a year with a scoring system. Rhine and Dawson (1998) conclude that while the sequence of decomposition is universal, the rate is highly variable and dependent on the environment. The authors acknowledge that this study could not fully account for insect and scavenging activity and that such activity accelerates the decomposition process. The "normal" sequence of decomposition is also said to be interrupted by mummification and adipocere formation. Rhine and Dawson recommend a methodology in which the researcher bases an estimate of the postmortem interval on a baseline of decomposition developed for the specific region in which the remains are found.

The use of ADD to estimate the PMI was acknowledged again by Love and Marks (2003). Love and Marks (2003) state that ADD provides an alternative method to measure the rate of decomposition by incorporating the effects of temperature with gross observations of the body. Love and Marks (2003) cite Vass et al. (1992) and write that researchers studying the rates of human decomposition recently turned their focus from correlating decomposition with time to correlating decomposition with ADD. The authors describe a pilot study (Marks et al. 2000) in which the authors plotted the stage of decomposition against ADD. However, Love and Marks (2003) also write that the pilot study did not have sufficient data to produce a reliable method of estimating the postmortem interval.

Continuing the trend described by Love and Marks (2003) of researchers utilizing ADD as a tool to measure the rate of decomposition, Megyesi and colleagues (2005) carried out a study in which ADD was correlated with decomposition stages for a total of 68 human cases. The central idea of the study was to develop a way to quantify decomposition stage, record ADD, and use these two variables to arrive at an estimation of the postmortem interval. Megyesi et al. (2005) used a method of scoring decomposition with a point-based system. This system was based upon the decomposition stages described by Galloway et al. (1989) and modified according to what Megyesi and others observed. For instance, adipocere formation was removed because the trait was considered to occur independently of decomposition. Qualitative stages of decomposition have operated as rough guidelines for describing the decay process for forensic anthropologists (Love and Marks 2003). Megyesi et al. (2005) utilized the stages of decomposition as a quasi-continuous process. The general characteristics found in each stage were assigned point values in order to quantify the qualitative observations. Observations were scored independently for the head, torso, and limbs, in order to account for different rates of decay for the sections of the body. Decomposition was considered a quasi-continuous variable during statistical analysis. These separate scores were summed and produced a "total body score" (TBS). When plotted against each other, Megyesi et al. (2005) found that the relationship between the PMI and TBS was curvilinear. The relationship between TBS and ADD was also curvilinear. After log-transforming the data, the researchers produced a regression equation to predict ADD from decomposition score. The authors concluded that ADD accounts for approximately 80% of the variation observed in human decomposition and that decomposition is best modeled as dependent on accumulated temperature as well as time.

However, there are prevailing issues with the study conducted by Megyesi and colleagues (2005). The data gathered from their sample size of 68 was collected from case files from two of the authors. Therefore, as with the work of Galloway (1997) and Rhine and Dawson (1998), the study was cross-sectional, only viewing the end result of the decomposition process of dozens of individuals rather than using continuous observations of the same subjects over time. If researchers only saw a snapshot of the decomposition process before the discovery of the body, then the decomposition stages the body went through were not directly observed and are therefore unknown. In addition, the method found in Megyesi et al. (2005) assigns sequential point values to the secondary characteristics in Galloway's (1997) stages of decomposition, which Galloway states do not fall into a sequential order. Forensic anthropology may benefit from employing a quantitative method to study the rate of decomposition, nonetheless the sequential nature of the decomposition scoring method needs to be evaluated.

The methodology developed by Megyesi and colleagues was adopted by Adlam and Simmons (2007) and applied to systematic longitudinal observations of decomposition. In their evaluation of whether or not taphonomic studies are an accurate representation of decomposition, the researchers utilized ADD to quantify ambient temperature. Adlam and Simmons (2007) state that using ADD in decomposition studies has the great advantage of enabling the comparison of studies across seasons and regions. ADD can also be a way to allow other researchers to replicate the observations and test the results (Adlam and Simmons 2007). The authors also state their hope that scoring decomposition in a quantitative and sequential manner will become just as standardized as the use of ADD as a measurement of ambient temperature over days. Adlam and Simmons (2007) assume that the relationship between ADD and stage of decomposition is reciprocal. While Megyesi et al. (2005) demonstrated that decomposition score can predict ADD interval, Adlam and Simmons (2007) state that it is reasonable to assume that ADD can then be used to predict decomposition score. While these studies support Megyesi et al.'s methodology, the researchers observed non-human subjects (rabbits), in their experiments. In addition to not conducting their experiments with human cadavers, this subsequent research does not specifically re-test the methodology of Megyesi et al. (2005). Instead, Adlam and Simmons (2007) use the assumptions that decomposition is sequential, that decomposition score accurately reflects the process, that ADD correlates with the decomposition score, and that ADD can be used to estimate the PMI and utilize the method to answer different taphonomic questions.

Before ADD and decomposition stage can be practically applied to estimating the PMI in a forensic case, the methodology should be evaluated. Not only has the decomposition scoring method and the relationship of ADD with TBS not been re-tested with direct observations of humans, but the sequential order of the decomposition process itself is not fully understood.

Other longitudinal decomposition studies have either used a small sample size (Rodriguez and Bass 1983; Mann et al. 1990; Vass et al. 1992; Love and Marks 2003) or focused on other specific areas, such as soil pH or entomology (Rodriguez and Bass 1983; Vass et al. 1992) and not on evaluating decomposition stages. The work of Megyesi et al. (2005) provided a way to potentially estimate the PMI from using observations of decomposition and ADD, but the model should be re-tested to evaluate its reliability and validity. Cross-sectional studies are useful to studying decomposition in that they may create large sample sizes to test (Galloway et al. 1989; Galloway 1997; Rhine and Dawson 1998). However, these studies are all retrospective.

Other longitudinal studies that support the method of Megyesi et al. (2005) in estimating the PMI observed non-human subjects, thus making this research potentially not directly applicable to human bodies (Adlam and Simmons 2007; Bachmann and Simmons 2010; Cross and Simmons 2010; Simmons et al. 2010a; Simmons et al. 2010b). Megyesi et al. (2005) also caution that the decomposition scoring method has limits. The method should not be used on burned, buried, or submerged bodies and was developed only using intact bodies that were not dismembered. The variability in decomposition scoring has not yet been tested with multiple practitioners and the model does not control for, nor address, the effects of scavengers (Megyesi et al. 2005). The authors conclude the study by encouraging other researchers to test the model and produce equations tailored to different environments.

In natural environments, forensic anthropological studies have investigated the taphonomic effects of several species including canids (Haglund et al. 1989), bears (Merbs 1997; Carson et al. 2000), rodents (Klippel and Synstelien 2007) and avian scavengers (Asamura et al. 2004; Reeves 2009), but the possible effects of scavenging animals on the PMI have not been quantified in ADD studies. Recent research, using pig models, has been conducted on the taphonomic effects of local avian scavengers at the Forensic Anthropology Research Facility at Texas State University-San Marcos (Reeves 2009). Reeves (2008) states that the extreme rate in which vultures can skeletonize a body is important to consider when estimating the PMI, however ADD studies have yet to incorporate scavenging as an important variable (Simmons et al. 2010a).

The following study tests Megyesi et al.'s (2005) model of scoring decomposition and its relationship to ADD. The purpose of this study is to test the system outlined by Megyesi et al. (2005) using longitudinal data. In addition, examining the decomposition process directly in a longitudinal manner will test the assumption that all of the stages and decomposition characteristics used by Megyesi et al. (2005) follow a sequential order, an assumption that contradicts Galloway's (1997) assertion that only the four general categories of fresh, early decomposition, advanced decomposition, and skeletonization entail a sequence. The study compliments previous research through its use of human cadavers, testing a method of estimating the PMI, and by incorporating the variable of scavenging into a quantitative longitudinal study.

III. MATERIALS

Donations

A total of 10 human cadavers were included in this study (Table 1). According to the Forensic Anthropology Center at Texas State website, "The Forensic Anthropology Center at Texas State accepts body donations for scientific research purposes under the Universal Anatomical Gift Act" (FACTS 2011). The Texas State program is a willed-body donation program, meaning that bodies are only acquired through the expressed and documented will of the donors and/or their next of kin (FACTS 2011).

Body donations must be transported from a hospital, funeral home, or healthcare facility to within 100 miles of the forensic facility in San Marcos (FACTS 2011). Such transportation and storage can require that the donation was refrigerated at some point in time, such as in a hospital morgue, funeral home, or on an aircraft (United States. Federal Trade 2004). Once the donation is in transportation range in the state of Texas, Texas State faculty or trained graduate students transport the donation in a non-refrigerated covered truck to the Forensic Anthropology Research Facility (FARF). The donation is placed outside on the ground surface of the research facility, in grassy or sparsely wooded areas. FACTS personnel then photograph and record cadaver measurements (e.g. cadaver height), note any wounds present on the body, and other pertinent information about the condition of the donation upon arrival that may aid in future research. The cadavers used in this study between November 2009 and July 2010 consisted of 7 males and 3 females. The sample included one donation self-identified as Hispanic and the rest self-identified as White. Biological information, along with whether or not the body was autopsied and whether or not the body was refrigerated before the cadaver was received by FACTS , is provided in Table 1.

Out of 10 donations, 4 were autopsied, which may have accelerated decomposition by providing additional access points for scavengers and insects (Mann et al. 1990). Autopsy may be considered analogous to trauma on a body associated with crime scenes. One donation, D10-2010, had additional trauma present in the form of two gunshot wounds. Descriptive statistics on the physical dimensions and age of the donors are provided in Table 2. The youngest donor (D10-2010) was 32, the oldest 91 (D11-2010), with a mean age of 65.7 for the sample. Stature ranged from 157 to 187 cm with a mean of 170.73 cm. Minimum weight was 102 lbs, maximum 250 lbs, with a mean of 152.1bs. None of the donations were clothed at placement.

Table 1. Biological Profile of Donated Subjects and Cadaver State Before Placement

Donation	**Sex**	**Ethnicity**	**Age**	**Cadaver Height**	**Autopsied?**	**Refrigeration?**
D10-2009	F	White	76	177 cm	No	Yes, at funeral home
D02-2010	M	White	71	177.8 cm	Yes	Yes, county ME
D03-2010	F	White	91	159 cm	No	Assumed
D04-2010	F	White	53	160 cm	No	No
D05-2010	M	White	67	178 cm	Yes	Assumed
D07-2010	M	White	46	157.5 cm	Yes	Yes, at funeral home
D08-2010	M	Hispanic	67	163 cm	No	Assumed
D09-2010	M	White	63	185.4 cm	No	Assumed
D10-2010	M	White	32	187 cm	Yes	Yes, county ME
D11-2010	M	White	91	162.6 cm	No	Assumed

The current study was able to provide visual assessment of decomposition after placement into the research facility. Due to the logistical issues of acquiring and placing a donation, a gap exists between time of death and time of placement (Table 3).

The following study was conducted under the assumption that storage significantly slowed the decomposition process and maggot development (Goff 2000) between time of death and placement outdoors, making this gap between death and placement inconsequential. However, it should be noted that researchers have proposed that maggots can still develop significantly under refrigerated conditions and have found that decomposition still progresses, albeit slowly, when a body is stored in refrigerated facilities (Huntington et al. 2007).

Cages were placed over certain donations to protect the body from avian scavengers (Figure 1). The FARF is fenced, preventing terrestrial scavengers such as canids from entering the facility. Both caged donations and those exposed to avian scavengers were included in the sample. Out of the 10 donations in the sample, 3 were left open to scavenging because they were involved in another ongoing research project. The cages were originally 6 by 3 feet, 2.5 feet tall, and with simple metal grids with spaces of 2 inches by 4 inches, but this design proved insufficient for keeping scavengers from accessing limbs and phalanges near the edges of the cage. Larger 7 by 5 feet cages were constructed and covered with a layer of metal mesh. The new cages effectively prevented access to the donations.

Table 2. Donor Biological Information Descriptive Statistics

	Minimum	Maximum	Mean	Std. Deviation
Age	32	91	65.7	18.5894
Stature	157 cm	187 cm	170.73 cm	11.42940
Weight	102 lbs	250 lbs	152.1 lbs	42.87048

Table 3. Dates of Death vs. Placement for Donations

Donation	Date of Death	Date of Placement
D10-2009	November 16	November 19
D02-2010	January 26	January 31
D03-2010	March 2	March 11
D04-2010	March 15	March 15
D05-2010	March 8	March 19
D07-2010	March 29	April 1
D08-2010	April 27	April 30
D09-2010	May 17	May 27
D10-2010	June 7	June 14
D11-2010	July 15	July 16

Figure 1. 7 by 5 foot cage covering D05-2010

Environment

The Forensic Anthropology Research Facility (FARF) at Texas State University-San Marcos is subject to a wide variety of weather conditions. The area is currently classified as a humid sub-tropical climate, in which occasional drought leads to semi-arid conditions (Dixson 2000).

The climatic summary of Freeman Ranch is based on weather observations from various cities in Central Texas including San Marcos, New Braunfels, Austin, and San Antonio (Dixson 2000). The annual temperature range is around 60°F (15.6°C) with summer highs typically in the low to mid 90s (over 32°C) and winter lows near 40°F (4-10°C) (Dixson 2000). Hazardous weather conditions may include relatively weak tornadoes, very infrequent snow, meteorological drought, and increased precipitation from dissipated hurricanes (Dixson 2000). The area is subject to periodic drought and flood. The has an average relative humidity of 67% (Dixson 2000).

Descriptive statistics of the environmental conditions were calculated by the author from the data provided by a weather station near Freeman Ranch and Texas A&M University. During the 9 month period of this study, the highest temperature recorded during the observation period was 38.2℃ (100.76°F) on July 17th, 2010. The lowest temperature recorded was -15.8℃ (3.5°F) on January 9, 2010. The average temperature across all seasons was 13.8℃ (56.84°F). The average relative humidity across the 9 months in which cadavers were observed was above average at 71.83%. The highest humidity percentage was 94.1% in November. The lowest was 11.49% in late March.

Observations

Cadavers that were placed outdoors between November 2009 and July 2011 were photographed and observed directly until skeletonization. For the purposes of this study, skeletonization is defined as exposed bones with less than one half of the skeleton covered by desiccated or mummified tissue (Galloway 1997). Donated cadavers were only observed until the donation was skeletonized (D10-2009, D03-2010, D09-2010, D10-2010), utilized for other teaching purposes (D02-2010, D04-2010, D05-2010, D07-2010, D11-2010) or collected for processing by trained forensic anthropology graduate students.

Photography and daily observations provided visual evidence for the study for the categorization of decomposition stages. Photographs were taken with a 7.1 megapixel Canon PowerShot SD1000 digital camera. Photographs were taken of the donated cadavers in addition to overall landscape photos to provide context for the placement of the body. Sectional photographs were taken in order to evaluate decomposition separately for the limbs and head. Evidence of specific events, such as scavenging, trauma, or anomalies were noted as well. Time delayed photography on a wildlife camera from another ongoing research project was used to photo document the specific scavengers, such as vultures, and their effect on the rate of decomposition on 2 donations.

While photography provides documentation for the study and an opportunity to test decomposition methods that utilize photography in the future (for example the work of Megyesi et al. 2005 was most developed through crime scene photographs), this study relied on direct observations by the author. For each day, decomposition was scored using the same scoring categories used by Megyesi et al. (2005) to represent the overall condition of remains (Table 4). Decomposition stage was assessed for the torso, limbs, and head separately and recorded on a data sheet (see Appendix A) to account for different areas of the body decomposing at different rates (Megyesi et al. 2005). Decomposition scores and observations are presented for each donation in Appendix A.

Direct observations were collected at around the same time (4-5 p.m.) to note decomposition in roughly 24 hour periods every day since placement. However, scheduling conflicts occasionally prevented following this schedule. Therefore, gaps exist in the timeline of observations for each donation and certain observations were gathered at different times.

Table 4. Categories and Stages of Decomposition (from Megyesi et al. 2005)

Categories and stages of decomposition for the head and neck.

A. Fresh

(1pt) Fresh, no discoloration

B. Early decomposition

(2pts) Pink-white appearance with skin slippage and some hair loss.

(3pts) Gray to green discoloration: some flesh still relatively fresh.

(4pts) Discoloration and/or brownish shades particularly at edges, drying of nose, ears and lips.

(5pts) Purging of decompositional fluids out of eyes, ears, nose, mouth, some bloating of neck and face may be present.

(6pts) Brown to black discoloration of flesh.

C. Advanced decomposition

(7pts) Caving in of the flesh and tissues of eyes and throat.

(8pts) Moist decomposition with bone exposure less than one half that of the area being scored.

(9pts) Mummification with bone exposure less than one half that of the area being scored.

D. Skeletonization

(10pts) Bone exposure of more than half of the area being scored with greasy substances and decomposed tissue.

(11pts) Bone exposure of more than half the area being scored with desiccated or mummified tissue.

(12pts) Bones largely dry, but retaining some grease.

(13pts) Dry bone.

Categories and stages of decomposition for the trunk.

A. Fresh

(1pt) Fresh, no discoloration.

B. Early decomposition

(2pts) Pink-white appearance with skin slippage and marbling present.

(3pts) Gray to green discoloration: some flesh relatively fresh.

(4pts) Bloating with green discoloration and purging of decompositional fluids.

(5pts) Postbloating following release of the abdominal gases, with discoloration changing from green to black.

C. Advanced decomposition

(6pts) Decomposition of tissue producing sagging of flesh; caving in of the abdominal cavity.

(7pts) Moist decomposition with bone exposure less than one half that of the area being scored.

(8pts) Mummification with bone exposure of less than one half that of the area being scored.

Table 4 - Continued

D. Skeletonization

(9pts) Bones with decomposed tissue, sometimes with body fluids and grease still present.
(10pts) Bones with desiccated or mummified tissue covering less than one half of the area being scored.
(11pts) Bones largely dry, but retaining some grease.
(12pts) Dry bone.

Categories and stages of decomposition for the limbs.

A. Fresh

(1pt) Fresh, no discoloration

B. Early decomposition

(2pts) Pink-white appearance with skin slippage of hands and/or feet.
(3pts) Gray to green discoloration; marbling; some flesh still relatively fresh.
(4pts) Discoloration and/or brownish shades particularly at edges, drying of fingers, toes, and other projecting extremities.
(5pts) Brown to black discoloration, skin having a leathery appearance.

C. Advanced decomposition

(6pts) Moist decomposition with bone exposure less than one half that of the area being scored.
(7pts) Mummification with bone exposure of less than one half that of the area being scored.

D. Skeletonization

(8pts) Bone exposure over one half the area being scored, some decomposed tissue and body fluids remaining.
(9pts) Bones largely dry, but retaining some grease.
(10pts) Dry bone.

Take each point value and sum them to find the total body score (TBS).

For example: 5 (head) + 5 (torso) + 5 (limbs) = 15 TBS

If an area of body has differential decomposition or different features (such as brown to black discoloration on relatively fresh skin on the torso) record both numbers. For the total body score, average the two numbers before totaling the body score.

Total body score is supposed to represent overall decomposition progression, so if you're unsure about where to fit a section of the body into a category either go for the lowest score or an average score.

Accumulated Degree-Days

For the purposes of replicating Megyesi et al.'s (2005) methodology, the base temperature was considered to be 0 °C (32°F) and temperatures lower than 0 °C were recorded as zero rather than negative values (et al. 2005). For each day a donation was observed, ADD was estimated by adding together daily average temperatures above 0 °C for all days from placement to skeletonization (Appendix B). Temperature data were not available for days before a cadaver was in the possession of FACTS personnel and therefore all subsequent analyses use the date of placement outside (Table 3) as the start of accumulating degrees.

0 °C was used as the established "base temperature." Base temperature represents the temperature at which decomposition essentially stops (Micozzi 1991; Megyesi et al. 2005). Micozzi (1991) states that putrefaction does not occur below 4 °C. Vass et al. speculated that salt concentrations in the human body causes decomposition processes to still occur in temperatures as low as 0 °C (1992). Based on the work of Vass et al. (1992), Megyesi et al. (2005) use 0 °C as the base temperature based on the idea that freezing temperatures hinders the processes involved in decomposition. In this study, temperatures below 0 °C are counted as zero when calculating ADD to avoid subtracting days from the PMI estimate through using negative numbers (Vass et al. 1992).

Weather data were collected from the weather station closest to Freeman Ranch and processed by Ray Kamps at Texas A&M University. The sensors used to gather temperature and humidity readings were 0.75 meters from the ground. There were several data gaps caused by equipment failure which were filled from another station after performing a linear regression against available data. The sensor at 0.75 meters from the ground had a 0.85 r-squared for filling in data gaps. ADD for each individual day was calculated by adding the maximum and minimum temperatures recorded by the weather station and dividing by two to find the average daily temperature. Each daily average was added to previous combined average temperatures to show the accumulated temperature while the donation was exposed outdoors (see Appendix B).

IV. METHODS

Megyesi et al. (2005) assume that categories of decomposition (Fresh, Early decomposition, Advanced decomposition, and Skeletonization) and the stages described within those categories (see Table 4) are sequential in appearance. This means that in order for a section of the body to have a score of 5, the body must have undergone stages 1-4. However, categories and stages are modeled after Galloway et al.'s (1989) descriptions of decomposition. The authors of that study specifically caution that these secondary categories that represent the overall condition of the remains, such as color, bloating, moisture, and insect activity, do not imply a sequence of events (Galloway et al. 1989). Thus, in the present study, TBS was calculated for each observed day to see if decomposition progression through the categories was linear, or as Megyesi et al. (2005) describe the process, quasi-continuous. By recording the appearance of decomposition stages every day, it was possible to comment on whether or not these secondary characteristics (such as color, general appearance, purging of fluids, and mummification) occur in a sequential pattern and thereby accurately represent overall decomposition. Skeletonization is defined as over 50% of the section of the body is exposed bone.

The suggested method of estimating the PMI provided by Megyesi et al. (2005) involves gathering local temperature data in order to predict the time of death. It is suggested that for a body found in a clandestine location that exhibits signs of decomposition and/or skeletonization, one would first calculate the TBS for the individual using the scoring strategy (Table 4). The TBS would then be entered into a provided equation developed from the original study's analysis of ADD and decomposition (Figure 2).

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

Figure 2. Prediction equation for ADD using TBS in order to estimate PMI with standard error (from Megyesi et al. 2005)

The resulting number is the number of accumulated degree-days that would have been needed for the body to reach that observed stage of decomposition. Using the temperature data gathered and treating negative temperatures as 0°C, authorities or the researcher would work backwards from the day of discovery until the day the accumulated sum is reached. That day would be the estimated date of death.

Megyesi and colleagues provided an example of how to use this method, "To predict the time of death for a new forensic case, one would first calculate the TBS for the individual using the previously outlined scoring strategy. The TBS (30, in this example) would then be plugged into the simplified equation given [...]. The resulting number (4073.81) is the number of accumulated degree-days that would have been needed for this individual to reach the stage of decomposition observed (TBS =30). One would then need to obtain local average daily temperatures from a weather station closest to where the individual was found. Treating negative temperatures as 0°C, degree-days would then be added together, working backwards in time from the day of discovery of the remains until the accumulated sum equaled 4073.81. The day of death for the individual would be the day that 4073.81 ADD is reached, after about [261.14] days of

60°F (15.6 °C) weather" (Megyesi et al. 2005: 6-7). Essentially, visual assessment of decomposition provided a TBS. That TBS can be used to estimate ADD. ADD in turn is used to estimate the PMI.

Statistical Analysis

The equation for estimating PMI from ADD and total body score (Figure 2) presented by Megyesi et al. (2005) was tested by comparing the estimated ADD provided by the equation with the actual ADD for each donation. Unlike cross-sectional studies, longitudinal data allowed for the testing of ADD over time until each category of decomposition was reached on the same subjects.

In the preliminary analysis, independent sample t-tests were conducted with SPSS 17.0 (SPSS 2008) to determine whether or not the differences between the estimated ADD using Megyesi et al.'s (2005) equation and the actual ADD were statistically significant. The null hypothesis is the mean difference between the ADD estimated by Megyesi et al. (2005) and the current study is 0. The alternate hypothesis is that significant differences exist between the ADD estimated from Megyesi et al.'s (2005) study and the mean ADD in the present study associated with decomposition categories.

The point estimate of the ADD interval provided by Megyesi et al.'s (2005) equation was used as a comparison to the actual ADD. For evaluating the ADD results for the longitudinal study to the original study, points of comparison were necessary for preliminary t-tests. Because ADD is used as a proxy for time in this study, including all decomposition scores would be including several ADD estimations and therefore several timelines. The goal was to test the ADD for a body to enter a specified decomposition stage against the estimated ADD. A TBS was recorded by this observer for each decomposition category, following what was originally published about decomposition characteristics and TBS range (Table 5 in Megyesi et al. 2005). For purposes of comparison, TBS 8 was used to represent entering the fresh category of decomposition (because TBS 6 was never observed for any donation), TBS 19 for advanced decomposition, and TBS 27 for skeletonization. These scores were chosen as points of comparison because they represent when the donation first reached a decomposition stage. Scores in the same stage represent different decomposition changes (such as bloating versus post bloating) and so including all scores for that stage in analysis would not represent when the donation first reached the stage. Only ADD associated with the first recorded score of 8, 19, or 27 (when a donation reached that stage of decomposition) for a donation were included in the t-tests.

To address whether or not scavenging could be the sole explanation for any differences, another set of independent sample t-tests were performed with the exclusion of body donations that were subject to scavenging (D10-2009, D02-2010, and D04-2010). To assess the influence of scavenging on the ADD recorded to reach a decomposition stage, independent sample t-tests between scavenged and caged remains were conducted between mean ADD to reach a major stage of decomposition.

These t-tests were conducted with the mean ADD compared to the point estimate produced from the Megyesi et al. (2005) and did not include the standard error. After preliminary statistics using t-tests, more extensive statistical analysis was conducted on the ability of TBS to estimate ADD by comparing the data from this study with the estimated ADD provided by the Megyesi et al. (2005) equation. This further analysis examined the entire range of ADD provided by the equation.

Exact binomial tests were used to examine if the number of successful ADD estimations are significantly different from a desired probability of success. For each possible TBS score, ranging from 3-35, an estimated ADD was calculated using the method equation (Megyesi et al. 2005). The counts in which the ADD in the sample successfully fell within the estimated range for that decomposition score were tallied. Exact binomial tests had the advantage of including the entire range of ADD provided by the equation (point estimate with standard error) in analysis, as opposed to the comparison of the means with the estimate in preliminary t-tests. The exact binomial tests were also able to test the entire sequence of decomposition recorded through TBS scores and ADD against the Megyesi et al. (2005) equation estimated ADD. Testing each TBS score also could reveal if estimating the ADD for a particular stage of decomposition can be relied upon better than others. R version 2.12.2 (Hornik 2011) was used for this analysis.

In taphonomic studies, experimental variables are often highly interrelated (Mann et al. 1990). The specific independent variables in this study will be narrowed down to ambient temperature represented by ADD and access to scavengers. The dependent variables recorded will be decomposition score and length of time until skeletonization. The qualitative variable is decomposition stage and quantitative variables are time and ADD.

V. RESULTS

Observations on Decomposition

Decomposition in Central Texas shows characteristics associated with climates of high temperatures and high humidity as observed by Galloway et al. (1989), with a rapid onset of advanced decomposition, high rates of maggot activity when avian scavengers do not have access, accelerated autolysis, and rapid skeletonization or adipocere formation. Around 7,238 photos were collected over the 9 month study period to document the study.

Megyesi et al. (2005) state that limbs do not bloat, however bloating of the limbs was observed. Color was also problematic, because shades of green, pink, and brown described by Galloway (1997) and Megyesi et al. (2005) did not always appear during decomposition before skeletonization or would appear at the same time on the same segment of a body. In the case of donation D04-2010, scavengers reduced the body to skin and bones and some patches of skin continued to decompose and change colors.

Secondary characteristics described by Galloway et al. (1989) such as color or desiccated tissues did not occur in a specific order. For example, observations confirmed anecdotal and quantitative evidence that "mummified" tissues can rehydrate (Ayers 2010; Godde 2011). The best examples were D05-2010 and D07-2010, which in April after heavy rains from Hurricane Alex, the leathery mummified skin encasing the bodies softened and became noticeably light in color. When scoring decomposition, a lower score would be produced once desiccated tissues regained the appearance of moist decomposition (Figure 3). Rehydrated mummified tissues are not scored accurately with a TBS method and may be mistaken for fresher remains.

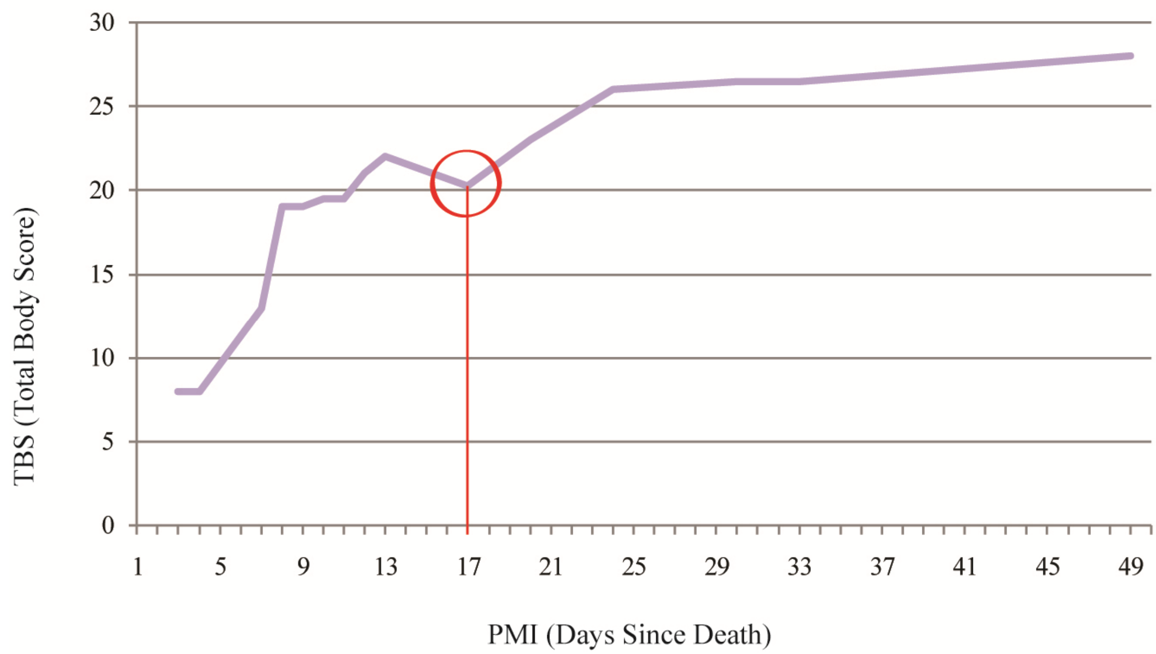

Figure 3. Example of a lowered TBS based on appearance. Note the lowered score on day 17, although more time has passed (Donation D07-2010)

Total Body Score and Accumulated Degree-Days

Observations of decomposition ranged from a recorded TBS of 3 (fresh) to 30 (skeletonized). Not all possible scores were observed, with TBS of 6 and 31+ not recorded by the observer. TBS is plotted against PMI and ADD in Figure 4. Neither relationship is linear, although the variables are positively correlated.

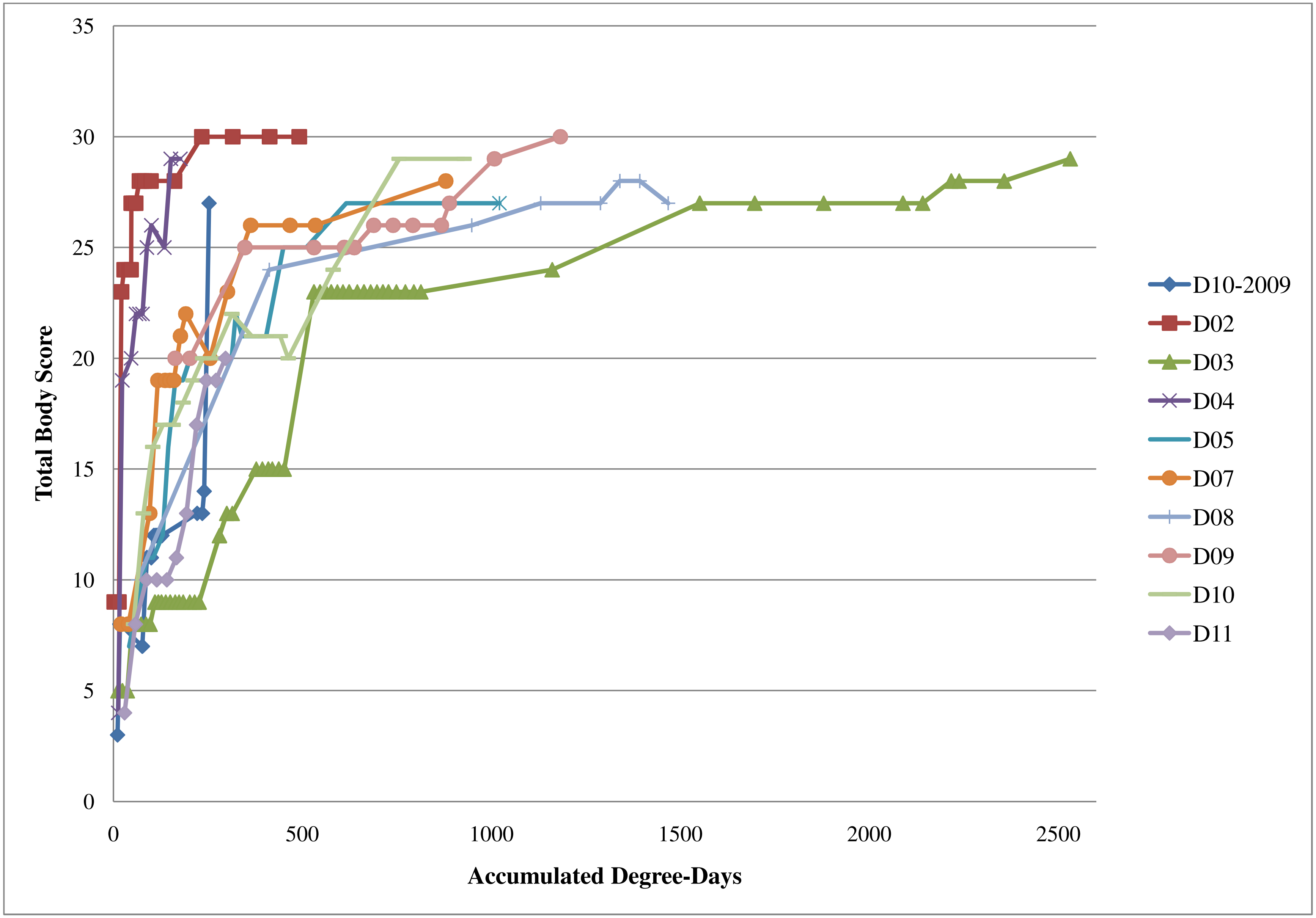

Figure 4. Total Body Score vs. Accumulated Degree-Days

In terms of PMI, the earliest full skeletonization of a body (TBS 27 with >50% exposed bone on the thorax, head, and limbs) was 12 days after placement for donations D02-2010 and D04-2010. Areas of the body can be skeletonized within 24 hours in scavenged cases (See Appendix A for D10-2009, D02-2010, and D04-2010). The body that took the longest amount of time to skeletonization was D03-2010 at nearly 85 days after placement, 94 days after death (see Appendix A). The mean PMI after placement outdoors to reach full skeletonization was 34.6 days for this sample.

Comparing Accumulated Degree-Days - Independent Sample T-tests

The mean ADD to reach each major decomposition category (Fresh, Advanced, and Skeletonization) was significantly different from the estimated ADD using the Megyesi et al. (2005) equation for ADD estimation from TBS ($p = 0.004$; $p = 0.011$; $p = 0.005$). Without the donations exposed to scavenging, the differences between mean ADD and estimated ADD were still significant ($p = 0.000$; $p = 0.001$; $p = 0.025$). The differences in ADD could not be solely explained through the activities of scavengers. This finding prompted the need to further examine the method and equation for ADD estimation provided by Megyesi et al. (2005).

Tables 5, 6, and 7 compare for each major decomposition category the current study ADD to the estimated ADD. A visual comparison is provided in Figure 5.

Table 5. Early Decomposition Comparison

Donation	TBS	PMI (After Death)	Outdoor Days	Megyesi et al. 2005 ADD	Current Study ADD	Scavenged?
D11	8	1	2	86.70	57.93	No
D03	8	12	3	86.70	50.05	No
D07	8	3	2	86.70	39.35	No
D10_10	8	8	1	86.70	53.07	No
D10_09	8	5	2	86.70	16.94	Yes

Table 6. Advanced Decomposition Comparison

Donation	TBS	PMI (After death)	Outdoor Days	Megyesi et al. 2005 ADD	Current Study ADD	Scavenged?
D11	19	9	9	340.41	245.70	No
D04	19	2	2	340.41	23.19	Yes
D05	19	23	10	340.41	202.97	No
D07	19	8	7	340.41	136.72	No
D10_10	19	14	7	340.41	210.54	No

Table 7. Skeletonization Comparison

Donation	TBS	PMI (After death)	Outdoor Days	Megyesi et al. 2005 ADD	Current Study ADD	Scavenged?
D02	27	16	11	1853.53	47.02	Yes
D03	27	94	85	1853.53	1551.15	No
D05	27	50	37	1853.53	651.89	No
D08	27	51	47	1853.53	1130.46	No
D09	27	45	35	1853.53	888.76	No
D10_09	27	41	37	1853.53	252.82	Yes

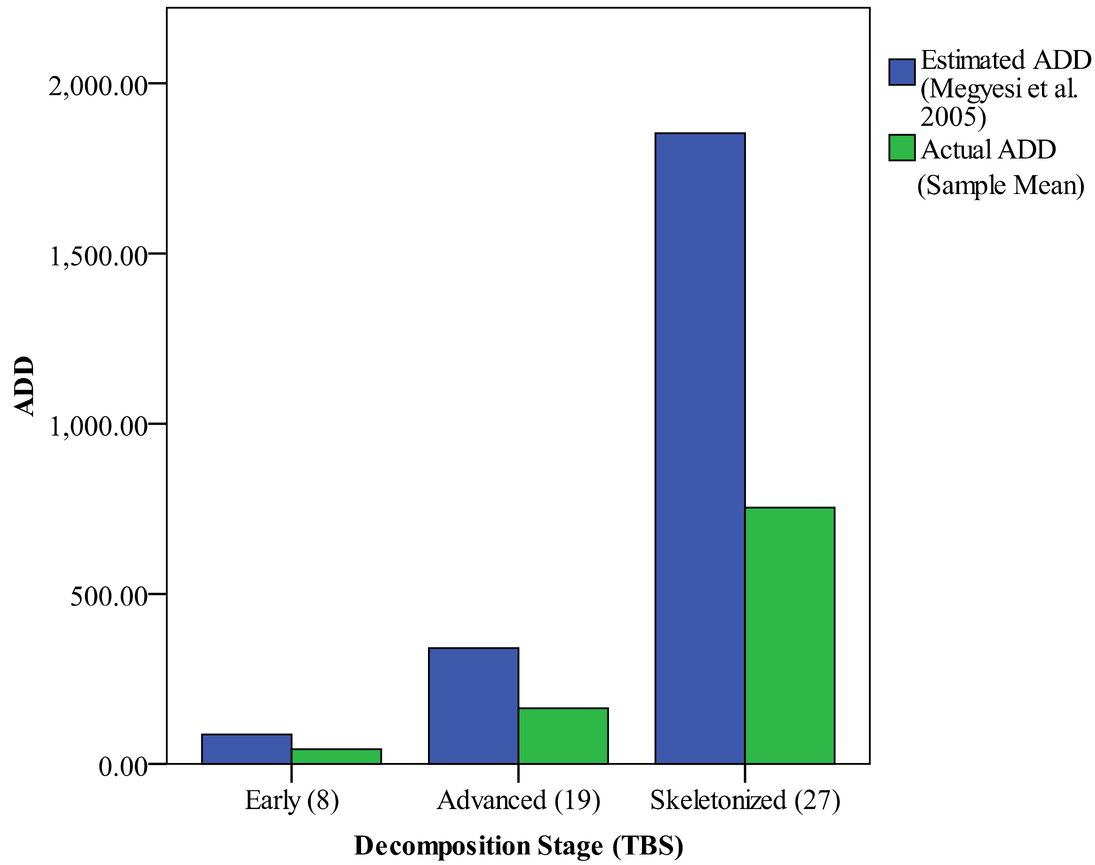

Figure 5. Estimated ADD compared with Actual ADD

<u>The Influence of Scavengers when Using ADD to Estimate PMI</u>

The mean ADD in this sample to reach each major decomposition category (Fresh, Advanced, and Skeletonization) was significantly different from the mean ADD for scavenged remains (p = 0.005; p = 0.041; p = 0.037). The mean ADD for exposed bodies was much lower than the caged donations. If ADD is used as a proxy for time, it can be inferred that scavenging has a significant influence on the acceleration of decomposition. Scavengers were quantitatively shown to have an influence on the ADD needed to reach a decomposition stage. However, this influence could not fully explain the differences seen in ADD from estimated ADD as demonstrated in other t-tests.

The species of avian scavengers seen on photos, from a wildlife camera used in another research study with two of the scavenged bodies, associated with the remains were the American black vulture (*Coragyps atratus*), turkey vulture (*Cathartes aura*), red-tailed hawk (*Buteo jamaicensis*), and Crested Caracara (*Caracara plancus*).

Using Total Body Score to Estimate Accumulated Degree-Days

The number of successes and failures for the actual ADD to fall within the standard error provided by the ADD via TBS equation for each decomposition score is shown in Table 8. Every TBS score of 21 and under (encompassing early and advanced decomposition) was 100% successful in falling within the estimated ADD range. With scores of 22 and up (advanced decomposition to skeletonization), the majority of actual recorded ADD fell outside of the standard error, with the exception of score 23. For TBS 25, 26, 29, and 30, there was 100% failure for the actual ADD to fall within the standard error. All of the actual ADD that fell outside the standard error were below the expected ADD.

For scores that showed a combination of successes and failures (TBS 22, 23, 24, 27, and 28), the results of binomial exact tests can be seen in Table 9. When seeking a 50% level of probability of success, the differences between the performance of the equation in predicting ADD for this sample and the actual ADD were not significant. However, when increased to a 75% success rate, the differences were significant from the expected probability of success. The exception was TBS 23, where the probability of success 89.5% was not significantly different from 75% (p = 0.1888) or 90% (p = 1). All successes for TBS 23 were observed on donation D03-2010.

Table 8. Counts of Success and Failures for a TBS score to Predict the Actual ADD from the Equation within the Standard Error

TBS	ADD Estimate and Standard Error	Success	Failure
3	67.3; -321.16 to 455.46	1	0
4	69.50; -318.66 to 457.662	2	0
5	72.44; -315.72 to 460.6	3	0
6	76.21; -311.95 to 464.37	N/A	N/A
7	80.91; -307.25 to 469.07	2	0
8	86.70; -301.46 to 474.86	10	0
9	93.76; -294.4 to 481.92	15	0
10	102.33; -285.83 to 490.49	4	0
11	112.72; -275.44 to 500.88	5	0
12	125.31; -262.85 to 513.47	7	0
13	140.61; -247.56 to 528.77	7	0
14	159.22; -232.94 to 543.38	1	0
15	181.97; -206.19 to 570.13	6	0
16	209.89; -178.3 to 598.05	2	0
17	244.34; -143.82 to 632.5	3	0
18	287.08; -101.08 to 675.24	1	0
19	340.41; -47.75 to 728.57	10	0
20	407.38; 19.22 to 795.54	15	0
21	492.04; 103.88 to 880.2	5	0
22	599.79; 211.63 to 987.95	2	4
23	737.9;349.74 to 1126.06	17	2
24	916.22; 528.06 to 1304.38	2	6
25	1148.15; 759.99 to 1536.31	0	8
26	1452.11; 1063.95 to 1840.27	0	9
27	1853.53; 1465.37 to 2241.69	6	10
28	2387.81; 1999.65 to 2775.97	3	8
29	3104.56; 2716.4 to 3492.72	0	6
30	4073.81; 3685.65 to 4461.97	0	5
31-35	Scores never recorded during observation	N/A	N/A

Table 9. Probability results testing the success rate of the equation to predict ADD against an expected success rate

TBS	Expected Probability of Success	Probability of Success	P-Value
22	.5	0.3333333	0.6875
23	.5	0.8947368	0.0007286
24	.5	0.25	0.2891
27	.5	0.375	0.4545
28	.5	0.2727273	0.2266
22	.75	0.3333333	0.0376
23	.75	0.8947368	0.1888
24	.75	0.25	0.004227
27	.75	0.375	0.001644
28	.75	0.2727273	0.001188
22	.9	0.3333333	0.00127
23	.9	0.8947368	1
24	.9	0.25	<0.000000
27	.9	0.375	<0.000000
28	.9	0.2727273	<0.000000

VI. DISCUSSION

The purpose of this study was to test the method of estimating ADD from numerically scored decomposition on a TBS scale for purposes of estimating the PMI (Megyesi et al. 2005), in addition to observing the sequence of decomposition to confirm anecdotal evidence and generalizations about decomposition from previous studies. Examining the decomposition process directly in a longitudinal manner tested the assumption that all of the stages and decomposition characteristics used by Megyesi et al. (2005) follow a sequential order, an assumption that contradicts the Galloway's (1997) assertion that only the general decomposition stages entail a sequence. The variable of scavenging was introduced as well, in order to account for how access to scavengers affected the estimation of ADD from TBS, something previous decomposition studies using ADD have not yet addressed (Simmons et al. 2010a).

Decomposition and Total Body Score

The first objective of this study was to monitor donated individuals according to the decomposition scoring method developed by Megyesi et al. (2005) based on Galloway's (1997) arid environment decomposition stages. The observations of this study support the general decomposition stages found in high temperature and high humidity environments (Galloway et al. 1989; Galloway 1997) with high rates of maggot activity when scavengers are controlled for, accelerated autolysis, and rapid rates of decomposition. Observations confirm previous reports of extensive maggot activity in taphonomic studies conducted in this area (Hyder 2007; Ayers 2010). Bloating seemed variable, with some cases demonstrating only slight bloating (D10-2009) and others with bloating of the whole body including the limbs (D05-2010, D07-2010, D10-2010). Decomposition in Texas can happen extremely rapidly, with bone exposure occurring within 4 days in one case (D10-2010) without the variable of scavenging. With scavenging, bone exposure to the point of skeletonization can occur within 24 hours.

However, there is too much variation to conclusively say with this sample that the secondary characteristics described by Galloway (1997) involving general appearance, color, and mummification are sequential. More research with larger sample sizes, studied in a longitudinal manner with quantification may reveal continuous characteristics of decomposition, but the current study shows that not all of these characteristics are linear in appearance and that TBS can lower. A previous study (Figure 11 in Cross and Simmons 2010) also shows lowered TBS when more time has passed, although the temporarily lowered TBS is not addressed nor explained.

For color, black generally followed brown tissue which followed fresh pink-white tissue. This sequence of color changes may not be applicable to individuals with different skin colors, as 9 out of 10 of the donated individuals were of white ancestry. Green discoloration would not always appear, or appear at the same time as black and brown coloration. Defining when tissue made the transition from brown to black was also difficult when using the Megyesi et al. (2005) decomposition descriptions. Various colors could also appear on the same segment of the body.

Bodies mummified according to descriptions provided by Galloway (1997), in which the skin is dehydrated, becomes hard and leathery and forms a thick shell over the body that may or may not protect moist and decomposing tissue underneath. However, rehydration of this mummified tissue was observed in at least two donations and moist decomposition resumed, supporting previous research that indicates this possibility (Ayers 2010; Godde 2011). Under the Megyesi et al. (2005) system, mummification is given a higher numerical score than moist decomposition. Thus, although more time had passed and more decomposition was attained with this reversal, moist decomposition showed a lower TBS score and PMI estimations could be affected. Because mummification can "revert" to moist decomposition on the TBS scale, the current system is not appropriate for desiccated remains that may be rehydrated. The precise length of time and conditions of tissue desiccation to achieve long-term cessation of decay is not currently known (Aufderheide 2003).

A distinction between this kind of dehydration from "true" mummification where all tissue decomposition has ceased might be possible in a revised TBS scale. Unfortunately, this difference, however it is defined, might not be visible from crime scene photography or even in person. The desiccation of D05-2010 and D07-2010, where outer layers of tissue were "mummified" but moist tissue remained underneath, was not understood until the remains were removed for processing and this observer was surprised to find soft tissue and extensive maggot activity. TBS was developed to be a visual means of recording decomposition, and the original study (Megyesi et al. 2005) used crime scene photography. Photography cannot convey touch, odor, moisture or other characteristics that might possibly influence an observer's recording of TBS.

Megyesi et al. (2005) also state that ranking mummification was altered in their scale to reflect the process as it occurs in non arid climates of the United States. This suggests that using the TBS decomposition scale is not appropriate in arid regions, and this observer does not recommend the use of this ranked scale in subtropical climates with periodic drought similar to the climate of Central Texas. If the total body score system (TBS) continues to be used in studies, researchers should be aware of the variables that may confound the use of ADD, TBS, and decomposition stage to estimate time since death.

Gaps exist in the timeline of observations for each donation and certain observations were gathered at different times. Automated photography could have possibly prevented these gaps, however a photograph can only produce a superficial visual representation of decomposition. While there are gaps in the timeline, it is felt that the observations gathered have significant value and the results contribute to the literature on decomposition.

The experience of the observer assigning a TBS may also play a role in observing a sequence of characteristics, with more experienced forensic anthropologists able to produce more linear results. If experience plays a significant role in accurately recording TBS, then such an issue must be examined. Decomposition stages are generally considered to be subjective (Galloway 1997), but the Megyesi et al. (2005) system considers decomposition stage to be a quasi-continuous objective variable. Future research is needed to test for interobserver error when recording decomposition stages with the TBS system.

The Influence of Scavengers on Decomposition

Mean ADD for the exposed human cadavers in this sample to reach each major decomposition category (Fresh, Advanced, and Skeletonized) was significantly different from the mean ADD of bodies placed under cages to restrict the access of scavengers. PMI and ADD for a body to become skeletonized was significantly shortened when the body was exposed to scavengers. Scavenging has a significant influence on the acceleration of decomposition in this sample, quantitatively supporting previous research on the taphonomic influences of vertebrate animals (Haglund et al. 1989; Willey and Snyder 1989; Haglund 1997; Reeves 2009) and the efficiency of vulture scavengers (McKinnerney 1978; Houston 1986; Reeves 2009).

The significant influence of vertebrate scavengers on the decomposition rate in this sample shows that decomposition studies need to consider the scavenging species in the natural setting in which human bodies may be found (Haglund et al. 1989; Mann et al. 1990; Reeves 2009). The variables of the body are not the only variables to consider, but rather the larger environment and the other species within that environment need consideration as well.

Simmons et al. (2010a; 2010b) state that insects alone accelerate decomposition, but also note that scavenging was not taken into account for these studies (Simmons et al. 2010a). The current study demonstrates that scavenging also significantly accelerates decomposition and insect access is not the only variable in decomposition to consider. In addition, while insect activity is intense in the absence of scavengers in this area (Galloway et al. 1989; Hyder 2007; Ayers 2010), limited access to scavengers may not be common depending on the environment a body is deposited in. In one study on the carrion communities in the Chihuahuan desert, less than 30% of the small carrion observed were sufficiently protected enough to develop insect activity and not be consumed by vertebrate scavengers (McKinnerney 1978). Willey and Snyder (1989) reported that 77.8% of the forensic skeletal collection at the University of Tennessee at the time of publication showed evidence of scavenging. Additionally, as avian species continue to grow in population and humans encroach on natural habitat, contact of avian scavengers with human bodies of a forensic interest will likely increase (Reeves 2009).

During the course of the study, it was difficult to prevent access to a body from vertebrate scavengers. Smaller fencing on the cages eventually prevented access. Damage to caged donations was small, with the pulling of limbs out of cages and beak holes found in the feet or hands to be the most common form of postmortem damage (see notes in Appendix A). This damage was considered small enough to still allow for ADD comparison, but the difficulty of preventing access is noted. This difficulty calls into question how practicable it is for taphonomic studies to control for scavengers. If Central Texas and similar environments are prone to high populations of scavenging animals, such as canids and avian species, the influence of scavengers on decomposition rates must be considered a significant issue. The most significant decomposers, be it insects or vertebrate scavengers, will depend on the environment.

Scavenging is common among vertebrate species and exists as an essential ecological process (Selva et al. 2005). Vertebrate animal scavenging is one of the most significant causes of postmortem trauma in outdoor environments (Asamura et al. 2004; Reeves 2009) and can significantly alter the estimation of the PMI. For accurate estimations of the PMI, naturally occurring variables such as scavenging should be included in taphonomic experiments (Willey and Snyder 1989).

The Use of Total Body Score to Predict Accumulated Degree-Days

Preliminary independent samples t-tests revealed significant differences between the mean ADD to reach a major decomposition stage in this study from the estimated ADD produced by the ADD estimation equation developed by Megyesi et al. (2005). Because ADD is used to measure time since death with this method, a significant difference in ADD would influence the estimation of the PMI. Scavengers were thought to have likely influenced these differences, and so another set of t-tests were performed with scavenged donations removed from the sample. The differences were still significant, meaning it was not only the inclusion of scavenged remains that caused the differences. This finding suggested that the equation itself might not have been effectively estimating ADD in this environment. Further examination of the equation for ADD estimation was required.

To more thoroughly examine the utility of this method, exact binomial probability tests were conducted on the probability of success for the equation to predict ADD from decomposition score. These statistical tests had the advantage of including the entire standard error into analysis, as opposed to the means with the preliminary t-tests. Estimating ADD from TBS both over performed and underperformed when using Megyesi et al.'s (2005) equation. While accuracy was at a 100% success rate for scores under 22, the method could not differentiate between stages of decomposition. The standard error provided with the Megyesi et al. (2005) equation is relatively large at

388.16, and made even larger if the suggestion of the authors to double the error is followed (Megyesi et al. 2005). With 388.16 ADD, TBS scores of up to 19 are possible and up to TBS of 23 with 776.32 ADD, which encompasses early and advanced decomposition. A standard error of several hundred means that a wide range of TBS scores are possible for specified ADD. Inversely, for a given TBS score a wide range of ADD is possible.

For example, a TBS of 23 (advanced decomposition with some bone exposure nearing skeletonization) has a point estimate of 737.9 ADD. The standard error creates a range of 349.74 to 1126.06 ADD, which translates to roughly 22.42 to 72.18 days of 60°F (15.6°C) weather as the PMI. When that standard error is doubled and input into a 95% prediction interval equation provided by Megyesi et al. (2005), the standard error becomes +/-787.71 and the range of ADD is now -49.81 to 1525.61 ADD, or 0 to 97.8 days at an average of 60°F (15.6°C) weather. Essentially, the equation cannot provide a precise enough estimation of the PMI to tell the practitioner if a nearly skeletonized body in advanced decomposition has been outdoors for only a few hours or over 3 months. In a cold climate region this interval would be extended, where the method would provide a PMI of 0 to 1040.2 days at an average temperature of 40°F (4.4°C).

The article by Megyesi et al. (2005) states that the goal of this method was to produce a more precise and accurate estimate of the PMI from decomposition. Ousley (1995) makes an important distinction between accuracy and precision in his evaluation on how forensic anthropologists estimate stature. Accuracy is the ability of a method to produce a correct estimation, whereas precision is the ability of a method to repeat or reproduce a result (Ousley 1995). When evaluating this method of estimating the PMI from decomposition, this distinction can explain the 100% accuracy results of early and advanced decomposition scores to estimate ADD. A fresh body (TBS 3) and one in advanced decomposition (TBS 23) can potentially have the same ADD within the 95% confidence interval. Both are possible in a natural setting and the equation may be correct in its estimation. The method, however, lacks precision. The equation produced for calculating the PMI (Megyesi et al. 2005) is not appropriate for precise estimations of ADD in a real world setting.

When determining ADD from late advanced decomposition to skeletonized remains, the method was not very successful, with prediction rates of 33%, 25%, 37.5%, and 27% depending on decomposition stage. Because of these low success rates, the equation provided (Megyesi et al. 2005) is not recommended for use on severely decomposed or skeletonized remains. Score 23 was successful with nearly a 90% accuracy rate, however all successes were recorded from one donation. This donation was D03-2010, an individual that was caged, placed in the shade, and naturally covered by growing vegetation for most of the body's exposure at the research facility. It has been suggested that bodies placed in the shade decompose slower due to a lowered ambient temperature (Shean et al. 1993) which could account for this donation decomposing at a rate similar to what Megyesi et al. (1995) recorded. However, four other donations (D05-2010, D07-2010, D08-2010, and D09-2010) were also placed in at least partially shaded areas.

With the unsuccessful TBS scores, (22-30, with the exception of 23), the method overestimated ADD to reach that score, meaning that decomposition in this region reached skeletonization with fewer ADD (i.e. faster) than in the original study sample.

Interestingly, it was recently reported that the Megyesi et al. (2005) equation underestimated ADD in a longitudinal study in New England (Sorg 2011). Simmons et al. (2010a) state that data comparison from many different environments and temperatures show no difference in decomposition progression when measured using TBS and ADD. These researchers advocate the used of ADD to standardize decomposition research. Current longitudinal studies, such as Sorg (2011) and this sample, do not support this assertion. Different environments may contain significant variables that the Megyesi et al. (2005) decomposition scoring system does not specifically address. And when one of those variables, scavenging, was controlled for, significant differences between the ADD in this study with the estimated ADD were still found.

Using ADD to estimate PMI itself has also been subject to critique, with Dabbs (2010) noting that not all weather data are reliable. When Dabbs (2010) compared the ADD of three relatively close weather stations, the author found significant differences between average daily temperatures. She suggested that care be taken when choosing weather stations to ensure that the station adequately reflects the environmental conditions surrounding a body at discovery (Dabbs 2010). In the current study, this problem was encountered when the choice between two temperature sensors was given. One sensor was 0.75 meters from the ground and the other was 1.5 meters from the ground. The 0.75 meter sensor was chosen in order to obtain readings closest to the ground where cadavers would be placed. There were also several data gaps caused by equipment failure and these gaps were filled from another station by Ray Kamps of Texas A&M University after performing linear regression against available data. The effects of these choices on the accuracy of ADD calculation are not known, and it is reasonable to assume that such choices and data gaps would be encountered in the application of the method on a forensic case.

The significantly low success rates for estimating ADD for very decomposed remains and the relatively large standard error for early and advanced stages of decomposition bring into doubt the utility of this method in a realistic forensic setting. The authors recognized the limitations of the original study (Megyesi et al. 2005; Nawrocki 2009) in that no observations were recorded for discovered remains between 80 and 130 postmortem days. This significant gap in data may have influenced the development of the equation for PMI estimation.

The relationship between TBS and ADD in this study was curvilinear, supporting previous research that found this same relationship (Rhine and Dawson 1998; Megyesi et al. 2005). Decomposition is highly variable, with multiple aspects of the environment potentially able to influence PMI estimations (Mann et al. 1990; Rhine and Dawson 1998). After skeletonization has been reached, little difference occurs in decomposition score between remains that have been exposed for a short time and for a long period of time (Rhine and Dawson 1998). Even with non-scavenged bodies placed under cages, the Megyesi et al. (2005) equation failed to sufficiently predict ADD from TBS after advanced decomposition and skeletonization was reached for some subjects. Scavenging significantly influenced rates of decomposition, but was not the sole cause of differences in ADD between this study and the equation (Megyesi et al. 2005) estimated ADD. The topic of whether or not it is possible to create a quantitative approach for precisely estimating the PMI from visual assessment of decomposition is open for debate. The longer a body is exposed, the less likely it is for an accurate estimation of the PMI to be produced (Marks et al. 2000). And as this study has demonstrated, the Megyesi et al. (2005) equation for predicting ADD from TBS is not appropriate for precise estimations.

VII. CONCLUSION

The estimation of the PMI is considered to be one of the most important components of death investigation (Knight 2002; Krompecher 2002; Love and Marks 2003; Geberth 2007). An accurate assessment of the PMI can assist with the determination of the identity of a victim or the perpetrator of the crime (Rodriguez and Bass 1983; Rhine and Dawson 1998; Knight 2002; Love and Marks 2003; Geberth 2007). This estimation is also considered difficult (Love and Marks 2003) and multivariate (Mann et al. 1990). Temperature has been considered to be the most important variable influencing decomposition (Mann et al. 1990; Love and Marks 2003) and it has been suggested that insects are the most significant environmental decomposers (Simmons et al. 2010b). Decomposition stages have been proposed for specific geographic regions including Tennessee (Mann et al. 1990; Vass et al. 1992; Love and Marks 2003), New Mexico (Rhine and Dawson 1998), Alberta (Komar 1998), and Arizona (Galloway 1997), but those studies emphasized that decomposition stages are region specific.

Recently, Megyesi et al. (2005) developed a quantitative method of estimating the PMI using accumulated degree-days (ADD) and a total body score (TBS), a form of numerically ranking qualitative observations of decomposition. This method was developed from cross-sectional data collected from crime scenes in several regions across the United States. Recently, this use of ADD to predict the PMI has gained popularity in taphonomic research focusing on decomposition (Adlam and Simmons 2007; Bachmann and Simmons 2010; Cross and Simmons 2010; Dabbs 2010; Simmons et al. 2010a; Simmons et al. 2010b).

The current study observed the decomposition of 10 donated human cadavers placed outside at a forensic anthropological research facility in Central Texas over a 9 month period. The purpose of this study was to test the method of estimating ADD from decomposition stage as ranked through TBS. Statistically significant differences were found between the estimation of ADD provided by the equation for ADD prediction (Megyesi et al. 2005) and the current study mean ADD for each major decomposition stage. Even when cadavers that were scavenged were removed from the analysis, the differences were still significant. The differences in ADD are not solely caused by exposure to scavenging activity, suggesting that the equation or the method itself is flawed.

With exact binomial tests, the rate of the equation produced by Megyesi et al. (2005) to successfully predict ADD was able to be compared against an expected success rate. The method over performed with 100% accuracy rates for decomposition scores less than 22. This revealed the method's lack of precision for early and advanced categories of decomposition, demonstrating that the equation is not appropriate for precise estimations of the PMI. Human cadavers also skeletonized much faster than what was estimated with the equation, and the low success rates for scores 22 and above make the equation not recommended for severely decomposed remains.

The observations of this study support the general decomposition stages found in high temperature and high humidity environments (Galloway et al. 1989; Galloway 1997) with high rates of maggot activity when scavengers cannot gain access to the body, accelerated autolysis, and rapid rates of decomposition. Secondary characteristics, however, did not always occur sequentially. If the total body score system (TBS) continues to be used in studies, researchers should be aware of variables that may confound the use of ADD and TBS to estimate the PMI. TBS is not perfectly linear, with changes in mummification able to influence the observer's recorded TBS. Desiccated tissues can rehydrate (Ayers 2010; Godde 2011) and the length of time and conditions to achieve long term mummification are not fully understood (Aufderheide 2003). Different colors could appear at the same time on the same section of the body, and some would not appear at all. Limbs were also observed to bloat on a few donations.

Previous studies (Galloway et al. 1989; Rhine and Dawson 1998; Megyesi et al. 2005) could not control for scavengers in a natural environment because of the use of cross-sectional data from police reports and forensic cases. Experimental studies (Simmons et al. 2010a) have not included scavenging as a variable nor tested the potential influence this factor may have on the decomposition rate and ADD. In this study, longitudinal data collection allowed for a comparison between scavenged and non-scavenged human bodies. Scavenged bodies had significantly lower ADD (i.e. faster rates) to reach major decomposition stages than protected cadavers. Simmons et al. (2010b) claimed that insects had the most significant influence on decomposition rate. However, this study shows in a quantitative manner that scavenging animals can have a significant impact on the estimation of the PMI from ADD. The decomposers that have the greatest impact on a decedent placed outdoors will depend on the environment. For a realistic understanding of decomposition rates, taphonomic research needs to consider local scavengers (Willey and Snyder 1989).

However, even with scavengers excluded from the sample significant differences between the mean ADD and the equation estimated ADD were found, and the equation still failed to successfully predict ADD on some non-scavenged cadavers. It has been suggested that, when decomposition is measured using ADD and TBS, PMI can be predicted regardless of environment (Simmons et al. 2010a). The results of this study show that different environments may contain significant variables that the Megyesi et al. (2005) decomposition scoring system did not specifically address. The significant differences in ADD found in this study support the assertion that decomposition progresses differently in different environments (Galloway et al. 1989; Willey and Snyder 1989; Mann et al. 1990; Galloway 1997; Komar 1998; Rhine and Dawson 1998; Love and Marks 2003). Furthermore, the low success rates for the Megyesi et al. (2005) equation to predict ADD from TBS above 22 and the wide standard error ranges provided with the equation demonstrate the need to reevaluate the use of this equation for PMI estimation from TBS.

APPENDIX A: DECOMPOSITION OBSERVATIONS

Donation: D10-2009
Date of Death: 11/16/2009
Date of placement: 11/19/2009

Date	Time	PMI Days	Head	Torso	Limbs	TBS
11/20/2009	8:10 am -10:35am	4	1	1	1	3
11/21/2009	11:18 am - 11:26 am	5	2	3	3	8
11/27/2009	5:16 pm - 5:33 pm	11	4	3	3	7
11/28/2009	4:06 pm - 4:446 pm	12	5	3	3	11
11/29/2009	6:01 pm - 6:05 pm	13	5	3	3	11
11/30/2009	6:11 pm - 6:16 pm	14	6	3	3	12
12/1/2009	5:53 pm - 5:58 pm	15	6	3	3	12
12/2/2009	2:11 pm - 2:16 pm	16	6	3	3	12
12/3/2009	5:50 pm - 5:54 pm	17	6	3	3	12
12/7/2009	6:11 pm - 6:16 pm	21	6	3	3	12
12/22/2009	4:57 pm - 5:03 pm	36	6	4	3	13
12/23/2009	6:03 pm - 6:09 pm	37	6	4	3	13
12/24/2009	5:03 pm - 5:05 pm	38	6	4	4	14
12/27/2009	2:50 pm - 2:56 pm	41	10	9	8	27
12/28/2009	5:27 pm - 5:33 pm	42	10	10	8	28
12/31/2009	5:28 pm - 5:34 pm	45	10	10	8	28
1/1/2010	6:42 pm - 6:49 pm	46	10	10	8	28
1/8/2010	5:55 pm - 6:00 pm	53	12	10	8	30
1/14/2010	7:52 am - 7:58 am	59	12	10	9	31
1/15/2010	4:17 pm - 4:21 pm	60	12	10	9	31

Date	Notes
11/27/2009	Marbling now obvious on torso and limbs.
11/28/2009	Bloating of the neck. Maggots have expanded nose and mouth.
11/29/2009	Rainfall.
11/30/2009	Face is becoming brown and discolored.
12/2/2009	Extensive skin slippage on the head. Darkening green and purple discoloration of the abdomen make stretch marks on the stomach visible.
12/22/2009	Skin slippage present on the limbs.
12/28/2009	Skin left over torso desiccating rapidly.

Donation: D02-2010
Date of death: 1/26/2010
Date of Placement: 1/31/2010

Date	Time	PMI Days	Head	Torso	Limbs	TBS
1/31/2010	2:42 pm - 2:48 pm	5	3	3	3	9
2/1/2010	6:29 pm - 6:33 pm	6	3	3	3	9
2/2/2010	5:37 pm - 5:47 pm	7	3	3	3	9
2/3/2010	3:23 am; 3:41 am	8	3	3	3	9
2/4/2010	3:27 pm - 3:32 pm	9	3	3	3	9
2/5/2010	5:42 pm - 5:33 pm	10	10	9	4	24
2/6/2010	5:23 pm - 5:34 pm	11	10	9	5	24
2/7/2010	5:57 pm - 6:03 pm	12	10	9	5	24
2/8/2010	4:53 pm - 5:00 pm	13	10	9	5	24
2/9/2010	5:25 pm - 5:39 pm	14	10	10	4	24
2/10/2010	10:16 am - 10:21 am	15	10	10	4	24
2/11/2010	3:51 pm - 3:57 pm	16	10	9	8	27
2/12/2010	5:53 pm - 6:02 pm	17	10	9	8	27
2/13/2010	3:57 pm - 4:03 pm	18	10	9	8	27
2/14/2010	5:45 pm - 5:48 pm	19	11	9	8	28
2/15/2010	5:04 pm - 5:08 pm	20	11	9	8	28
2/16/2010	6:12 pm - 6:15 pm	21	12	9	8	28
2/18/2010	4:55 pm - 4:59 pm	23	12	9	8	28
2/25/2010	4:57 pm - 5:01 pm	30	12	9	8	28
3/5/2010	4:49 pm - 4:57 pm	38	12	10	8	30
3/11/2010	2:12 pm - 2:19 pm	44	12	10	8	30
3/19/2010	4:48 pm - 4:51 pm	52	12	10	8	30
3/26/2010	4:45 pm - 4:48 pm	59	12	10	8	30

Date	Notes
1/31/2010	Autopsied individual.
2/7/2010	Skin becoming leathery, but pink areas still present on feet.
2/8/2010	Flesh on right calf gone, flesh still present on left calf. Skin brown/yellow, with the exception of pink areas on the feet and left calf.
2/9/2010	Skin of torso drying. Relatively fresh flesh exposed by scavengers on right foot.
2/11/2010	Flesh entirely removed from left calf. Some remains on feet and hands, but otherwise there only skin remains on the limbs. Rain and rehydration restart moist decomposition.
2/12/2010	Blood still visible on pelvis.
2/14/2010	Torso greasy. Skin on limbs desiccating and largely brown/black.
3/5/2010	Green discoloration on right kneecap.

Donation: D03-2010
Date of death: 3/2/2010
Date of placement: 3/11/2010, 12:00 pm

Date	Time	PMI Days	Head	Torso	Limbs	TBS
3/11/2010	2:05 pm - 2:06 pm	9	2	1	2	5
3/13/2010	3:54 pm - 3:58 pm	11	2	1	2	5
3/14/2010	4:01 pm - 4:04 pm	12	4	2	2	8
3/15/2010	4:04 pm - 4:08 pm	13	4	2	2	8
3/16/2010	4:52 pm - 4:54 pm	14	4	2	2	8
3/18/2010	10:56 am - 11:00 am	16	4	2	2	8
3/19/2010	4:53 pm - 4:59 pm	17	4	2	3	9
3/20/2010	3:49 pm - 3:52 pm	18	4	2	3	9
3/21/2010	3:15 pm - 3:18 pm	19	4	2	3	9
3/22/2010	5:05 pm - 5:08 pm	20	4	2	3	9
3/23/2010	5:00 pm - 5:03 pm	21	4	2	3	9
3/26/2010	4:50 pm - 4:54 pm	24	4	2	3	9
3/27/2010	5:16 pm - 5:22 pm	25	4	2	3	9
3/29/2010	4:13 pm - 4:17 pm	27	4	2	3	9
4/1/2010	1:58 pm - 2:00 pm	30	6	3	3	12
4/2/2010	3:33 pm - 3:35 pm	31	6	3	4	13
4/3/2010	5:10 pm - 5:12 pm	32	6	3	4	13
4/6/2010	5:34 pm - 5:37 pm	35	8	3	4	15
4/7/2010	4:25 pm - 4:27 pm	36	8	3	4	15
4/8/2010	5:50 pm - 5:50 pm	37	8	3	4	15
4/9/2010	2:45 pm - 2:47 pm	38	8	3	4	15
4/10/2010	3:57 pm - 3:59 pm	39	8	3	4	15
4/11/2010	3:51 pm - 3:54 pm	40	8	3	4	15
4/12/2010	4:05 pm - 4:07 pm	41	8	3	4	15
4/16/2010	5:22 pm - 5:24 pm	45	10	6	7	23
4/19/2010	4:58 pm - 4:59 pm	48	10	6	7	23
4/23/2010	4:50 pm - 4:51 pm	52	10	6	7	23
4/29/2010	4:48 pm - 4:51 pm	58	10	6	7	23
5/2/2010	4:44 pm - 4:45 pm	61	10	6	7	23
5/18/2010	6:00 pm - 6:02 pm	77	10	7	7	24
6/4/2010	10:59 am - 11:03 am	94	11	8	8	27
6/10/2010	2:39 pm - 2:41 pm	100	11	8	8	27
6/17/2010	12:10 pm - 12:13 pm	107	11	8	8	27
6/25/2010	6:25 pm - 6:26 pm	115	11	8	8	27
6/27/2010	4:42 pm - 4:44 pm	117	11	8	8	27
6/30/2010	2:14 pm - 2:17 pm	120	11	9	8	28
7/1/2010	6:07 pm - 6:10 pm	121	11	9	8	28

7/6/2010	6:43 pm - 6:44 pm	126	11	9	8	28
7/13/2010	4:59 pm - 4:59 pm	133	11	10	8	29

Date	**Notes**
3/11/2010	Feeding tube removed from chest, creating an open wound.
3/19/2010	Maggot larva filling nose
3/20/2010	Maggots hatched
3/22/2010	Maggots filling nose again and in wound of chest
3/23/2010	Hands and feet now covered to try to ease bone recovery.
3/26/2010	Lips and edges of wound in chest now black. More distinct brown discoloration of the face
3/27/2010	Flies present.
3/29/2010	Discoloration around wound spreading.
4/1/2010	Gray/green discoloration around wound. Insect feeding on skin of torso. Skin black and slippage around genitals. Maggot activity on face.
4/6/2010	Extensive maggot activity on face. Bone exposure of the mandible. Blackened skin. Arms are brown. Brown and black areas on the torso with relatively fresh looking skin present. Wound in chest now creates a depression when viewing the body from the side. Limbs scored as 4 and 5 averaged.
4/9/2010	Large mass of maggots on chest wound as well as face now. Skin of chest becoming leathery to the touch.
4/10/2010	Maggots still present on chest, but most have hatches. Vultures rip off end of bootie on one foot.
4/11/2010	Torso very brown.
4/16/2010	Flesh has a mottled appearance with the skin appearing beige, brown, red, bright yellow, and gray fleshy colored. Right hand is scavenged. Scoring proved very difficult for the torso based on color and the lack of a bloat stage. Limbs given an average score from 6 and 8.
4/19/2010	Skin returns to black and brown coloration. Lower torso and limbs retain a mottled appearance. Mold/fungus possibly. Maggots in chest cavity again. Lower torso has a swollen appearance. Torso given an average score from 4, 6, and 8 to account for the swollen appearance, leathery chest, and sagging of flesh. Right hand no longer visible, possibly missing (<-- definitely missing when bones recovered).
4/23/2010	Chest bubbling. Torso bloating. Given an average score of 4 and 8 (6).
4/29/2010	Torso caving in.
5/2/2010	Torso completely collapsed. Skin greasy and leathery.
6/4/2010	Arm bones covered in green moss/fungus. Skin mostly leathery. Skull mostly dry but with desiccated tissue still present (ear, hair, some skin). No flesh still visibly present other than skin
6/30/2010	Rain makes skin wet and greasy. Larva in rain collected on chest. Skin pulling apart over torso, exposing vertebral body beneath.

Donation: D04-2010
Date of Death: 3/15/2010 (4 a.m.)
Date of Placement: 3/15/2010

Date	Time	PMI Days	Head	Torso	Limbs	TBS
3/15/2010	4:09 pm - 4:12 pm	1	1	2	1	4
3/16/2010	4:57 pm - 5:04 pm	2	10	5	4	19
3/18/2010	11:01 am - 11:07 am	4	10	5	5	20
3/19/2010	5:01 pm - 5:08 pm	5	11	5.5	5.5	22
3/20/2010	3:52 pm - 3:57 pm	6	11	6	5	22
3/21/2010	3:20 pm - 3:26 pm	7	11	6	5	22
3/22/2010	5:10 pm - 5:16 pm	8	11	8.5	5.5	25
3/23/2010	5:04 pm - 5:07 pm	9	11	8	7	26
3/26/2010	4:55 pm - 5:00 pm	12	11	8	6	25
3/27/2010	5:23 pm - 5:31 pm	13	11	10	8	29
3/29/2010	4:18 pm - 4:23 pm	15	11	10	8	29

Date	Notes
3/16/2010	2;8 for torso. 2;6 for limbs. Vulture scavenging. Internal organs removed. Skull skeletonized. Limbs have beak holes and muscle/tissue have been removed from the arms and legs. Feet remain fresh. Skin is pink and white and relatively fresh.
3/18/2010	2;8 for torso. 4;6 for limbs. Vultures damage limbs, remove tissue.
3/19/2010	2;8 for torso. Brown discoloration and drying of skin.
3/20/2010	3;9 for torso. Green discoloration appears on torso and feet.
3/21/2010	Extremely varied coloration continues from the day before. Presence of pinkish white, green, and brown/black on the same areas. Ranking according to the decomposition scale is difficult.
3/22/2010	Drying out of torso. Color variation remains, however the dried feel of the skin lends to the classification of mummifying skin.
3/23/2010	Desiccation of skin on limbs.
3/26/2010	Mummified skin, moist decomposition with maggot activity inside limbs. Evidence of more vulture scavenging.
3/27/2010	Body moved by scavengers. Bones exposed from mummified skin.
3/29/2010	Some bone scatter. Remains moved to burial.

Donation: D05-2010
Date of Death: 3/08/2010
Date of placement: 3/19/2010, 7:30 pm

Date	Time	PMI Days	Head	Torso	Limbs	TBS
3/22/2010	5:19 pm - 5:23 pm	14	2	2	3	7
3/26/2010	5:03 pm - 5:09 pm	18	4	3	5	11
3/27/2010	5:33 pm - 5:37 pm	19	4	3	5	11
3/29/2010	4:25 pm - 4:32 pm	21	4	3	5	12
4/1/2010	1:32 pm - 1:33 pm	22	6	4	6	16
4/2/2010	3:27 pm - 3:28 pm	23	8	5	6	19
4/3/2010	5:16 pm - 5:18 pm	24	8	5	6	19
4/6/2010	5:40 pm - 5:44 pm	27	8	6	6	20
4/7/2010	4:31 pm - 4:33 pm	28	8	6	6	20
4/8/2010	5:57 pm - 5:58 pm	29	8	6	6	20
4/9/2010	2:50 pm - 2:51 pm	30	8	6	6	20
4/10/2010	4:02 pm - 4:06 pm	31	8	6	6	20
4/11/2010	3:59 pm - 4:02 pm	32	9	6	7	22
4/12/2010	4:11 pm - 4:13 pm	33	9	6	7	21
4/16/2010	5:29 pm - 5:32 pm	37	8	7	6	21
4/19/2010	5:02 pm - 5:04 pm	40	11	7	7	25
4/23/2010	4:56 pm - 4:58 pm	44	11	7	7	25
4/29/2010	4:55 pm - 4:58 pm	50	11	8	8	27
5/2/2010	4:46 pm - 4:50 pm	53	11	8	8	27
5/18/2010	6:10 pm - 6:12 pm	69	11	8	8	27

Date	Notes
3/22/2010	Autopsied. Marbling visible. Signs of insect feeding on skin. Lividity. Fingertips black and desiccated.
3/26/2010	Arms fed on by vultures. Mold first appears on limbs.
3/27/2010	Limbs dry out.
4/1/2010	Maggot masses first appear. Green, bloating legs. Black, brown arms.
4/2/2010	Large amounts of skin slippage with maggots under the epidermis.
4/3/2010	Skin turning black on all areas of the body.
4/10/2010	Mandible exposed.
4/12/2010	Legs no longer green.
4/16/2010	After rain, skin has a pale green and white appearance. Bone exposure on the torso
4/19/2010	Skin brown and leathery again. Skull more exposed with skin mummified. Skin on back of torso begins to have a papery appearance.
4/23/2010	Calves collapsed and no longer bloated.
5/18/2010	Ribs visible through skin. No major visible categorical changes.

Donation: D07-2010
Date of Death: 3/29/2010
Date of Placement: 4/1/2010 1:00 p.m.

Date	Time	PMI Days	Head	Torso	Limbs	TBS
4/2/2010	3:29 pm	3	4	2	2	8
4/3/2010	5:18 pm -5:20 pm	4	4	2	2	8
4/6/2010	5:44 pm - 5:46 pm	7	6	3	4	13
4/7/2010	4:34 pm - 4:36 pm	8	10	5	4	19
4/8/2010	5:54 pm - 5:56 pm	9	10	5	4	19
4/9/2010	2:52 pm - 2:54 pm	10	10	5	4	19
4/10/2010	4:06 pm - 4:09 pm	11	10	5	4	19
4/11/2010	4:02 pm - 4:06 pm	12	10	6	5	21
4/12/2010	4:14 pm - 4:16 pm	13	10	6	6	22
4/16/2010	5:33 pm - 5:36 pm	17	10	6	4	20
4/19/2010	5:04 pm - 5:05 pm	20	10	7	6	23
4/23/2010	4:58 pm - 5:00 pm	24	12	7	7	26
4/29/2010	4:59 pm - 5:01 pm	30	12	7	7	26
5/2/2010	4:51 pm	33	12	7	7	26
5/18/2010	6:13 pm	49	12	8	8	28

Date	Notes
4/2/2010	Autopsied. Evidence of insect feeding on skin of limbs, marbling.
4/3/2010	More insect feeding on the skin of limbs and torso.
4/6/2010	Immense maggot activity around head and shoulders.
4/7/2010	Intense maggot activity on torso and underneath skin. Face skeletonized. Vultures snipped holes in feet.
4/9/2010	Flesh colored skin still appears on feet, but the rest of the limbs are becoming brown and leathery.
4/11/2010	Sagging and caving in of flesh.
4/16/2010	Pale coloration of decomposing tissue. Possible adipocere formation. Skull more exposed. Vultures dragged arms out of cage.
4/19/2010	Shrinking and drying out of tissue.
4/23/2010	Arms completely skeletonized and greasy. Legs brown and leathery.
4/29/2010	Mummifying skin over torso, inside still wet.
5/18/2010	7;9 for limbs.

Donation: D08-2010
Date of Death: 4/27/2010
Date of Placement: 4/30/2010

Date	Time	PMI Days	Head	Torso	Limbs	TBS
5/2/2010	4:38 pm - 4:30 pm	5	5	3	2	10
5/18/2010	6:17 pm - 6:18 pm	21	11	7	6	24
6/10/2010	2:04 pm - 2:15 pm	44	11	9	6	26
6/17/2010	12:22 pm - 12:29 pm	51	11	10	6	27
6/23/2010	6:19 pm - 6:20 pm	57	11	10	6	27
6/25/2010	5:56 pm - 6:06 pm	59	11	10	7	28
6/27/2010	4:16 pm - 4:19 pm	61	11	10	7	28
6/30/2010	1:55 pm - 1:56 pm	64	11	10	6	27
7/1/2010	5:39 pm - 5:42 pm	65	11	9	6	26
7/6/2010	6:19 pm - 6:20 pm	70	11	10	7	28
7/13/2010	4:33 pm - 4:35 pm	77	11	10	7	28
7/16/2010	12:41 pm	80	11	10	7	28
7/26/2010	4:47 pm	90	11	10	7	28

Date	Notes
5/2/2010	Abscessed scrotum. Abscess in mouth. Flies present.
5/18/2010	Bone exposure of eye orbits and maxilla. Bone exposure of pelvis. Bone exposure of left arm.
6/30/2010	Skin moist again. Beetle larvae on legs.
7/1/2010	Skin over torso decomposes and is now gone.
7/6/2010	Skin is dry and papery again.

Donation: D09-2010
Date of Death: 5/17/2010
Date of Placement: 5/27/2010, 9:05 a.m.

Date	Time	PMI Days	Head	Torso	Limbs	TBS
6/2/2010	7:21 am - 7:25 am	16	8	6	6	20
6/4/2010	11:08 am - 11:14 am	18	8	6	6	20
6/10/2010	2:19 pm - 2:32 pm	24	10	9	6	25
6/17/2010	12:16 pm - 12:20 pm	31	10	9	6	25
6/20/2010	12:24 pm - 12:29 pm	34	10	9	6	25
6/21/2010	11:52 am - 11:53 am	35	10	9	6	25
6/23/2010	6:15 pm - 6:18 pm	37	10	9	7	26
6/25/2010	6:10 pm - 6:11 pm	39	10	9	7	26
6/27/2010	4:23 pm - 4:27 pm	41	10	9	7	26
6/30/2010	2:00 pm - 2:02 pm	44	10	9	7	26
7/1/2010	5:46 pm - 5:51 pm	45	10	9	8	27
7/6/2010	6:23 pm - 6:25 pm	50	11	10	8	29
7/13/2010	4:38 pm - 4:41 pm	57	11	11	8	30

Date	Notes
6/2/2010	Large maggot masses, to the point where scoring the torso is difficult because of the amount of maggots obscuring the view of the flesh.
6/10/2010	Arms dragged out of cage and away from body. Large amount of fungus growth on torso and limbs. Organs gone, with only wet skin over torso.
6/23/2010	6;8 for limbs. Skin lightening. Skin over feet disintegrating.
7/1/2010	Pale skin, rib exposure, possible adipocere formation.
7/6/2010	Drying out of tissue over torso. Papery texture.
7/13/2010	8;9 for limbs. Nearly complete skeletonization. Papery skin still present on limbs. Some hair still on back of skull. Decomposition fluid and tissue underneath torso.

Donation: D10-2010
Date of Death: 6/07/2010
Date of Placement: 6/14/2010

Date	Time	PMI Days	Head	Torso	Limbs	TBS
6/15/2010	4:06 pm - 4:18 pm	8	3.5	2	2.5	8
6/16/2010	2:00 pm - 2:18 pm	9	6	3	4	13
6/17/2010	11:44 am - 12:07 pm	10	8	4	4	16
6/18/2010	11:14 am - 11:34 am	11	8	4.5	4.5	17
6/19/2010	11:03 am - 11:45 am	12	8	4.5	4.5	17
6/20/2010	11:22 am - 12:15 pm	13	8	5	5	18
6/21/2010	11:57 am - 12:37 pm	14	8	6	5	19
6/22/2010	11:29 am - 11:43 am	15	9	6	5	20
6/23/2010	5:55 pm - 6:01 pm	16	9	6	5	20
6/25/2010	6:18 pm - 6:21 pm	18	9	6	7	22
6/27/2010	4:34 pm - 4:39 pm	20	9	6	6	21
6/30/2010	2:09 pm - 2:11 pm	23	9	6	6	21
7/1/2010	5:56 pm - 6:03 pm	24	8	6	6	20
7/6/2010	6:33 pm - 6:38 pm	29	10	7	7	24
7/13/2010	4:50 pm - 4:55 pm	36	12	9	8	29
7/19/2010	5:31 pm - 5:32 pm	42	12	9	8	29

Date	Notes
6/15/2010	3;4 for head. 2;3 for limbs.
6/17/2010	Limbs are bloated
6/18/2010	4;5 for torso. 4;5 for limbs. Legs are extremely bloated
6/22/2010	Torso and limbs all collapse post-bloat; Fungus forms on extremities
6/25/2010	Pink/red coloring still present on thighs; extremities turning pale
6/30/2010	More fungus appears on the torso and head. Dessication of tissue. More disintegration and bone exposure of limbs
7/6/2010	6;8 for limbs. pale; moist; significant bone exposure; vultures accessed feet
7/13/2010	Vultures accessed skull

Donation: D11-2010
Date of Death: 7/15/2010
Date of Placement: 7/16/2010

Date	Time	PMI Days	Head	Torso	Limbs	TBS
7/16/2010	12:36 pm - 12:41 pm	1	1	1	2	4
7/17/2010	4:56 pm - 4:58 pm	2	4	1	3	8
7/18/2010	3:55 pm - 3:58 pm	3	4	2	4	10
7/19/2010	5:24 pm - 5:28 pm	4	4	2	4	10
7/20/2010	5:05 pm - 5:09 pm	5	4	2	4	10
7/21/2010	4:37 pm - 4:41 pm	6	5	2	4	11
7/22/2010	5:06 pm - 5:13 pm	7	5	4	4	13
7/23/2010	5:06 pm - 5:14 pm	8	6	5	6	17
7/24/2010	4:58 pm - 5:03 pm	9	7	6	6	19
7/25/2010	4:51 pm - 5:06 pm	10	7	6	6	19
7/26/2010	4:47 pm - 4:56 pm	11	7	7	6	20

Date	Notes
7/16/2010	Donation first placed outside.
7/17/2010	Lips drying out. Ants present in oral cavity. Limbs marbling. Insect feeding apparent on cheeks, forehead, and limbs.
7/18/2010	Maggots present in esophagous (visible through oral cavity). Skin on head and limbs turning brown and dry. Marbling of the abdomen.
7/19/2010	Maggots hatched into flies. Continued drying and browning of extremities. Insect feeding and browning of areas on the upper torso.
7/20/2010	Skin slippage. Maggot activity under skin. Fluid in ear. Blackening of neck and fluid. Black areas on arms, but not yet leathery in appearance.
7/21/2010	Bloating of neck and face. Massive amounts of skin slippage on torso. Green discoloration on feet. Exposure of medical device.
7/22/2010	Skin turning to black on head and upper torso. Torso turning brown. Purging of decomposition fluid from neck. Skin slippage on legs. Feet still pale green. Arms turning black. Abdomen bloated. Openings on torso.
7/23/2010	Openings on legs. Small areas of bone exposure on arms and legs.
7/24/2010	Collapse of bloating of neck. Bone exposure on upper torso. Abdomen not sagging.
7/25/2010	Caving in of abdomen.
7/26/2010	Green discoloration of abdomen and legs.

APPENDIX B: ACCUMULATED DEGREE-DAY DATA

Donation: D10-2009

Date	MAX	MIN	ADD
11/20/2009	15.1	6.801	10.9505
11/21/2009	7.84	4.133	16.937
11/22/2009	16.12	0.798	25.396
11/23/2009	20.75	0	35.771
11/24/2009	17.64	7.75	48.466
11/25/2009	19.84	0	58.386
11/26/2009	18.67	0	67.721
11/27/2009	17.56	0	76.501
11/28/2009	19.45	4.28	88.366
11/29/2009	15.9	7.65	100.141
11/30/2009	9.64	3.867	106.895
12/1/2009	8.04	0.27464	111.052
12/2/2009	5.907	0	114.005
12/3/2009	4.14333	0	116.077
12/4/2009	0.82181	0	116.488
12/5/2009	5.34028	0	119.158
12/6/2009	7.79829	0	123.057
12/7/2009	7.34943	3.34929	128.407
12/8/2009	11.7739	2.92395	135.755
12/9/2009	5.58608	0	138.548
12/10/2009	4.01509	0	140.556
12/11/2009	4.50669	1.0067	143.313
12/12/2009	6.97539	2.22074	147.911
12/13/2009	16.2303	2.99341	157.523
12/14/2009	13.954	7.92653	168.463
12/15/2009	13.0242	0.93937	175.445
12/16/2009	4.0899	0	177.49
12/17/2009	6.77234	0	180.876
12/18/2009	15.85	0	188.801
12/19/2009	10.9403	0	194.271
12/20/2009	12.725	0	200.633
12/21/2009	15.3861	0	208.326
12/22/2009	17.2883	8.78149	221.361

Donation: D10-2009 continued

Date	MAX	MIN	ADD
12/23/2009	19.212	8.42882	235.182
12/24/2009	9.97844	0	240.171
12/25/2009	5.04104	0	242.692
12/26/2009	10.1174	0	247.75
12/27/2009	10.1387	0	252.82

Donation: D02-2010

Date	MAX	MIN	ADD
2/1/2010	3.67	0	1.86
2/2/2010	6.94	2.55	6.61
2/3/2010	6.16	3.23	11.31
2/4/2010	3.61	2.62	14.43
2/5/2010	13.74	0	21.3
2/6/2010	14.18	0	28.39
2/7/2010	6.04	1.14	31.98
2/8/2010	13.63	4.35	40.97
2/9/2010	8.81	0	45.38
2/10/2010	2.39	0	46.58
2/11/2010	0.87	0	47.02
2/12/2010	9.67	0	51.86
2/13/2010	13.34	0	58.52
2/14/2010	20.23	0	68.64
2/15/2010	12.43	0	74.86
2/16/2010	14.77	0	82.25
2/17/2010	17.6	0	91.05
2/18/2010	16.54	0	99.32
2/19/2010	11.45	6.15	108.12
2/20/2010	15.54	7.57	119.68
2/21/2010	23.86	8.58	135.9
2/22/2010	13.67	3.37	144.42
2/23/2010	3.31	0	146.08
2/24/2010	13.51	0	152.84
2/25/2010	17.07	0	161.38
2/26/2010	14.7	2.68	170.07
2/27/2010	18.92	0	179.53
2/28/2010	17.79	0	188.43
3/1/2010	14.4	1.63	196.45
3/2/2010	15.6	0.63	204.57
3/3/2010	19.52	0	214.33
3/4/2010	19.98	0	224.32
3/5/2010	15.41	3.65	233.78
3/6/2010	17.84	7.64	246.52
3/7/2010	14.2	10.38	259.26
3/8/2010	15.39	10.89	272.4
3/9/2010	25.41	5.65	287.93
3/10/2010	26.63	4.06	303.28
3/11/2010	24.19	0.25	315.5
3/12/2010	21.86	1.25	327.06
3/13/2010	25.57	0	339.85
3/14/2010	26.5	0.49	353.35
3/15/2010	20.56	5	366.13

Donation: D02-2010 continued

Date	MAX	MIN	ADD
3/16/2010	13.51	7.31	376.54
3/17/2010	22.16	4.25	389.75
3/18/2010	19.97	0.75	400.11
3/19/2010	22.67	3.28	413.09
3/20/2010	15.16	2.71	422.03
3/21/2010	16.66	0	430.97
3/22/2010	22.79	0	442.37
3/23/2010	23.71	0	454.23
3/24/2010	14.96	11.19	467.31
3/25/2010	20.68	6.07	480.69
3/26/2010	21.69	0	491.54

Donation: D03-2010

Date	**MAX**	**MIN**	**ADD**
3/11/2010	24.19	0.248	12.219
3/12/2010	21.86	1.25	23.774
3/13/2010	25.57	0	36.559
3/14/2010	26.5	0.487	50.0525
3/15/2010	20.56	5.004	62.8345
3/16/2010	13.51	7.31	73.2445
3/17/2010	22.16	4.253	86.451
3/18/2010	19.97	0.747	96.8095
3/19/2010	22.67	3.28	109.7845
3/20/2010	15.16	2.708	118.7185
3/21/2010	16.66	0	127.0485
3/22/2010	22.79	0	138.4435
3/23/2010	23.71	0	150.2985
3/24/2010	14.96	11.19	163.3735
3/25/2010	20.68	0	173.7135
3/26/2010	21.69	0	184.5585
3/27/2010	28.08	6.455	201.826
3/28/2010	22.36	3.665	214.8385
3/29/2010	23.93	0	226.8035
3/30/2010	25.61	4.417	241.817
3/31/2010	27.69	9.55	260.437
4/1/2010	24.92	15	280.397
4/2/2010	26.84	11.93	299.782
4/3/2010	27.67	1.618	314.426
4/4/2010	24.62	15.95	334.711
4/5/2010	27	16.04	356.231
4/6/2010	25.62	17.51	377.796
4/7/2010	24.16	14.57	397.161
4/8/2010	22.61	2.317	409.6245
4/9/2010	21.56	0	420.4045
4/10/2010	24.49	9.5	437.3995
4/11/2010	15.91	12.91	451.8095
4/12/2010	23.19	10.6	468.7045
4/13/2010	23.76	8.54	484.8545
4/14/2010	20.08	11.81	500.7995
4/15/2010	16.39	13.87	515.9295
4/16/2010	16.14	12.95	530.4745
4/17/2010	20.54	11.44	546.4645
4/18/2010	20.37	10.51	561.9045
4/19/2010	16.98	11.22	576.0045
4/20/2010	23.52	9.01	592.2695
4/21/2010	25.06	5.24	607.4195
4/22/2010	18.61	13.59	623.5195

Donation: D03-2010 continued

Date	MAX	MIN	ADD
4/23/2010	28.21	15.43	645.3395
4/24/2010	26.78	8.18	662.8195
4/25/2010	28.83	6.8	680.6345
4/26/2010	29.5	3.871	697.32
4/27/2010	23.64	7.41	712.845
4/28/2010	25.9	3.678	727.634
4/29/2010	27.82	14.3	748.694
4/30/2010	29.66	17.79	772.419
5/1/2010	28.64	16.12	794.799
5/2/2010	29.4	8.01	813.504
5/3/2010	30.2	4.581	830.8945
5/4/2010	32.54	4.007	849.168
5/5/2010	33.64	8.26	870.118
5/6/2010	32.32	13.47	893.013
5/7/2010	33.4	18.63	919.028
5/8/2010	23.85	18.69	940.298
5/9/2010	24.31	15.49	960.198
5/10/2010	28.49	19.99	984.438
5/11/2010	31.39	19.41	1009.838
5/12/2010	32.06	18.02	1034.878
5/13/2010	31.13	20.31	1060.598
5/14/2010	22	13.14	1078.168
5/15/2010	27.46	12.33	1098.063
5/16/2010	27.35	12.97	1118.223
5/17/2010	30.27	12.72	1139.718
5/18/2010	28.5	13.67	1160.803
5/19/2010	28.82	13.63	1182.028
5/20/2010	27.75	18.92	1205.363
5/21/2010	30.25	18.71	1229.843
5/22/2010	30.43	19.89	1255.003
5/23/2010	30.47	20.86	1280.668
5/24/2010	27.62	19.03	1303.993
5/25/2010	26.32	17.58	1325.943
5/26/2010	29.93	15.77	1348.793
5/27/2010	32	13.39	1371.488
5/28/2010	33.26	13.63	1394.933
5/29/2010	32.6	14.65	1418.558
5/30/2010	31.63	16.27	1442.508
5/31/2010	31.72	13.76	1465.248
6/1/2010	31.44	13.02	1487.478
6/2/2010	32.54	16.04	1511.768
6/3/2010	20.15	14.32	1529.003
6/4/2010	31.74	12.55	1551.148

Donation: D03-2010 continued

Date	MAX	MIN	ADD
6/5/2010	31.29	13.01	1573.298
6/6/2010	32.32	20.94	1599.928
6/7/2010	32.72	18.15	1625.363
6/8/2010	28.3	19	1649.013
6/9/2010	28.05	15.93	1671.003
6/10/2010	31.19	19.88	1696.538
6/11/2010	30.49	21.12	1722.343
6/12/2010	30.98	22.14	1748.903
6/13/2010	31.41	21.48	1775.348
6/14/2010	31.79	21.49	1801.988
6/15/2010	32.35	20.51	1828.418
6/16/2010	32.19	20.05	1854.538
6/17/2010	31.65	17.59	1879.158
6/18/2010	32.82	21.83	1906.483
6/19/2010	33.01	20.54	1933.258
6/20/2010	32.62	19.66	1959.398
6/21/2010	33.36	19.62	1985.888
6/22/2010	33.71	18.05	2011.768
6/23/2010	33.87	16.84	2037.123
6/24/2010	32.46	18.17	2062.438
6/25/2010	33.9	18.78	2088.778
6/26/2010	33.94	18.33	2114.913
6/27/2010	34.84	17.5	2141.083
6/28/2010	35.58	19.54	2168.643
6/29/2010	32.2	19.26	2194.373
6/30/2010	26.03	18.37	2216.573
7/1/2010	22.98	18.97	2237.548
7/2/2010	21.38	18.48	2257.478
7/3/2010	30.02	18.98	2281.978
7/4/2010	30.2	19.9	2307.028
7/5/2010	31.57	18.26	2331.943
7/6/2010	32.82	16.75	2356.728
7/7/2010	32.4	17.54	2381.698
7/8/2010	21.24	18.73	2401.683
7/9/2010	29.39	17.58	2425.168
7/10/2010	31.34	17.83	2449.753
7/11/2010	31.79	18.62	2474.958
7/12/2010	35.08	20.65	2502.823
7/13/2010	33.917	22.963	2531.263

Donation: D04-2010

Date	MAX	MIN	ADD
3/15/2010	20.56	5	12.78
3/16/2010	13.51	7.31	23.19
3/17/2010	22.16	4.25	36.395
3/18/2010	19.97	0.75	46.755
3/19/2010	22.67	3.28	59.73
3/20/2020	15.16	2.71	68.665
3/21/2010	16.66	0	76.995
3/22/2010	22.79	0	88.39
3/23/2010	23.71	0	100.245
3/24/2010	14.96	11.19	113.32
3/25/2010	20.68	0	123.66
3/26/2010	21.69	0	134.505
3/27/2010	28.08	6.455	151.773
3/28/2010	22.36	3.665	164.785
3/29/2010	23.93	0	176.75

Donation: D05-2010

Date	MAX	MIN	ADD
3/19/2010	22.67	3.28	12.975
3/20/2010	15.16	2.71	21.91
3/21/2010	16.66	0	30.24
3/22/2010	22.79	0	41.635
3/23/2010	23.71	0	53.49
3/24/2010	14.96	11.19	66.565
3/25/2010	20.68	0	76.905
3/26/2010	21.69	0	87.75
3/27/2010	28.08	6.455	105.018
3/28/2010	22.36	3.665	118.03
3/29/2010	23.93	0	129.995
3/30/2010	25.61	4.417	145.009
3/31/2010	27.69	9.55	163.629
4/1/2010	24.92	15	183.589
4/2/2010	26.84	11.93	202.974
4/3/2010	27.67	1.618	217.618
4/4/2010	24.62	15.95	237.903
4/5/2010	27	16.04	259.423
4/6/2010	25.62	17.51	280.988
4/7/2010	24.16	14.57	300.353
4/8/2010	22.61	2.317	312.816
4/9/2010	21.56	0	323.596
4/10/2010	24.49	9.5	340.591
4/11/2010	15.91	12.91	355.001
4/12/2010	23.19	10.6	371.896
4/13/2010	23.76	8.54	388.046
4/14/2010	20.08	11.81	403.991
4/15/2010	16.39	13.87	419.121
4/16/2010	16.14	12.95	433.666
4/17/2010	20.54	11.44	449.656
4/18/2010	20.37	10.51	465.096
4/19/2010	16.98	11.22	479.196
4/20/2010	23.52	9.01	495.461
4/21/2010	25.06	5.24	510.611
4/22/2010	18.61	13.59	526.711
4/23/2010	28.21	15.43	548.531
4/24/2010	26.78	8.18	566.011
4/25/2010	28.83	6.8	583.826
4/26/2010	29.5	3.871	600.512

Donation: D05-2010 continued

Date	MAX	MIN	ADD
4/27/2010	23.64	7.41	616.037
4/28/2010	25.9	3.678	630.826
4/29/2010	27.82	14.3	651.886
4/30/2010	29.66	17.79	675.611
5/1/2010	28.64	16.12	697.991
5/2/2010	29.4	8.01	716.696
5/3/2010	30.2	4.581	734.086
5/4/2010	32.54	4.007	752.36
5/5/2010	33.64	8.26	773.31
5/6/2010	32.32	13.47	796.205
5/7/2010	33.4	18.63	822.22
5/8/2010	23.85	18.69	843.49
5/9/2010	24.31	15.49	863.39
5/10/2010	28.49	19.99	887.63
5/11/2010	31.39	19.41	913.03
5/12/2010	32.06	18.02	938.07
5/13/2010	31.13	20.31	963.79
5/14/2010	22	13.14	981.36
5/15/2010	27.46	12.33	1001.25
5/16/2010	27.35	12.97	1021.41
5/17/2010	30.27	12.72	1042.91
5/18/2010	28.5	13.67	1063.99

Donation: D07-2010

Date	MAX	MIN	ADD
4/1/2010	24.92	15	19.96
4/2/2010	26.84	11.93	39.345
4/3/2010	27.67	1.618	53.989
4/4/2010	24.62	15.95	74.274
4/5/2010	27	16.04	95.794
4/6/2010	25.62	17.51	117.359
4/7/2010	24.16	14.57	136.724
4/8/2010	22.61	2.317	149.188
4/9/2010	21.56	0	159.968
4/10/2010	24.49	9.5	176.963
4/11/2010	15.91	12.91	191.373
4/12/2010	23.19	10.6	208.268
4/13/2010	23.76	8.54	224.418
4/14/2010	20.08	11.81	240.363
4/15/2010	16.39	13.87	255.493
4/16/2010	16.14	12.95	270.038
4/17/2010	20.51	11.44	286.013
4/18/2010	20.37	10.51	301.453
4/19/2010	16.98	11.22	315.553
4/20/2010	23.52	9.01	331.818
4/21/2010	25.06	5.24	346.968
4/22/2010	18.61	13.59	363.068
4/23/2010	28.21	15.43	384.888
4/24/2010	26.78	8.18	402.368
4/25/2010	28.83	6.8	420.183
4/26/2010	29.5	3.871	436.868
4/27/2010	23.64	7.41	452.393
4/28/2010	25.9	3.678	467.182
4/29/2010	27.82	14.3	488.242
4/30/2010	29.66	17.79	511.967
5/1/2010	28.64	16.12	534.347
5/2/2010	29.4	8.01	553.052
5/3/2010	30.2	4.581	570.443
5/4/2010	32.54	4.007	588.716
5/5/2010	33.64	8.26	609.666
5/6/2010	32.32	13.47	632.561
5/7/2010	33.4	18.63	658.576
5/8/2010	23.85	18.69	679.846
5/9/2010	24.31	15.49	699.746

Donation: D07-2010 continued

Date	**MAX**	**MIN**	**ADD**
5/10/2010	28.49	19.99	723.986
5/11/2010	31.39	19.41	749.386
5/12/2010	32.06	18.02	774.426
5/13/2010	31.13	20.31	800.146
5/14/2010	22	13.14	817.716
5/15/2010	27.46	12.33	837.611
5/16/2010	27.35	12.97	857.771
5/17/2010	30.27	12.72	879.266
5/18/2010	28.5	13.67	900.351

Donation: D08-2010

Date	MAX	MIN	ADD
4/30/2010	29.66	17.79	23.725
5/1/2010	28.64	16.12	46.105
5/2/2010	29.4	8.01	64.81
5/3/2010	30.2	4.581	82.2005
5/4/2010	32.54	4.007	100.474
5/5/2010	33.64	8.26	121.424
5/6/2010	32.32	13.47	144.319
5/7/2010	33.4	18.63	170.334
5/8/2010	23.85	18.69	191.604
5/9/2010	24.31	15.49	211.504
5/10/2010	28.49	19.99	235.744
5/11/2010	31.39	19.41	261.144
5/12/2010	32.06	18.02	286.184
5/13/2010	31.13	20.31	311.904
5/14/2010	22	13.14	329.474
5/15/2010	27.46	12.33	349.369
5/16/2010	27.35	12.97	369.529
5/17/2010	30.27	12.72	391.024
5/18/2010	28.5	13.67	412.109
5/19/2010	28.82	13.63	433.334
5/20/2010	27.75	18.92	456.669
5/21/2010	30.25	18.71	481.149
5/22/2010	30.43	19.89	506.309
5/23/2010	30.47	20.86	531.974
5/24/2010	27.62	19.03	555.299
5/25/2010	26.32	17.58	577.249
5/26/2010	29.93	15.77	600.099
5/27/2010	32	13.39	622.794
5/28/2010	33.26	13.63	646.239
5/29/2010	32.6	14.65	669.864
5/30/2010	31.63	16.27	693.814
5/31/2010	31.72	13.76	716.554
6/1/2010	31.44	13.02	738.784
6/2/2010	32.54	16.04	763.074
6/3/2010	20.15	14.32	780.309
6/4/2010	31.74	12.55	802.454
6/5/2010	31.29	13.01	824.604
6/6/2010	32.32	20.94	851.234
6/7/2010	32.72	18.15	876.669

Donation: D08-2010 continued

Date	MAX	MIN	ADD
6/8/2010	28.3	19	900.319
6/9/2010	28.05	15.93	922.309
6/10/2010	31.19	19.88	947.844
6/11/2010	30.49	21.12	973.649
6/12/2010	30.98	22.14	1000.21
6/13/2010	31.41	21.48	1026.65
6/14/2010	31.79	21.49	1053.29
6/15/2010	32.35	20.51	1079.72
6/16/2010	32.19	20.05	1105.84
6/17/2010	31.65	17.59	1130.46
6/18/2010	32.82	21.83	1157.79
6/19/2010	33.01	20.54	1184.56
6/20/2010	32.62	19.66	1210.7
6/21/2010	33.36	19.62	1237.19
6/22/2010	33.71	18.05	1263.07
6/23/2010	33.87	16.84	1288.43
6/24/2010	32.46	18.17	1313.74
6/25/2010	33.9	18.78	1340.08
6/26/2010	33.94	18.33	1366.22
6/27/2010	34.84	17.5	1392.39
6/28/2010	35.58	19.54	1419.95
6/29/2010	32.2	19.26	1445.68
6/30/2010	26.03	18.37	1467.88
7/1/2010	22.98	18.97	1488.85
7/2/2010	21.38	18.48	1508.78
7/3/2010	30.02	18.98	1533.28
7/4/2010	30.2	19.9	1558.33
7/5/2010	31.57	18.26	1583.25
7/6/2010	32.82	16.75	1608.03
7/7/2010	32.4	17.54	1633
7/8/2010	21.24	18.73	1652.99
7/9/2010	29.39	17.58	1676.47
7/10/2010	31.34	17.83	1701.06
7/11/2010	31.79	18.62	1726.26
7/12/2010	35.08	20.65	1754.13
7/13/2010	33.917	22.963	1782.57
7/14/2010	35.777	23.26	1812.09
7/15/2010	33.55	21.94	1839.83
7/16/2010	37.82	20.98	1869.23

Donation: D08-2010

Date	MAX	MIN	ADD
7/17/2010	38.25	18.83	1897.77
7/18/2010	37.42	20.7	1926.83
7/19/2010	34.6	20.02	1954.14

Donation: D09-2010

Date	MAX	MIN	ADD
5/27/2010	32	13.39	22.695
5/28/2010	33.26	13.63	46.14
5/29/2010	32.6	14.65	69.765
5/30/2010	31.63	16.27	93.715
5/31/2010	31.72	13.76	116.455
6/1/2010	31.44	13.02	138.685
6/2/2010	32.54	16.04	162.975
6/3/2010	20.15	14.32	180.21
6/4/2010	31.74	12.55	202.355
6/5/2010	31.29	13.01	224.505
6/6/2010	32.32	20.94	251.135
6/7/2010	32.72	18.15	276.57
6/8/2010	28.3	19	300.22
6/9/2010	28.05	15.93	322.21
6/10/2010	31.19	19.88	347.745
6/11/2010	30.49	21.12	373.55
6/12/2010	30.98	22.14	400.11
6/13/2010	31.41	21.48	426.555
6/14/2010	31.79	21.49	453.195
6/15/2010	32.35	20.51	479.625
6/16/2010	32.19	20.05	505.745
6/17/2010	31.65	17.59	530.365
6/18/2010	32.82	21.83	557.69
6/19/2010	33.01	20.54	584.465
6/20/2010	32.62	19.66	610.605
6/21/2010	33.36	19.62	637.095
6/22/2010	33.71	18.05	662.975
6/23/2010	33.87	16.84	688.33
6/24/2010	32.46	18.17	713.645
6/25/2010	33.9	18.78	739.985
6/26/2010	33.94	18.33	766.12
6/27/2010	34.84	17.5	792.29
6/28/2010	35.58	19.54	819.85
6/29/2010	32.2	19.26	845.58
6/30/2010	26.03	18.37	867.78
7/1/2010	22.98	18.97	888.755
7/2/2010	21.38	18.48	908.685
7/3/2010	30.02	18.98	933.185
7/4/2010	30.2	19.9	958.235

Donation: D09-2010

Date	MAX	MIN	ADD
7/5/2010	31.57	18.26	983.15
7/6/2010	32.82	16.75	1007.94
7/7/2010	32.4	17.54	1032.91
7/8/2010	21.24	18.73	1052.89
7/9/2010	29.39	17.58	1076.38
7/10/2010	31.34	17.83	1100.96
7/11/2010	31.79	18.62	1126.17
7/12/2010	35.08	20.65	1154.03
7/13/2010	33.917	22.963	1182.47

Donation: D10-2010

Date	MAX	MIN	ADD
6/14/2010	31.79	21.49	26.64
6/15/2010	32.35	20.51	53.07
6/16/2010	32.19	20.05	79.19
6/17/2010	31.65	17.59	103.81
6/18/2010	32.82	21.83	131.135
6/19/2010	33.01	20.54	157.91
6/20/2010	32.62	19.66	184.05
6/21/2010	33.36	19.62	210.54
6/22/2010	33.71	18.05	236.42
6/23/2010	33.87	16.84	261.775
6/24/2010	32.46	18.17	287.09
6/25/2010	33.9	18.78	313.43
6/26/2010	33.94	18.33	339.565
6/27/2010	34.84	17.5	365.735
6/28/2010	35.58	19.54	393.295
6/29/2010	32.2	19.26	419.025
6/30/2010	26.03	18.37	441.225
7/1/2010	22.98	18.97	462.2
7/2/2010	21.38	18.48	482.13
7/3/2010	30.02	18.98	506.63
7/4/2010	30.2	19.9	531.68
7/5/2010	31.57	18.26	556.595
7/6/2010	32.82	16.75	581.38
7/7/2010	32.4	17.54	606.35
7/8/2010	21.24	18.73	626.335
7/9/2010	29.39	17.58	649.82
7/10/2010	31.34	17.83	674.405
7/11/2010	31.79	18.62	699.61
7/12/2010	35.08	20.65	727.475
7/13/2010	33.917	22.963	755.915
7/14/2010	35.777	23.26	785.434
7/15/2010	33.55	21.94	813.179
7/16/2010	37.82	20.98	842.579
7/17/2010	38.25	18.83	871.119
7/18/2010	37.42	20.7	900.179
7/19/2010	34.6	20.02	927.489

Donation: D11-2010

Date	**MAX**	**MIN**	**ADD**
7/16/2010	37.8181	20.9754	29.3967
7/17/2010	38.2456	18.8273	57.9331
7/18/2010	37.4227	20.6975	86.9932
7/19/2010	34.6013	20.0242	114.306
7/20/2010	32.7	20.4944	140.903
7/21/2010	33.52	17.28	166.303
7/22/2010	33.1	20.23	192.968
7/23/2010	32.45	20.79	219.588
7/24/2010	34.05	18.17	245.698
7/25/2010	33.95	15.91	270.628
7/26/2010	33.45	17.68	296.193

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