Decomposition and the Freeze-Thaw Process in Northwestern Montana: A Preliminary Study

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DECOMPOSITION AND THE FREEZE-THAW PROCESS IN NORTHWESTERN MONTANA:

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The goal of this project is to observe decomposition rates of four wolf carcasses over the duration of winter in northwestern Montana and to consider these rates as they apply to humans. Four wolf carcasses were studied in order to assess decomposition rates, particularly winter intervals of the freeze-thaw process and the possibility of the re-emergence of insects during ideal conditions. It is hypothesized that the majority of insect activity on the carcasses will be limited to only internal activity during harsh weather conditions. Both carcasses placed in June decayed at predictable rates of decompositional stages and wolves 1 and 2 remained in the dry stage of decomposition in May. Wolves 3 and 4 were placed in September. Wolf 4 decayed at predictable rates of decompositional stages, yet wolf 3 took much longer to transition from the active decay stage to the dry stage. Both carcasses remained in the dry stage of decomposition until May. Continual fluctuations of weather during the winter months at the Lubrecht Forest provided useful information regarding the freeze-thaw process and the presence of insects during conditions otherwise thought to be inhospitable to their activity. Larvae were observed on all carcasses, even after periods of snow fall and snow melt. After numerous freeze-thaw cycles, wolf 3 was still observed to linger in the advanced stage of decomposition.

If applicable to humans, these results provide very useful information regarding what might occur during the decomposition process in an environment such as northwestern Montana. Although the classifications of insects in this study are basic, the proof that they exist and, in fact, re-emerge during winter conditions is significant in itself. The interpretation of this data as it applies to forensic cases offers forensic anthropology a new aspect of the time since death interval.
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The rate at which human beings decompose, from the moment the last breath is breathed to the time the body becomes a part of the earth, is a process that remains fascinating to all researchers who have any interest in the process of death. For any human, for that matter, the occurrences involving death are ones of mystery and wonder. For the forensic anthropologist, the task of identifying the postmortem interval can be far more complicated than one might assume. Temperature, exposure of the corpse, mummification, forces including fire or water, geographical location, and manner of death all affect decomposition in ways that vary significantly from one another. It is the responsibility of forensic specialists to become familiar with these processes, and for anthropologists it is imperative to gain more knowledge about human decomposition in order to be able to estimate the time of death of a victim.

**Related Studies**

Studies of the postmortem interval for human beings are becoming increasingly necessary as this information is vital to death scene investigation and all other situations involving human remains. At present, there are a select number of studies concerning decomposition rates of individuals specifically focusing on environmental and temperature factors. Bornemissza (1957) used guinea pig specimens in Australia to study insect activity. Through his observations he was able to recognize five stages of carcass decomposition, which included initial decay (0-2 days), putrefaction (2-12 days), black putrefaction (12-20 days), butyric fermentation (20-40 days), and dry decay (40-50 days)
(Smith, 1986 p.17). During the mid-1960s Payne (1965) studied the idea of insect succession and compared the decomposition of pig carcasses exposed to insects with those protected from insect activity (Goff; 2000 p.14). His observations resulted in the recording of over 500 species of organisms.

Extensive studies have been conducted in locations such as the University of Tennessee at Knoxville and the University of Florida at Gainesville (Bass and Rodriguez, 1983; Love and Marks, 2003; Mann et al., 1990; Reed, 1958), where environmental and weather patterns are very different from those of Montana. Factors including temperature and seasonal differences, humidity, and insect variability all strongly influence the rate at which a corpse decomposes.

Among these studies, only a handful have closely examined rates of decay over winter intervals involving the freeze-thaw process, and even fewer published research exists regarding Montana climate conditions and its affect on these processes. Micozzi (1997) addresses ideas of postthaw decomposition changes and the effects of prior freezing. Reed (1958) and Johnson (1975) observed four phases of decay; however they used specimens that had previously been frozen. Both studies observed a bloat stage that persisted for several weeks in freeze-thaw cycles. Johnson (1975) further observed that animals that had been subjected to freezing and subsequently thawed appeared to decompose from the outside in, while unfrozen animals seemed to decompose from the inside out (Micozzi, 1986). The purpose of this thesis is to report on the decomposition rates of wolf carcasses in an effort to develop a general paradigm for estimating human decay rates in a northwestern Montana climate.
Forensic Entomology

Once we create standards for decay in contrasting settings, they can be applied to a forensic framework. These standards should include decomposition patterns and the sequence of insect succession. The use of insects as a method for determining time since death in investigations has only become common in North America within the last 30 years (Catts and Haskell, 1990). Studies of forensic entomology are scattered throughout the literature. Forensic entomology is defined as the use of insect evidence to help answer questions pertaining to legal issues (Dupras et al., 2006). Anderson (1999) defines forensic entomology as any legal activity that involves insects or other arthropods.

In the 1950s, a Tennessee entomologist by the name of H. B. Reed examined insect activity in 45 carcasses (Reed, 1958). His expectations of intense insect activity during warm months were confirmed. However, to his surprise certain individual species of insects experienced peaked populations during colder weather. In addition to these observations, Reed (1958) recorded and documented all species of insects, including adult and larvae.

During the 1960s Dr. William Bass noted insect activity as he was excavating Arikara graves in South Dakota. Bass (2003) noticed that some of the graves had many pupal casings, while others contained little or no casings at all. He realized this was due to the fact that some individuals were buried in the summer when insect activity was prevalent, while others were buried during the winter season when flies are inactive. It was then that Bass understood the need for an intense entomological study that would help figure out ways of identifying the exact season when a human being died. The
person for this project would be William Rodriguez, one of Dr. Bass’s graduate students. For months Rodriguez closely observed insect activity on human corpses and recorded the details. By marking blowflies bright orange, the color of a University of Tennessee football fan, he was able to keep a close eye on the number of repeat feeders that came back day after day. And there were, in fact, flies that returned to the corpse even days after they had last been observed (Bass, 2003 p.106).

The majority of research conducted using animal substitutes for human decomposition rates has been work done on pigs, since they are an accepted comparative model and decomposition takes place in time frames similar to those of humans (Haskell, 1989; Payne, 1965). The work done by Robert J. Morton and Wayne D. Lord (1999) is most comparable. In their research, Morton and Lord (1999) used pigs as substitutes for children in order to create standards for decomposition and taphonomic influences. Only pigs weighing less than 30 pounds were used in this study, being analogous to child-like remains. The time period was from May 1998 to July 1998, with a total of 75 monitored days. Location of the experimental site was a wooded area in Virginia. Temperatures ranged from the 60s °F (low) to 80s °F and 90s °F (high) for the entire 75 day period. A total of five sites in this study were used to observe and record a variety of decay stages and taphonomic changes. Scavenging was allowed and photos were regularly taken as to observe the activity in order for identification.

Results for this study showed the complete skeletonization of each pig within twelve days, with the exception of the experimental specimen from site 4, where a suspended pig mummified due to desiccation from wind and the absence of insect infestation and scavenging. Morton and Lord (1999) mentioned that research on buried
bodies shows a retardation in the decomposition process, as factors such as reduced oxygen availability and the slowing down of bacterial putrefaction through cooler, more homogeneous temperatures greatly affect normal decay processes. Also, a layer of soil acts as a shield, deterring easy carrion detection, insect access, and large animal scavenging.

Another study where pigs were used to create or broaden existing categories of human decomposition rates was conducted by Tiffany Terneny (1997). This study is most comparable to my research since Terneny (1997) conducted her study in northwestern Montana. Only two pigs were used in this study, and the pigs exhibited weights comparable to human beings (160 pounds and 180 pounds). Both were studied for the duration of one year. Pig 1 was buried and placed out on April 5, 1996, while pig 2 was placed on the surface of the ground uncovered on the same day. Insects found in and around the carcass of pig 2 were collected, identified, and recorded. Pig 1 was exhumed twice during the study and decomposition characteristics were noted. The first exhumation date took place on September 1, 1996 and the second and final exhumation took place on April 5, 1997. The infrequency of examination for pig 1 insured as little disruption as possible to decaying processes.

As a conclusion to her project, Terneny (1997) stated that the sequence of decomposition for the pig carcasses was consistent with previous studies done in the United States, however the rate or stage of decomposition and the length of each varied with the warmer study areas. The stages Terneny (1997) used are fresh, bloat, active decay, advanced decay, dry, and remains. The fresh stage marks the beginning of the decomposition process. The bloat stage includes the build up of gasses and putrefaction.
The active decay stage involves the eradication of soft tissue and begins once bloat is complete. The advanced decay stage occurs once most of the soft tissue has eradicated. The dry stage of decomposition is marked by the remaining mummified or desiccated tissue, cartilage, and bone. Finally, the remains stage is characterized by mostly bone remaining. Decay rates for the two pigs occurred more slowly, probably due to a generally colder climate. Although these stages were prolonged, Terneny (1997) found that all stages of decomposition were generally lengthened, thus supporting her original hypothesis that the same principles of the decay process as a method of estimating time since death apply even in states that have different environments from that of northwestern Montana. Since this study focused mainly on spring and summer insect activity, data concerning winter intervals does not exist.

Dillon’s (1997) experiment, set in Canada, found no difference between types of blowfly species in shade versus sun (Dillon, 1997). He also discovered that clothed carcasses experienced longer stages of decay and retained fluids longer (Dillon, 1997). In addition, Dillon (1997) stated that it was very difficult to determine when the post-decay stage concluded, that is when carcasses were officially reduced to the remains stage (Dillon, 1997).

In a case study comparing burned and unburned pig specimens in northwestern Montana, Seth Barnes (2000) utilized the University of Montana Lubrecht Experimental Forest to conduct his research. Using standards comparable to an earlier study done by Dillon (1997), Barnes’ (2000) first goal for the project was to discern decomposition patterns based on forensic entomological studies in a similar biogeoclimatic zone. Barnes (2000) compared faunal data previously collected by Dillon (1997) to his own
results hoping to aid forensic investigators working in this area. Barnes (2000) created a study where burned and unburned pigs were placed in a partially shaded site. He compared burned and unburned pig specimens to test differences in stages of decomposition. Lastly, Barnes (2000) observed insect patterns and diversity of species and hypothesized that carcasses present in a mixed urban/rural and rural area will be distinguishable.

For results, Barnes (2000) concluded that there were similarities in the succession of insects in a Montana climate and a similar biogeoclimatic zone in British Columbia, Canada. He also discovered that burned and unburned pig specimens provide similar insect activity to that observed in Dillon’s (1997) study where pigs were placed in both sunny and shady areas. Finally, he concluded from his research that comparisons of species in mixed urban/rural and rural areas to an earlier study by Terneny (1997) is difficult to determine, since cooler temperatures probably occurred in the spring during her study. With a lack of climatological data in Terneny’s (1997) research, this comparison is difficult to do.

**Climate Studies**

Alison Galloway (1997) reviewed detailed reports of autopsies and forensic anthropological cases from southern Arizona to offer guidelines for estimating time since death in that particular climate. Characterized by hot, arid summers and mild winters, southern Arizona experiences temperatures in the summer months of about 100 °F and in the winter sees temperatures ranging in the mid-60s °F. It is important to note that during the winter months temperatures can drop to almost freezing at night. From the 468 cases
Galloway selected from the Human Identification Laboratory of the Arizona State Museum at the University of Arizona, the postmortem interval could be established in 189 cases. Deposits of eggs were noted as early as the second day of exposure.

Galloway (1997) noted evidence of slower rates of decay in late fall and early winter as further proof of the correlation between early decomposition rates and time of year. Mummification occurred in many cases as early as the third day due to the aridity of the region. Interestingly, once a body became mummified a strong odor was still being emitted from the individual. This was most likely due to continued maggot activity under the shell of the mummified skin. Galloway (1997) stated that the most complicated aspect of the project involved the inhospitable environment insects encountered on a dry carcass. She explained that maggot activity would most likely begin later and on the more internal tissues once autolysis allows for more accessible material, which is why many cases in early decomposition do not show signs of external maggot activity (Galloway, 1997 p.146). With the passage of time, she noted that maggot activity decreased and dermestid beetles continued the feeding process.

Galloway (1997) concluded that experiments such as those at the Tennessee facility, where climate varies greatly from the Arizona-Sonoran Desert, showed slower decomposition during the winter months due to greater seasonal variability in temperature and humidity. Factors ranging from humidity and rainfall to soil pH and condition of the body all determine the rate at which decomposition occurs, including how attracted the insects are to the remains.

Clearly, it is ineffective to compare these observances of decay in such an arid climate to rates witnessed in areas where seasonal rainfall variance is significant. It is
useful, however, to note differences in insect infestation during summer and winter months that Galloway (1997) identified during this study. During the summer, the presence of insects such as the sarcophagids depended solely on temperature and sunlight. Thus, during cloudy days, egg-laying was deterred. If it was too hot, however, shade was needed in order to lay eggs. In the winter, sunlight was the main necessity, and larvae were only active during the day. She concluded that perhaps since larvae need both moisture and accessibility to air, mummified remains provide an inhospitable environment on the exterior and decomposition is limited to internal tissues only. This concept can be directly applied to decomposition rates during colder periods. While external maggot activity may not be apparent due to dryness or accessibility of remains, this certainly does not indicate an absence of internal occupation.

Although these standards created by Galloway (1997) provide useful information towards solving the mysteries involving the postmortem interval, Love and Marks (2003) ruled out these hypotheses for cases examined in areas such as Tennessee, where climatological differences exist. However, they did agree with Galloway (1997) in that the rate at which a body progresses from a flesh stage to skeletonization is dependent on factors such as temperature and humidity, rather than the passage of time. For this reason it is imperative for studies to be conducted ranging across the globe to involve varying climatological conditions in order to provide a confident amount of information regarding decompositional changes.

Another aspect of the decomposition process that is important to study involves larval activity and their reactions to temperature and weather conditions. Bass (1997) has argued that maggots do not like sunlight and use skin as an “umbrella” in order to shade
themselves. He used an example of a case where an individual had been placed in a black body bag and transported to a different locale. Before transportation, only a few maggots had been observed on the remains. However, once the bag was re-opened, Bass and others witnessed countless little feeders that had left the body cavity within the comfort of a dark environment in order to “feed more actively on the skin” (Bass, 1997 p.182). Bass explained that he had seen many bodies in the field where maggots had left only the skin above the ground as protection against the sun, and no internal organs remained. Accordingly, the ground/body interface is approximately one or two inches above the ground surface. This is the area the maggots have eaten away in order to allow air to circulate under the skin, causing drying of the skin and therefore protection from the sun.

For winter intervals, Bass (1997) states that the process of decomposition slows greatly, yet it certainly persists inside the body cavity. Heat generated within the body can even be seen with the naked eye and is sure evidence of insect activity. He suggests that insects leave the skin and migrate into the body cavity for protection from the elements such as sun, wind, rain, and snow. Since there is no activity present once the skin is abandoned by the insects, the skin will dry and become leathery.

In Micozzi (1997) postmortem freezing and thawing are introduced as taphonomic processes that directly effect decomposition. An experimental study of effects of freezing and thawing was performed to:

observe postmortem change in soft tissue and skeletal remains, to
determine the effects of freezing and thawing on those patterns of change,
to observe the effects of mechanical injury on postmortem change, and to compare the effects of freezing and thawing to those of mechanical injury. (Micozzi, 1997 p175).
Fresh-killed animals were compared to animals frozen and then thawed. Micozzi (1997) does not specify what species were used in this project. Differences in decomposition rates were noted and Micozzi (1997) determined that frozen-thawed animals were more susceptible to external decay whereas fresh-killed animals were more susceptible to invasion by insects and microorganisms internally. Basically, animals that were frozen then allowed to thaw decayed from the “outside in” and freshly killed animals did so “inside out.” Disarticulation was also noted as occurring slower in the fresh-killed animals than in the frozen-thawed animals. The purpose of Micozzi’s (1997) study was to attempt to interpret the rate at which human remains might decay if they wintered over and were discovered in the spring or summer. If the remains endured freeze-thaw cycles, the information provided by Micozzi (1997) could be used to help discern decompositional stages.

Nothing affects the rate of decomposition more than insects (Bass, 1997; Goff, 2000; Pickering and Bachman, 1997; Smith, 1986;) and if this insect activity is studied continually throughout the decomposition process, including winter conditions, this activity will be better understood. We already know that frozen human corpses decompose very slowly if at all; however, once a body thaws, decomposition can occur rapidly given the right conditions. Pickering and Bachman (1997) state that with frequent temperature changes at higher elevations, repeated cycles of freezing and thawing greatly accelerate the decomposition process. The decomposition rates of wolf carcasses in a northwestern Montana winter climate provide a useful source of information for inferring human decomposition rates. By collecting this information, standards for estimating time since death of human corpses can be applied to legal investigations. It has been
discovered that the larvae of winter gnats feed on carrion (Broadhead, 1980; Erzinclioglu, 1980), so what is the outcome if a carcass partially or fully thaws and then once again freezes? Do these insects survive the drastic or sensitive changes of weather patterns in such a climate as northwestern Montana?

Since few studies have been conducted involving the freeze-thaw process, and as northwestern Montana winter weather patterns fluctuate arbitrarily, results from such a study can be seen more as novel and experimental. I hypothesize that the majority of insect activity on the carcasses will be limited to only internal activity during harsh weather conditions, however varying weather patterns involving a freeze-thaw process will provide as of yet uncertain results. Since this project is experimental and no studies on the decay rates of wolf carcasses exist presently in the literature, expectations are rudimentary.

Through reviewing existing literature, it is obvious that much attention has been paid to forensic entomology and the use of insects to help determine time since death. We see repeatedly the use of nonhuman samples to imitate human beings in numerous forensic settings. Pigs are most popularly utilized, as they are comparable to human specimens. Other nonhuman species could also be used as long as their weights are appropriately comparable to humans. As we have seen, studies conducted in warmer environments where weather patterns are less seasonal, such as Tennessee, have been consistent when compared to one another. However, not enough research exists concerning environments where weather patterns fluctuate at dramatic rates. The process of “over-wintering” is one that exists in localities such as Tennessee; however, that region has milder winter temperatures and does not experience the sudden weather
fluctuations and severe cold temperatures as northwestern Montana. Although we have seen studies involving freeze-thaw decomposition rates, it is difficult to apply these patterns to specimens that have “over-wintered” rather than those beginning the decomposing process at the frozen stage.

Also, not enough information exists involving as to the possibility of insects re-emerging after the temperature has been below freezing. Simple questions still exist that seem to be more difficult to answer, such as: Where do maggots go when outside conditions prove to be unbearable? Do they die? Do they remain inside the corpse in a dormant stage? If so, can maggots re-emerge after months of slumber to finish what they started? Can forensic scientists rely on maggot succession after multiple periods of freeze-thaw processes? With a project such as this, many questions are asked. With these questions, we will get answers, and probably more questions, as well. With hope, this project will expand the repertoire of forensic anthropology and help to significantly narrow the postmortem interval.
CHAPTER 2: MATERIALS AND METHODS

Carleen Gonder organized a research project studying wildlife time since death as a response to the lack of programs involving wildlife crime scene investigation, as well as limited information regarding wildlife forensics. With Carleen’s extensive experience with US Fish and Wildlife Service (FWS), as well as her passion for wildlife law enforcement, she developed a research project to holistically study a four season approach of decomposition rates of various species including black bear, grizzly bear, wolf, deer, elk, and mountain lion. Within this project, a sister study was organized involving over-winter decomposition rates on a subset of the carcasses. Although over-wintering was also closely studied among other carcasses during the project, the particular interests for research presented here focused on four wolves. Decomposition in the wolf carcasses was carefully studied over the course of fall, winter and spring in hopes of developing hypotheses about decomposition in humans during the colder months of an arid climate at higher latitude and the possibility of the re-emergence of insect species during cycles of freezing and thawing.

Study Area

The study site for this project is located in northwestern Montana at the Lubrecht Experimental Forest in Missoula County, which is owned and operated by the University of Montana Forestry Department. Lubrecht Forest is located nearly 25 miles east of Missoula. The site is approximately 1.5 miles from the main road and is approximately 4,300 feet in elevation with vegetation that consists predominantly of Ponderosa Pine
Canopy cover is around 30% with little understory while the terrain is slightly sloping to flat and has an eastern aspect (Gonder, 2007).

The specimens were put in two containment areas (Figure 1). The two containment areas were in close proximity to one another and therefore were nearly identical in elevation and vegetation type. As described in Gonder (2007), containment area 1 measures 16 feet by 16 feet by 4 feet and was constructed of heavy duty livestock mesh panels. Containment area 2 measures 12 feet by 60 feet by 6 feet and was constructed of chain link fencing. No flooring was installed in either containment areas due to the desire for a simulated natural environment. A ½ inch wire mesh topping was employed as a roof structure in order to prevent avian scavengers. On November 14, 2006 the mesh topping was taken down due to stress from the weight of heavy snowfall. Wire strands were strung in place of the mesh topping six inches apart and flagged in efforts to deflect scavengers. Scavenging of small animals and birds was allowed during this project. A three strand electric fence was installed surrounding containment area 2, and fencing from containment area 1 was electrified by currents shared with the former. A solar panel provided power for electrification of the fences, where a consistent voltage of 6000 helped to deter large scavengers.
Carcasses were laid out approximately 3 to 6 meters apart to allow for larvae migration and to prevent the merging of insect populations from other carcasses (Gonder, 2007). Since this was a study revolving around decomposition, entomological studies were a crucial part of time since death observations. Based on the protocol developed by Gonder (2007), insects were not only collected from on and around each carcass, identification attempts were also performed and samples of individual species were stored in the Lubrecht Conference Center wet laboratory. Pit fall traps were installed in the four cardinal directions around each carcass and insects were collected from the traps until the first significant snowfall. Digital pictures were taken of each carcass at every visit as a method of observing meticulous physical changes that might have gone unnoticed during the site visit, as well as a way to document and organize stages of change through photographs.

**Animal Cadavers**

Four wolf carcasses were used in this research in order to provide information on decomposition during the fall, winter and spring, as well as information on the effects of
the freeze-thaw cycle. It is important to note here that all carcasses used for this project were selectively removed from the population for management reasons due to livestock depredation and were not euthanized for the purpose of this project (Gonder, 2007). The four mature wolves studied were placed in two compounds at separate times throughout the year.

The following information is from Gonder (2007). Wolf 1 (W1) was the first carcass placed into containment area 1 on June 17, 2006 at 1500. W1 was previously frozen and then was set out to thaw prior to placement at the site. W1 was a female yearling weighing approximately 79 pounds with a total body length of 56.5 inches and a girth of 27.5 inches. Since the tail of this carcass was only approximately 13 inches long, it was wondered if there was a previous injury to W1. There was a fresh but dried wound on the end of the tail. Wounds included one on the left aspect of the hind leg through the skin, possibly from a trap. On the right rear of the carcass the same type of wound existed, although no skin was broken. There was a third wound on the left shoulder. A temperature probe connected to a data logger was inserted approximately 3.5 inches in the abdomen. A thigh temperature probe was inserted 1.5 inches and a soil temperature probe was placed under the center body mass of W1 approximately 3 inches deep.

Wolf 2 (W2) was laid out the same day as W1 on June 17, 2006 around 1500. W2 was previously frozen and then was set out to thaw prior to placement at the site. W2 was also a female yearling. Weight of W2 when set out was 88 pounds. Total body length was 57.0 inches and girth was 27.0 inches. When placed in containment area 1 this carcass showed signs of bleeding underneath its right side. Fur in the right ear was bloody and a small open wound existed on the right side of the neck. A bullet wound
was on the right shoulder probably due to the fatal shot by removal agencies. There was also an abrasion on the right flank. An abdominal temperature probe connected to a data logger was inserted 3.5 inches and a thigh probe was placed in 1.5 inches. A soil temperature probe was inserted 3 inches under the center body mass.

Wolf 3 (W3) was removed from the population by Idaho Fish and Game Wildlife Services on September 1, 2006. The same day of removal the wolf was frozen in Salmon, Idaho. The carcass was received on September 11, 2006 from Idaho Fish and Game wolf biologist Jason Husseman and was immediately set out to thaw under mosquito netting. The carcass was transported to containment area 2 on September 15, 2006. This wolf was an adult female with a weight of 86 pounds, a total body length of 65 inches and a girth of 34 ½ inches. W3 exhibited a bloodied backside, possibly as a result of the removal actions by management. The left rear leg and back of the thigh were slightly swollen with blood on the outside, possibly as a result of a bullet wound. A soil temperature probe connected to a data logger was placed under the center body mass at 3 inches.

Wolf 4 (W4) was also received from Idaho Fish and Game wolf biologist Jason Husseman on September 11, 2006. The same day it was set out under mosquito netting to thaw. On September 15, 2006 the carcass was set out in the pen next to W3. W4 was a female adult that was collected as roadkill on February 21, 2005 by Idaho Fish and Game conservation officer Gary Gadwa, who brought the carcass to his resident within a few hours of time of death. Although the carcass was stored in the officer’s vehicle overnight, temperatures were recorded at freezing. The following day the carcass was placed in a freezer. The weight of W4 was 92 pounds with a total body length of 65 ½
inches and a girth of 31 ½ inches. Abrasions were noted on the left shoulder and hip points. Shoulder abrasion area was 2.8 cm wide x 3.0 cm high. The abrasion on the hip was measured as 4.9 cm wide x 3.6 cm high. A soil temperature probe connected to a data logger was placed under the center body mass at 3 inches.

**Research Design**

Decomposition activity of the wolf carcasses was monitored beginning in the fall of 2006 and concluded in the spring of 2007 once winter conditions had subsided. This research design is similar to that described in Gonder (2007), but is geared to collecting information regarding the effects of the arid, cold temperatures of the northwestern Montana fall, winter and spring and the freeze-thaw cycle that exists in this climate. Weather, including micro-climate, were regularly recorded in order to document significant fluctuation patterns that might have been present in this area of northwestern Montana. The general appearance of each carcass was recorded, including effects of scavenging and sequences of disarticulation. The duration of decomposition stages was noted and differences were noted. Insects were photographed, collected and identified, where possible, in order to study the frequency of insect activity and the role played, if any, during cycles of freezing and thawing. Odor was classified for each carcass based on the “type” of smell and its strength compared to others. Levels of odor from carcasses play a substantial role in documenting the decomposition process and as an indication of internal decay activity. Finally, photographic documentation assisted in providing yet another important source of information for tracking carcass decomposition.
Climate

Weather readings were taken during each site visit. These recordings included relative humidity, precipitation data, cloud coverage, wind speed, wind direction, maximum temperature of the previous day, minimum temperature of the previous day, current temperature, and snow depth if applicable (Gonder, 2007). Exact time of weather recordings was noted.

Precipitation data, or rainfall, was recorded using a standard forestry rain gauge located at the site (Gonder, 2007). Snow depth was measured by two standard snow-gauges (Figure 2). One was placed in each containment area and then removed after winter conditions subsided. Cloud coverage was recorded visually. Wind speed and wind direction were estimated both visually by utilizing flagging from the roof of containment area 2, as well as using a Dwyer handheld wind anemometer. Relative humidity was measured using a standard forester’s sling psychrometer, where a wet bulb and dry bulb were factored to give a percentage of humidity. Other instruments used at the site that did not involve weather included a Brunton 7 x 18 field scope in which to observe activity on the carcasses at a magnified level.

Figure 2: Standard snow-gauge in containment area 2.
Stages of Decomposition

Aside from insect activity, decomposition can be considered a competitive contest between moisture and aridity, while internal microbial activity contributes to the depletion of the organism (Love and Marks, 2003 p.164). Many forensic scientists use a series of stages of decay in order to characterize intervals of significant change. Conventional classifications of decomposition usually consist of five to six stages. These stages include fresh, bloat, active decay, advanced decay, dry, and remains. However the current understandings of carcass reaction to winter climate where freeze-thaw intervals were numerous are vague and ambiguous. Basically, we considered these stages of grouping physical and chemical transformations to be possibly indistinct when performing this project. These stages are described below.

Fresh Stage

This stage is characterized as the beginning of the decomposition process, that is once the individual is deceased. Calliphoridae (blow flies), Sarcophagidae (flesh flies), and Muscidae (house flies) are usually among the first insects to arrive on a carcass or corpse during the initial decomposition stage (Payne, 1965). These flies typically lay their eggs in the dark, damp orifices of the body or carcass and any open wounds that might exist in search of bodily fluids on which to feed (Bass, 2003). Gross morphologic changes such as livor, rigor, and algor mortis occur. Livor mortis refers to the pooling of blood which is visible within hours of death. Rigor mortis is the stiffening of muscles and is a signature occurrence of death. Finally, algor mortis is the cooling of the body immediately after death. According to pathologists, on average the human body loses 1.5
°F per hour after death (Love and Marks, 2003 p.166). However, it is important to note here that bodies cool at inconsistent rates. The fresh stage of decomposition lasts until bloating occurs.

**Bloat Stage**

The bloat stage involves the build up of gasses in the body. Putrefaction is the result of this process and is defined as the decay of proteins in the body that progressively break down. Autolysis also occurs where cells die and tissue necrosis takes place. Even in the absence of animals and insects these processes transpire (Love and Marks, 2003). Apart from the microbial activity on a carcass, there is a plethora of events that progress in the decaying of an organism.

As a result of the build up of abdominal gases, tissues rupture or naturally subside and leak from the body orifices causing a reduction to perimortem size and smaller (Galloway, 1997). The rate of bloating is entirely reliant on the weather and ambient temperature. In warmer weather, bloating will occur at a rapid rate and can last from 2 to 5 days (Terneny, 1997). However, if the weather is cooler, a specimen will go through a series of inflations and deflations over a longer period of time and often happens during cycles of freezing and thawing (Johnson, 1975). Insects are frequent during this stage.

**Active Decay Stage**

The active decay stage of decomposition begins once bloating has ceased and most of the soft tissue is gone (Terneny, 1997). Intense insect activity occurs during active decay where a variety of species occupy the carcass. According to Johnson
(1975), two important processes occur during the active decay stage that aid in active decomposition. First, oxygen that enters the carcass by way of burrowing insects exposes areas of the interior allowing decomposition to occur. Secondly, inner tissue liquefies from enzymes secreted by maggots.

Odor during this stage is strongest due to the breakdown of these tissues. It is important to note here that larvae are most active during this stage of decomposition due to the availability of food that is soft and manageable on which for them to feed. Insects that also remains as occupants on the carcass include Callihoridae (blow flies), Muscidae (house flies), and Sarcophagidae (flesh flies). Insects that occupy the carcass for the first time include Staphylinidae (rove beetles), Sespidae (black scavenger flies), Histeridae (hister beetles), and Otitidae (picture – winged flies) (Payne, 1965). According to Payne (1965) the following are also present: Silphidae (carrion beetles), Phalangidae (daddy – long legs), Tachinidae (a type of fly that preys on fly larvae), Syrphidae (syrphid flies or flower flies), Sphaeroceridae (small dung flies), Apoidea (bees), Geotrupinae (earth – boring dung beetles), and Carabidae (ground beetles).

Advanced Decay Stage

In the advanced decay stage of decomposition arthropods begin to migrate from the carcass and often burrow in the soil (Reed, 1958). The majority of the soft tissue on the carcass has decomposed (or is absent) and odor has reduced significantly. Insect activity has also diminished greatly. Calliphoridae (blow flies) and Muscidae (house flies) activity is nearly ended yet Sphaeroceridae (small dung beetles), Drosophilidae (small fruit flies), and Otitidae (picture - winged flies) increase their activity (Payne,
Types of beetles present, including Staphylinidae (rove beetles) and Histeridae (hister beetles), are still consistent (Payne, 1965).

**Dry Stage**

In this stage of decomposition, mummified or desiccated skin, cartilage, and bone are all that remain (Terneny, 1997). Insect activity is reduced to species that feed on the remainder of the carcass, including dry skin and other available areas. Animals that feed on the remaining material include the following: snails, millipedes, isopods (tweedle bugs), centipedes, Leptoceridae (long-horned caddis flies), Dermestidae (hide beetles), Nitidulidae (sap beetles), Cleridae (checkered beetles), mites, and ants (Payne, 1965). Bones in this stage might become bleached yet are still not completely exposed.

**Remains Stage**

The remains stage of decomposition is the final stage. It is difficult to determine when the dry stage ends and the remains stage begins and very few clues exist as help (Terneny, 1997). Odor during this stage is minimal as only dried flesh and bone remain. The remains stage is especially difficult to determine in mammal carcasses since a mummified hide creates challenges in the identification of what is left.

**Insects**

Using insects to pinpoint time since death has only become popular within the last few decades (Catts and Haskell, 1990). Insects can be used in a variety of ways in order to narrow the time since death interval and each type of insect plays a crucial role in the
death and decomposition process. For example, not only do Calliphoridae (blow flies) respond to a carcass within the first few hours of death, their colonized remains subsist on a victim and endure for weeks, months, and even years (Anderson and Cervenka, 2002 p.174). There are also insects that feed on other insects that occupy a carcass or cadaver and become an equally integral part of the decomposition process. Insects that feed on both decaying organic materials and dead materials are called saprophagous insects (Catts and Haskell, 1990).

Insects for this project were only collected from the exterior of all carcasses as to avoid disturbing the overall process of decomposition. A future project should investigate internal insect activity on carcasses in order to examine this behavior. All the insect collections were done per Dr. Greg Johnson's protocols.

Both flying and crawling insects were collected for observation and identification in the Lubrecht Forest Conference Center wet laboratory. Insects were collected by waving a sweep net back and forth over each carcass approximately three times in order to collect as many insects as possible (Gonder, 2007). If nothing was gathered during the first three attempts, a fourth set of sweeps was added. Insects were also manually collected by using soft forceps and then placed in small vials for later processing in the laboratory.

Pit fall traps were installed when the first two carcasses (W1 and W2) were laid out in the summer of 2006. W3 and W4 also were surrounded by pit fall traps in the four cardinal directions. Carcasses deposited during the winter season had no pit fall traps installed due to a rapid reduction in flying insect activity during that time interval. Pit fall traps were constructed by Gonder as described in Gonder (2007). A two-liter bottle
was cut in half and the bottom placed in a six inch dug hole and a plastic cup was placed in the hole and filled with antifreeze in order to preserve insects. The top of the two-liter bottle was then placed inside the hole upside down to act as a funnel directing insects into the cup. Flat pans approximately 12 inches in diameter elevated by metal slates served as makeshift covers for the traps. Insects were collected from the pit fall traps by draining the antifreeze into a moist paper towel. The paper towel was then folded and placed in a Ziploc bag and labeled with the following information: name of the carcass, date, time of collection (a.m. or p.m.), and location of the pit fall trap from which insects were collected (north, east, south, or west).

Insects manually collected from on the carcass or by way of netting were stored alive in small vials and labeled as follows: name of the carcass, date, time of collection (a.m. or p.m.), and either the location of the insect on the carcass at the time of collection or specified via net collection (Gonder, 2007). Specimens were collected with pliable forceps and placed in small jars with a moist paper towel in order to help preserve them. Jars were labeled accordingly.

Once insects were collected, all specimens were brought back to the Lubrecht Conference Center wet laboratory for proper storage and documentation (Gonder, 2007). Insects collected from pit fall traps were transported and stored in a refrigerator present in the laboratory to later be analyzed by the Montana State University entomology department for an additional study. Samples stored in vials were either placed in the freezer for preservation or stored in a vial of alcohol at room temperature for preservation, depending on the number of species collected. All were labeled accordingly.
Larvae were separated into two different environments: a vial of alcohol and a rearing container (Gonder, 2007). Proper entomological rearing chambers were used, however, once those chambers were all occupied rearing containers were constructed by taking plastic food storage containers and cutting a small square in the lids for ventilation. Screening was secured over the opening by electrical tape. Vermiculite was used as bedding and filled 1/3 of the way full. A petri dish also filled with Vermiculite was placed in the container. Then, small liver pieces were placed in the petri dish for on which the larvae would feed. Finally, larvae were carefully placed on the liver. Containers were labeled with appropriate information including the carcass on which the specimens were found. Rearing containers were regularly monitored by Carleen Gonder and any emergence was recorded. Once flies emerged in the rearing chambers they were preserved by freezing upon emergence and properly labeled, including date of emergence, name of carcass, and date collected from that particular carcass.
CHAPTER 3: RESULTS

**Temperature and Moisture**

Temperature and moisture were recorded during every site visit. Table 1 represents the range of temperature and amount of precipitation recorded for each of the 18 site visits. Site visit 3 marked the first significant snowfall. It was also the first recorded visit where temperatures reached freezing. The coldest witnessed visit was January 16, 2007 where the temperature at the time of weather recording was 15 °F. The greatest amount of snowfall was also recorded that day at 4 to 6 inches in both containment areas 1 and 2. Since all carcasses were placed 3 to 6 meters apart, there were varying amounts of snow cover for each. Estimations of snow depth were made from snow gauges positioned at a central location in each containment area. It is important to note that wolves 3 and 4 were positioned at one end of the containment area while the snow gauge was located in the center of the containment area, thus meaning that all measurements recorded from that snow gauge might not be exactly what wolves 3 and 4 experienced.

Figure 3 represents ambient temperatures observed and recorded during all 18 site visits. Fluctuations in temperatures, especially between freezing and above freezing, are obvious in this representation. January 2007 was the coldest month for site visit observations, where the current temperature was 15 °F on site visit 7. The warmest temperatures were witnessed in November 2006 and April 2007 at 45 °F. November 2006 to December 2006 a gradual decline in site visit temperatures existed, with intermittent fluctuations between freezing and above freezing temperatures.
Table 1. Temperature and moisture information for site visits.

<table>
<thead>
<tr>
<th>Site Visit</th>
<th>Date</th>
<th>Visit Temperature</th>
<th>Temperature Range for Day</th>
<th>Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6 Oct 2006</td>
<td>not recorded</td>
<td>not recorded</td>
<td>not recorded</td>
</tr>
<tr>
<td>2</td>
<td>8 Nov 2006</td>
<td>43 °F</td>
<td>34 – 50 °F</td>
<td>0.41 in rainfall</td>
</tr>
<tr>
<td>*3</td>
<td>14 Nov 2006</td>
<td>32 °F</td>
<td>27 – 39 °F</td>
<td>1.5 in snow</td>
</tr>
<tr>
<td>4</td>
<td>21 Nov 2006</td>
<td>36 °F</td>
<td>30 – 39 °F</td>
<td>.21 in rainfall</td>
</tr>
<tr>
<td>*5</td>
<td>6 Dec 2006</td>
<td>26 °F</td>
<td>17 – 37 °F</td>
<td>4 in snow (1) 3.5 in snow (2)</td>
</tr>
<tr>
<td>*6</td>
<td>13 Dec 2006</td>
<td>32 °F</td>
<td>27 – 37 °F</td>
<td>2 – 3 in snow</td>
</tr>
<tr>
<td>*7</td>
<td>16 Jan 2007</td>
<td>15 °F</td>
<td>7 – 15 °F</td>
<td>4 – 5 in snow (1) 5 – 6 in snow (2)</td>
</tr>
<tr>
<td>*8</td>
<td>25 Jan 2007</td>
<td>32 °F</td>
<td>20 – 41 °F</td>
<td>minimal coverage</td>
</tr>
<tr>
<td>9</td>
<td>10 Feb 2007</td>
<td>38 °F</td>
<td>27 – 38 °F</td>
<td>0 – 3 in snow (1) 3 – 6 in snow (2)</td>
</tr>
<tr>
<td>10</td>
<td>15 Feb 2007</td>
<td>41 °F</td>
<td>22 – 41 °F</td>
<td>2 – 3 in snow (1) 5 – 6 in snow (2)</td>
</tr>
<tr>
<td>11</td>
<td>22 Feb 2007</td>
<td>40 °F</td>
<td>21 – 40 °F</td>
<td>1 – 1.5 in snow (1) 2.5 – 3 in snow (2)</td>
</tr>
<tr>
<td>*12</td>
<td>1 Mar 2007</td>
<td>28 °F</td>
<td>15 – 38 °F</td>
<td>3 in snow</td>
</tr>
<tr>
<td>13</td>
<td>8 Mar 2007</td>
<td>43 °F</td>
<td>32 – 53 °F</td>
<td>0 in snow (1) 0 – 4 in snow (2)</td>
</tr>
<tr>
<td>14</td>
<td>22 Mar 2007</td>
<td>43 °F</td>
<td>29 – 44 °F</td>
<td>n/a</td>
</tr>
<tr>
<td>15</td>
<td>28 Mar 2007</td>
<td>45 °F</td>
<td>30 – 45 °F</td>
<td>.13 in rain/snow</td>
</tr>
<tr>
<td>16</td>
<td>5 Apr 2007</td>
<td>43 °F</td>
<td>29 – 43 °F</td>
<td>.06 in rain</td>
</tr>
<tr>
<td>17</td>
<td>12 Apr 2007</td>
<td>45 °F</td>
<td>24 – 50 °F</td>
<td>n/a</td>
</tr>
<tr>
<td>18</td>
<td>19 Apr 2007</td>
<td>40 °F</td>
<td>30 – 40 °F</td>
<td>.78 in snow</td>
</tr>
</tbody>
</table>

* Indicates site visits where the current temperature was at or below freezing.
Figure 3. Recorded ambient temperatures tracked by site visits.
Stages of Decomposition

Carcasses were observed and documented through their respective stages of decomposition. Table 2 represents the sequence of decomposition stages for wolves 1 through 4 and each site visit where these observations were observed and recorded. Wolves 3 and 4 progressed from the active decay stage of decomposition to the advanced stage of decomposition at the same rate, from October 2006 to November 2006. However, wolf 4 progressed into the dry stage of decomposition in April 2007 before wolf 3.

Figure 4 illustrates the individual rates of decay for each carcass. An aspect of variation in decay involves wolves 1 and 2. Since wolves 1 and 2 reached the dry stage of decomposition well before winter conditions set in, it is interesting to analyze the continued activity that these carcasses experienced while remaining in the dry stage even into April 2007. Another area of interest involves wolf 3 and the obvious delayed rate of decomposition. Wolf 3 remained in the advanced decay stage of decomposition nearly one month longer than wolf 4, which was placed in the same containment area on the same day in September.

Figure 5 represents the individual rates of decay for each carcass, as well as the site visits where decomposition was observed and recorded. Site visits where the current temperature reached freezing are indicated.
Table 2. Recorded observations for stages of decomposition.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>6 Oct 2006</td>
<td>Dry</td>
<td>Dry</td>
<td>Active Decay</td>
<td>Active Decay</td>
</tr>
<tr>
<td>8 Nov 2006</td>
<td>Dry</td>
<td>Dry</td>
<td>Advanced Decay</td>
<td>Advanced Decay</td>
</tr>
<tr>
<td>*14 Nov 2006</td>
<td>Dry</td>
<td>Dry</td>
<td>Advanced Decay</td>
<td>Advanced Decay</td>
</tr>
<tr>
<td>21 Nov 2006</td>
<td>Dry</td>
<td>Dry</td>
<td>Advanced Decay</td>
<td>Advanced Decay</td>
</tr>
<tr>
<td>*6 Dec 2006</td>
<td>Dry</td>
<td>Dry</td>
<td>Advanced Decay</td>
<td>Advanced Decay</td>
</tr>
<tr>
<td>*13 Dec 2006</td>
<td>Dry</td>
<td>Dry</td>
<td>Advanced Decay</td>
<td>Advanced Decay</td>
</tr>
<tr>
<td>*16 Jan 2007</td>
<td>Dry</td>
<td>Dry</td>
<td>Advanced Decay</td>
<td>Advanced Decay</td>
</tr>
<tr>
<td>*25 Jan 2007</td>
<td>Dry</td>
<td>Dry</td>
<td>Advanced Decay</td>
<td>Advanced Decay</td>
</tr>
<tr>
<td>10 Feb 2007</td>
<td>Dry</td>
<td>Dry</td>
<td>Advanced Decay</td>
<td>Advanced Decay</td>
</tr>
<tr>
<td>15 Feb 2007</td>
<td>Dry</td>
<td>Dry</td>
<td>Advanced Decay</td>
<td>Advanced Decay</td>
</tr>
<tr>
<td>22 Feb 2007</td>
<td>Dry</td>
<td>Dry</td>
<td>Advanced Decay</td>
<td>Advanced Decay</td>
</tr>
<tr>
<td>*1 Mar 2007</td>
<td>Dry</td>
<td>Dry</td>
<td>Advanced Decay</td>
<td>Advanced Decay</td>
</tr>
<tr>
<td>8 Mar 2007</td>
<td>Dry</td>
<td>Dry</td>
<td>Advanced Decay</td>
<td>Advanced Decay</td>
</tr>
<tr>
<td>22 Mar 2007</td>
<td>Dry</td>
<td>Dry</td>
<td>Advanced Decay</td>
<td>Advanced Decay</td>
</tr>
<tr>
<td>28 Mar 2007</td>
<td>Dry</td>
<td>Dry</td>
<td>Advanced Decay</td>
<td>Advanced Decay</td>
</tr>
<tr>
<td>5 Apr 2007</td>
<td>Dry</td>
<td>Dry</td>
<td>Advanced Decay</td>
<td>Dry</td>
</tr>
<tr>
<td>12 Apr 2007</td>
<td>Dry</td>
<td>Dry</td>
<td>Advanced Decay</td>
<td>Dry</td>
</tr>
<tr>
<td>19 Apr 2007</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry, almost Remains</td>
<td>Dry</td>
</tr>
</tbody>
</table>

* Indicates site visits where the current temperature was at or below freezing.
Figure 4. Rates of decomposition across study period.
Figure 5. Rates of decomposition tracked by site visit.
Carcass Appearance

Important aspects of results to be discussed include physical observations that might relate to stages of decomposition. Table 3 represents recorded physical observations of each carcass during each site visit. One significant aspect involved teeth. Wolves 1 and 2, in the dry stage, displayed white, polished teeth that were cracked. Wolves 3 and 4 displayed pink teeth that were not cracked while in the advanced decay stage and eventually the dry stage of decomposition. These discernable differences could be used to further differentiate stages of decomposition. Another physical observation to address involves the sunken in appearance of carcass abdomens. It was obvious during observation and photographing on March 28, 2007 that the abdomens of wolves 1, 2, and 3 were more concave than that of wolf 4. During that site visit wolves 1 and 2 were in the dry stage of decomposition while wolves 3 and 4 were in the advanced stage of decomposition. Size could be an effecting possibility, since wolf 4 was the largest specimen placed in the containment areas at 92 lbs. However, it would present a question of whether it was temperature and weather conditions or size of the animal that affected the rate of decomposition.

Other physical observances noted in Table 3 include perforations in the foot pads and evidence of animal activity. Foot pads of all carcasses were marked by many tiny holes that were believed to be caused by larval activity. Moisture from rain and/or snowfall assisted in softening the foot pads, thus rendering them suitable for larvae to feed on.

Animals other than insects utilized the carcasses. The presence of small animals was detected through footprints and disturbances within and around the carcasses. A squirrel was thought to have gained access to a carcass through the fence in both containment areas 1 and 2 during the month of December 2006 (Gonder, personal communication). In February 2007 rodent tracks were observed leading from under one specimen to another in containment area
1 and continuing into containment area 2. Although purely speculation, it was believed a rodent was living under wolf 2 because hair had been obviously pulled away from the posterior end but not pulled out. Also, the tracks only led to the carcass and not away from it (Gonder, personal communication).
Table 3. Recorded observations for appearance.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>6 Oct 2006</td>
<td>Teeth polished and cracked</td>
<td>Teeth polished and cracked</td>
<td>Noticeably pink teeth</td>
<td>Noticeably pink teeth. Incisors 1 and 2 of mandible and maxilla pink on distal aspects.</td>
</tr>
<tr>
<td>8 Nov 2006</td>
<td>carcass wet</td>
<td>carcass wet</td>
<td>carcass wet; abdomen caved in</td>
<td>carcass wet; abdomen not nearly as caved in as W3</td>
</tr>
<tr>
<td>*14 Nov 2006</td>
<td>dusted with snow</td>
<td>dusted with snow</td>
<td>dusted with snow</td>
<td>dusted with snow</td>
</tr>
<tr>
<td>21 Nov 2006</td>
<td>carcass wet</td>
<td>carcass wet</td>
<td>carcass wet</td>
<td>carcass wet</td>
</tr>
<tr>
<td>*6 Dec 2006</td>
<td>snow-covered</td>
<td>snow-covered</td>
<td>snow-covered</td>
<td>snow-covered</td>
</tr>
<tr>
<td>*13 Dec 2006</td>
<td>snow-covered</td>
<td>snow-covered</td>
<td>snow-covered</td>
<td>snow-covered</td>
</tr>
<tr>
<td>*16 Jan 2007</td>
<td>snow-covered</td>
<td>snow-covered</td>
<td>snow-covered</td>
<td>snow-covered</td>
</tr>
<tr>
<td>*25 Jan 2007</td>
<td>carcass exposed and wet</td>
<td>carcass exposed and wet</td>
<td>carcass exposed and wet</td>
<td>carcass exposed and wet</td>
</tr>
<tr>
<td>10 Feb 2007</td>
<td>dusted with snow</td>
<td>dusted with snow</td>
<td>snow-covered</td>
<td>snow-covered</td>
</tr>
<tr>
<td>15 Feb 2007</td>
<td>carcass exposed</td>
<td>carcass exposed</td>
<td>carcass exposed</td>
<td>carcass exposed</td>
</tr>
<tr>
<td>22 Feb 2007</td>
<td>tiny perforations in foot pads</td>
<td>tiny perforations in foot pads</td>
<td>tiny perforations in foot pads</td>
<td>tiny perforations in foot pads</td>
</tr>
<tr>
<td>*1 Mar 2007</td>
<td>mostly snow covered</td>
<td>mostly snow covered</td>
<td>mostly snow covered</td>
<td>mostly snow covered</td>
</tr>
<tr>
<td>8 Mar 2007</td>
<td>carcass wet</td>
<td>carcass wet</td>
<td>carcass wet</td>
<td>carcass wet</td>
</tr>
<tr>
<td>22 Mar 2007</td>
<td>carcass exposed</td>
<td>carcass exposed</td>
<td>carcass exposed</td>
<td>carcass exposed</td>
</tr>
</tbody>
</table>

* Indicates site visits where the current temperature was at or below freezing.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>28 Mar 2007</td>
<td>cracked and polished teeth; abdomen sunken in</td>
<td>cracked and polished teeth; abdomen sunken in</td>
<td>pink and polished teeth; abdomen sunken in</td>
<td>pink and polished teeth</td>
</tr>
<tr>
<td>5 Apr 2007</td>
<td>carcass wet</td>
<td>carcass wet</td>
<td>carcass wet</td>
<td>carcass wet</td>
</tr>
<tr>
<td>12 Apr 2007</td>
<td>mummified tissue that has hardened over previous months; polished and cracked teeth</td>
<td>mummified tissue; polished and cracked teeth</td>
<td>tips of incisors and premolars pink; distal end of left humerus at about 2 inches exposed for first time</td>
<td>pink teeth, more so than W3</td>
</tr>
<tr>
<td>19 Apr 2007</td>
<td>white, polished, and cracked teeth</td>
<td>white, polished, and cracked teeth</td>
<td>pink, polished teeth not cracked</td>
<td>pink, polished teeth not cracked</td>
</tr>
</tbody>
</table>

*Indicates site visits where the current temperature was at or below freezing.
Odor

Odor played a significant role in detecting decay activity. Table 4 represents the presence and absence of odor for each carcass and descriptions of these odors as they apply to each site visit. On rainy days or during periods after rain, odors of carcasses were either nonexistent or had a mildew smell. In general, this occurred whenever the carcasses were damp, such as during or after snowfall and snowmelt, where the dampness of carcasses was also prevalent. However, it was noticed during some site visits that some carcasses emitted strong odors when snow was present.

Site visits where the current temperature was at or below freezing presented interesting information. On January 25, 2007 the current temperature was 32 °F. On that day wolves 3 and 4 were recorded as having stronger, more significant odors even though the carcasses were wet and partially covered in snow. This could indicate internal decomposition activity, including the possibility of insect occupation. More significantly, nearly two weeks later on February 10, 2007 noteworthy insect activity was observed, including the discovery of a later instar larva on the foot pad of wolf 1. This indicates that when temperatures reach the freezing mark, insect activity is prevalent and can be observed.
## Table 4. Recorded Levels of Odor

<table>
<thead>
<tr>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>6 Oct 2006</td>
<td>not recorded</td>
<td>not recorded</td>
<td>not recorded</td>
<td>not recorded</td>
</tr>
<tr>
<td>8 Nov 2006</td>
<td>mildew-like</td>
<td>mildew-like</td>
<td>mild and mildew-like</td>
<td>stronger, more acerbic</td>
</tr>
<tr>
<td>*14 Nov 2006</td>
<td>mild</td>
<td>mild</td>
<td>mild</td>
<td>mild</td>
</tr>
<tr>
<td>21 Nov 2006</td>
<td>mild</td>
<td>mild</td>
<td>mild and mildew-like</td>
<td>average and mildew-like</td>
</tr>
<tr>
<td>*6 Dec 2006</td>
<td>mild</td>
<td>mild</td>
<td>mild</td>
<td>mild</td>
</tr>
<tr>
<td>*13 Dec 2006</td>
<td>mild</td>
<td>mild</td>
<td>mild</td>
<td>mild</td>
</tr>
<tr>
<td>*16 Jan 2007</td>
<td>mild</td>
<td>mild</td>
<td>mild</td>
<td>mild</td>
</tr>
<tr>
<td>*25 Jan 2007</td>
<td>non-existent</td>
<td>non-existent</td>
<td>stronger, more significant</td>
<td>stronger, more significant</td>
</tr>
<tr>
<td>10 Feb 2007</td>
<td>robust</td>
<td>robust</td>
<td>average</td>
<td>average</td>
</tr>
<tr>
<td>15 Feb 2007</td>
<td>faint and difficult to detect</td>
<td>faint and difficult to detect</td>
<td>mild to average</td>
<td>mild to average</td>
</tr>
<tr>
<td>22 Feb 2007</td>
<td>average</td>
<td>average</td>
<td>average</td>
<td>average</td>
</tr>
<tr>
<td>*1 Mar 2007</td>
<td>mild</td>
<td>mild</td>
<td>mild</td>
<td>mild</td>
</tr>
<tr>
<td>8 Mar 2007</td>
<td>mild</td>
<td>mildew-like</td>
<td>mild</td>
<td>mild</td>
</tr>
<tr>
<td>22 Mar 2007</td>
<td>mild and mildew-like</td>
<td>mild and mildew-like</td>
<td>very mild</td>
<td>slightly stronger than W3 but still mild</td>
</tr>
<tr>
<td>28 Mar 2007</td>
<td>mild, wet, and mildew-like</td>
<td>mild, wet, and mildew-like</td>
<td>mild, but stronger than W1 and W2</td>
<td>mild</td>
</tr>
<tr>
<td>5 Apr 2007</td>
<td>mild and mildew-like</td>
<td>mild and mildew-like</td>
<td>mild and mildew-like</td>
<td>mild and mildew-like</td>
</tr>
<tr>
<td>12 Apr 2007</td>
<td>slightly stronger but mild and mildew-like</td>
<td>slightly stronger but mild and mildew-like</td>
<td>slightly stronger</td>
<td>noticeably stronger at mild to average</td>
</tr>
<tr>
<td>19 Apr 2007</td>
<td>mild and mildew-like</td>
<td>mild and mildew-like</td>
<td>mild and mildew-like</td>
<td>noticeably stronger at mild to average yet mildew-like</td>
</tr>
</tbody>
</table>

* Indicates site visits where the current temperature was at or below freezing.
Insect Presence and Activity

With the temperatures witnessed during this project, the amount of activity observed is no wonder. Table 5 represents these observances and tracks insect activity over the 18 site visits. An example of the presence of a freeze-thaw effect occurred on March 8, 2007 exactly one week after a previous site visit on March 1, 2007 where the current temperature was 28 °F. On March 8, a later instar larva was observed on the back right foot pads of wolf 1. Snow depth had reduced from 3+ inches to light patches of snow in one week. This further supports the hypothesis of internal insect activity re-emerging once the carcass becomes exposed. All larvae observed during these colder temperatures measured .5-1 centimeters long or smaller, indicating that these could very well be the offspring of the unidentified small flying insects previously observed (Gonder, personal communication).

Another important observation involves insect activity as it relates to the decomposition rate of wolf 3. In Table 5, it appears that wolf 4 experienced more insect activity and this could be a legitimate reason as to why wolf 3 decomposed slower.

More insect activity that presents questions involves the unidentified hopping insects that dominated snow-covered carcasses. On days when no carcass was visible due to snow depth, tiny unidentified hopping insects were observed on top of each carcass (see Figure 6). They existed in groups of two or three and seemed to only be present when the sun was absent. It is uncertain as to if these insects were attracted to the carcasses or to the snow, since that was the only time they were observed (Gonder, personal communication).

Also observed was the activity of flying insects. It became a noticeable pattern that when the sun was out and temperatures were suitable, flying insects were present. Weather
conditions including snow, rain, clouds, and fog, seemed to deter these insects. It also became apparent that flying insects were not observable below freezing temperatures.

All types of insect succession were observed on wolf carcasses 1 through 4. Insects including Diptera (flies), Coleoptera (beetles), Arachnida (spiders and mites), Hemiptera (true bugs), and Hymenoptera (ants and wasps) occupied carcasses at various stages of decomposition (Johnson, 2007). Insects described as “unidentified hopping insects” might be associated with the order Diptera, more specifically from the super family Sphaeroceridae (see Figure 6).

Figure 6: Dipteran species on wolf 3.
Table 5: Insect presence and activity.

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<tbody>
<tr>
<td>Wolf 1</td>
<td>hair being relocated by insect activity</td>
<td>no insects recorded</td>
<td>no insects recorded</td>
<td>no insects recorded</td>
<td>unidentified small flying insects</td>
<td>no insects recorded</td>
<td>no insects recorded</td>
</tr>
<tr>
<td>Wolf 2</td>
<td>hair being relocated by insect activity</td>
<td>no insects recorded</td>
<td>no insects recorded</td>
<td>no insects recorded</td>
<td>unidentified small flying insects</td>
<td>no insects recorded</td>
<td>no insects recorded</td>
</tr>
<tr>
<td>Wolf 3</td>
<td>minimal insect activity; pupae; larvae; hair being relocated by insect activity</td>
<td>unidentified insect without wings collected from abdomen</td>
<td>no insects recorded</td>
<td>unidentified flying insect observed</td>
<td>no insects recorded</td>
<td>unidentified small flying insects</td>
<td>no insects recorded</td>
</tr>
<tr>
<td>Wolf 4</td>
<td>black caterpillar; hair being relocated by insect activity</td>
<td>two unidentified insects without wings were collected from mouth</td>
<td>no insects recorded</td>
<td>no insects recorded</td>
<td>unidentified flying insect</td>
<td>unidentified small flying insects</td>
<td>no insects recorded</td>
</tr>
</tbody>
</table>

* Indicates site visits where the current temperature was at or below freezing.
<table>
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</thead>
<tbody>
<tr>
<td>Wolf 1</td>
<td>no insects recorded</td>
<td>later instar larvae identified on foot pad; larvae approximately .5-1.0 centimeters long; tiny hopping insects observed</td>
<td>tiny hopping insects observed; unidentified larger insect observed</td>
<td>larvae observed; tiny hopping insects identified; tiny hopping insects observed; larger hopping insect observed</td>
<td>tiny hopping insects observed</td>
<td>* indicates site visits where the current temperature was at or below freezing.</td>
</tr>
<tr>
<td>Wolf 2</td>
<td>no insects recorded</td>
<td>tiny hopping insects observed</td>
<td>tiny hopping insects observed; unidentified large insect with long body observed</td>
<td>larvae observed; tiny hopping insects observed; larger hopping insect observed</td>
<td>tiny hopping insects observed</td>
<td>later instar larvae observed in back right foot pads</td>
</tr>
<tr>
<td>Wolf 3</td>
<td>no insects recorded</td>
<td>2 unhatched pupae observed on abdomen; tiny hopping insects observed</td>
<td>tiny hopping insects observed; unidentified large insect with long body observed</td>
<td>larvae observed; tiny hopping insects observed; larger hopping insect observed</td>
<td>tiny hopping insects observed</td>
<td>no insect activity observed</td>
</tr>
<tr>
<td>Wolf 4</td>
<td>no insects recorded</td>
<td>pupae mass, old and hatched, on posterior end; tiny hopping insects observed; unidentified large insect with long body observed</td>
<td>tiny hopping insects observed; unidentified large insect with long body observed</td>
<td>larva identified on the second maxillary premolar; tiny hopping insects observed; larger hopping insect observed</td>
<td>tiny hopping insects observed</td>
<td>old larvae in later instar on back left leg, apparently dead since fall</td>
</tr>
</tbody>
</table>

* Indicates site visits where the current temperature was at or below freezing.
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Wolf 1</td>
<td>unidentified flying insect observed; unidentified hopping insect observed</td>
<td>large fly collected for observation and identification from cheek</td>
<td>unidentified small flying insect observed</td>
<td>unidentified hopping insects observed</td>
<td>insect activity observed</td>
</tr>
<tr>
<td>Wolf 2</td>
<td>unidentified hopping insects observed</td>
<td>no insect activity observed</td>
<td>no insect activity observed</td>
<td>no insect activity observed</td>
<td>moth identified inside mouth on upper lip</td>
</tr>
<tr>
<td>Wolf 3</td>
<td>unidentified hopping insect observed</td>
<td>unidentified small ant-type insect observed</td>
<td>unidentified hopping insect observed</td>
<td>unidentified ant-type insects observed</td>
<td>no insect activity observed</td>
</tr>
<tr>
<td>Wolf 4</td>
<td>unidentified tiny hopping insect observed; unidentified insect observed on right rear leg</td>
<td>2 tiny hopping insects observed</td>
<td>no insect activity observed</td>
<td>3 unidentified ant-type insects observed</td>
<td>no insect activity observed</td>
</tr>
</tbody>
</table>

* Indicates site visits where the current temperature was at or below freezing.
The interest in the effects of the freeze-thaw cycle and the Montana environment on decomposition was generated by a case analyzed by the Department of Anthropology at the University of Montana. On April 19, 2005 the department received a case containing the skeletal remains of an unidentified human. Although no obvious perimortem trauma was observed, the remains had been thoroughly scavenged (McKeown et al., 2005).

The remains were mostly skeletonized with only desiccated soft tissue adhering. After storage in the laboratory, both maggots and beetles were present with the skeletal material, especially on the os coxae and skull. After the insects were collected and analyzed, they were identified. The maggots, which measured between 6.65 mm to 7.16 mm in length, were identified as *Piophilidae casei* sp. larva, or cheese skippers, due to their signature behavior of jumping when threatened or disturbed. These larvae were a larger size, indicating that they were in a 2nd or 3rd instar, thus being associated with a late stage of decomposition (Suzukovich, 2005). Although the remains were skeletonized and heavily scavenged, enough soft tissue still remained to accommodate maggot feeding. The beetles were identified as Nitidulidae *Omosita discoidea* Fabricius, or sap beetles, by Montana State University IPM/Insect Diagnostic Laboratory entomologist Dr. William Lanier. Based on insect information and the presence of adhering desiccated tissue as well as evidence of extensive animal scavenging case examiners believed the condition of the remains to be consistent with a postmortem interval of at least one year (McKeown et al., 2005).
Eli Suzukovich, a student from the University of Montana Anthropology Department, analyzed entomological evidence from the case. Based on Barnes’ (2000) observance of increased Piophilidae sp. activity in Mid-July and October, Suzukovich (2005) proposed that this individual had died possibly around mid-June to mid-August, 2004, which is less than one year from recovery. In his experimental study of burned and unburned pig carcasses, Barnes (2000) identified Piophilidae in the stage of decomposition he labeled Post-Decay Stage, which he classified as 14-37 days after death. In the Remains Stage, which Barnes classified from 38 days + following death, he observed a significant increase of Piophilidae, especially in Mid-July and October (Barnes, 2000 p.24). More significantly, after adults had mated and laid their eggs in the month of October, the adults were no longer seen (Barnes, 2000 p.24). The Piophilidae larvae discovered from the skull, innominate, and long bones of the described case were in a later instar and very likely came from eggs laid in 2004 prior to the first consistent days of cold ambient temperatures, which was documented by the National Weather Service as October 16, 2004. Suzukovich (2005) believed this information to be consistent with that of Barnes (2000), who witnessed a cease in Piophilidae adult activity after in month of October.

The Piophilidae are mostly scavengers and are often found around carcasses, bones, garbage, and any highly proteinaceous foods of the drier kind (Smith, 1986 p.90). The larvae of *Piophila casei* (L.), are also known as the “cheese-skipper,” which are noted to curl, jump or “skip” when threatened or disturbed. An early study by M.G. Motter (1898) found remains of *P. casei* in ten of the 150 graves he examined, which were anywhere from three to ten years old and three to six feet deep. Although no ideas
were presented of as to how the flies entered the grave, it was proof enough that
oviposition in a dark environment is certainly possible (Smith, 1986 p.93).

Not only was it proven that these larvae could oviposit in the dark, many years
later it was discovered that such larvae could survive extreme temperature changes.
Smart (1935) found that these larvae could survive temperatures as high as 52 °C, or 125
°F, for one hour and 45 °C, or 113 °F, for a 24 hour exposure (Smith, 1986 p.90). At
high temperatures eggs were observed to hatch in one day and larval stages were
completed in about five days, while emergence from the pupal stage could occur in 5-8
days (Smith, 1986 p.90).

According to insect information gathered from the University of Montana case,
including the observance of increased Piophilidae sp. activity, Suzukovich (2005)
believed the individual to have died during the summer of 2004, thus challenging the
original time since death estimation of at least one year. However, there is an obvious
inconsistency with insect activity and the decomposition stage in which the individual
was found. According to McKeown et al. (2005) enough soft tissue still adhered to
accommodate maggot feeding. However, the individual was in the remains stage of
decomposition at the time of discovery and the adhering tissue were only desiccated
scrap. It can be stated that the individual did not die during the winter season due to the
presence of later instar Piophilidae which have been observed in other studies (Barnes,
2000; Smith, 1986) mainly during the months of June to October. However, if the
individual had died in the summer of 2004 it is likely that there would be more tissue for
arthropod consumption. It is more feasible that the individual died sometime during the
summer or fall of 2003 or spring of 2004, more towards periods when Piophilidae sp. were still active.

It is also very possible that the individual experienced a series of freeze-thaw events, allowing insects to over-winter and emerge in a later instar once temperatures were most suitable. As seen in this study with wolves, two carcasses laid out to decompose beginning in the month of June do so at a completely different rate than those laid out to decompose beginning in the month of September. Although maggots were discovered on the foot pad of wolf 1 during the month of February, structural differences between wolves and humans must be considered (i.e. fur, foot pads, body fat content). Regardless of these differences, the individual from the University of Montana case probably died somewhere during late summer, early fall of 2003 or spring of 2004 to allow for extensive decomposition and the remains stage of decay.

Morton and Lord (1999) stated that buried bodies experienced slower decomposition rates, since oxygen was greatly reduced and bacterial putrefaction through cooler, more homogenous temperatures slowed typical rates of decay. Perhaps this concept can be applied to snow pack on carcasses. However, it should be noted that snow is an insulator and creates warmer pockets of air around the covered carcass (Gonder, personal communication). The idea, well-expressed in this article, might apply in that snow-buried carcasses might suppress insect colonization. Perhaps a more advanced study could compare wolf decomposition rates to those of pigs, preferably specimens of similar size, to see the differences in insect colonization and decomposition rates.
Temperature Variance

The importance of temperature in decomposition studies can be demonstrated by analyzing the similarities and differences between the results of this project and those of Johnson (1975), Terneny (1997), and Micozzi (1997). Johnson (1975) used smaller research specimens, such as rabbits and a cat, in order to study stages of decomposition in Illinois. He followed each animal’s progression through stages of decay. Most significantly, Johnson (1975), after noticing the specimens remained in the bloat stage for a prolonged period during colder temperatures, stated that in a cold environment, or when a carcass is exposed to cycles of freezing and thawing, the bloat stage can persist for several weeks (Johnson, 1975). Although Johnson (1975) combined some stages of decay (active with advanced) he was able to track their progression from 35 days to nearly 8 months. A series of three depositions took place where specimens were laid out from March to May, June to August, and September to November. Carcasses exposed from March to May decomposed at similar rates to those exposed from September to November.

Data from Johnson’s (1975) research can be compared to the data collected from this project in that wolves 1 through 4 progressed though the fresh and bloat stages at very similar rates (within 2-3 weeks). However, the variation occurs once the active decay stage commenced. In late June, early July wolves 1 and 2 spent as little as two weeks in this stage, while it took nearly a month for wolves 3 and 4 to progress into the advanced stage of decay, beginning in mid-October. While wolves 1 and 2 spent July through September (2 months) in the advanced stage of decay wolves 3 and 4 took much longer. Wolf 3 spent mid-October to May (6 ½ months) in the advanced decay stage.
Wolf 4 spent mid-October to April (5 ½ months) in the advanced decay stage. Wolves 1 and 2 remained in the dry stage of decomposition for all recorded site visits and never reached a remains stage. Wolves 3 and 4 also never reached the remains stage during recorded observations. It can be said that, like Johnson’s (1975) study, wolves laid out to decompose in the spring could possibly do so at similar rates to those set out in the fall.

Terneny (1997) observed prolonged stages of bloat during colder temperatures in her study just as did Johnson (1975). Terneny (1997) observed pig carcasses from April to July. She noticed that when temperatures fluctuated and hit a low of 47 °F carcasses would deflate and then bloat again once those temperatures increased. While in the active decay stage Terneny (1997) noticed an increase in insect activity on carcasses on days following rain. The advanced decay stage was governed by consistent temperatures and therefore occurred rather quickly (June 21 – July 6, 1996). Although the wolves in the presented study witnessed harsher weather conditions, data from Terneny’s (1997) research can be applied. Wolves 1 through 4 were observed as having “sunken in” abdomens which helps to indicate the stage of decomposition each carcass was in. However, the abdomen of wolf 4 was recorded on November 8, 2006 as being not as caved in as wolf 3. The current temperature for that site visit was 43 °F and some precipitation existed in the form of rain. Although already in the advanced stage of decomposition, wolves 3 and 4 decomposed at different rates. The “sunken in” appearance of the abdomens could indicate the rate of insect activity as it occurred inside the carcass. If the insects were feeding from the inside during times where internal tissue was available for consumption, the abdomen of each carcass could be noticeably reduced by this activity.
Micozzi (1997) conducted an experimental study where he compared the decomposition rates of fresh-killed animal carcasses with frozen carcasses in a controlled environment. He discovered that carcasses that were frozen then thawed appeared to decomposed form the outside in, while the fresh-killed animals did so from the inside out. Micozzi (1997) explains that this study can be directly compared to human remains. He states that humans might over winter and be discovered in the spring or summer, following one or more freeze-thaw cycles, and after the onset of postthaw decompositional changes (Micozzi, 1997 p.177). This idea offers a great opportunity for comparison of data in the present study. During site visits where carcasses were snow-covered odor was still recorded as present. On the site visit of February 15, 2007 odor for wolves 3 and 4 were recorded as mild to average. The current temperature was 41 °F with a snow accumulation of 5-6 inches in containment area 2. Carcasses were very much snow-covered but a decomposition odor was still detectable. This further supports the idea of internal decomposition but disagrees with Micozzi’s (1997) proposal of the freeze-thaw cycle allowing for carcasses to decay from the outside in, since this presence of odor tends to represent internal activity where the carcass is decaying from the inside out. However, it can be said that for carcasses covered in snow insects are forced to remain in an environment that allows them to generate heat and feed on any available material. It is when the melting of snow takes place and the carcass thaws that insects can re-emerge to continue their process.

It is known that insect development is temperature dependent. The metabolic rate of an insect increases with increased temperatures, and this results in a faster rate of development (Chapman, 1980 p.305). The duration of development decreases in a linear
manner with increased temperature and vice versa within optimum temperatures for that species (Chapman, 1980 p.305). Anderson (1999) further explains that insects are only active during warm weather and are also active during winter in climates that are warmer than Canada. She states that if a person is found in winter in a climate such as Canada with no insects associated with the corpse, then that individual probably died after the insect season for that particular region. However, if the victim found in winter has evidence of insect colonization, then they died prior to the onset of winter (Anderson, 1999 p.318).

When decomposition rates were observed for wolf carcasses in a northwestern Montana biogeoclimatic zone insect activity was observed when current temperatures were recorded at a cool 38 °F. On Saturday February 10, 2007 tiny larvae were observed on the foot pads of wolf 1 and advanced development suggested a later generation of insect. Larvae were approximately 1 to .5 centimeters long (Gonder, personal communication). The foot pads of wolf 1 were gelatinous in texture and therefore allowed for easy processing by larvae mouth parts, which are designed to break down soft tissue. Four days earlier, on February 6, 2007, larvae were observed by Gonder on wolf 1 and wolf 2. Temperatures that day had reached nearly 53 °F (Gonder, personal communication). So, with the knowledge of temperature fluctuations as witnessed in this project during the winter season in northwestern Montana, it is possible for the re-emergence of insects to occur during warmer periods, depending on food availability. If temperatures allow for the softening of tissues, it seems insects thrive despite cold temperatures. But where do they reside when food availability appears to be scarce?
During site visit 17 (April 12, 2007) the current temperature was recorded at 45 °F. Wolf 3 still remained in the advanced stage of decomposition as it had been since November 8, 2006. The site visit the following week (April 19, 2007) wolf 3 had finally progressed into the dry stage of decomposition. During that site visit the current temperature was 40 °F. However, during the previous week temperatures had reached at least 50 °F, thus allowing for wolf 3 to quickly transition from the advanced stage to the dry stage of decomposition. Odor for wolf 3 was recorded on April 12, 2007 as strong, which could very well have been an indication of an increase in decay activity.

It is also interesting to point out within the data of this project the relationship between temperature and odor. On both site visits 7 (January 16, 2007) and 8 (January 25, 2007), carcasses experienced some of the lowest temperatures recorded during this study. On January 16, 2007 the current temperature was 15 °F and temperatures ranged from 7 – 15 °F in a 24 hour period. Snow accumulation ranged from 4-6 inches. Odor was recorded as mild. However, nearly one week later on January 25, 2007 odor was much stronger and much more significant. The current temperature was 32 °F and had ranged from 20 – 41 °F within a 24 hour period. Little snow existed on the carcasses, with just a minimal amount of coverage. This noted transition from a faint, almost non-existent smell to a strong odor within one week during the coldest noted winter month is significant. It further solidifies the tight relationship between temperature and odor as it relates to the decomposition process.
Discerning Larval Succession

These types of temperature fluctuations are not unusual for this time of year in northwestern Montana. What is unusual, however, is the noted presence and absence of insect species and their offspring. This presence and absence is characterized by the process of freezing and thawing as a result of these temperature fluctuations. It is obvious that insects over-winter in the carcass, since later instar larvae were observed on the footpad of wolf 1 and in the mouth of wolf 4. If a fly lays eggs on a day such as March 8, when temperatures were relatively warm within the past 24 hours, and temperatures remained consistent, those eggs would hatch and feed on any type of soft material available. However, what happens when temperatures suddenly decrease and winter conditions, including snowfall, occur? How do you determine if those larvae in the later instar over-wintered or just emerged from the warm spell? Forensic scientists who rely on entomology and larvae succession in a case may not be able to do so in climates such as northwestern Montana, since the extent of the effects of the freeze-thaw cycle or really the difference between larvae that survived the winter and those who hatched later during warmer temperatures is unknown.

Larvae, such as Piophilidae sp., are able to survive cold weather by generating heat when congregating together. This is how the over-wintering of larvae prevails. Pickering and Bachman (1997) state that at high elevations with frequent temperature extremes, repeated freezing and thawing accelerate decomposition (Pickering and Bachman, 1997 p.100). Although this might be true, the condition of remains after initial stages of decay occur is also important to study because the carcass is still very much active. Wolf carcasses 1 through 4 were laid out in warm weather and decomposed
quickly. However, these carcasses never reached a remains stage, as Terneny (1997) classified as complete termination of insect activity and possible remnants of dried skin. Wolves 1 through 4 entered the coldest months (November to March) in advanced decay and dry stages where fur and skin was very much present. During these cold months, insect activity was observed when temperatures allowed for the softening of available tissue on the carcasses. Fluctuating temperatures created signature opportunities for insects to re-emerge to continue the process they started. However, with so much variation in temperature, even on a day-to-day basis, it is difficult to distinguish the duration larvae have encountered on each carcass. There may be no method of discerning larvae that lived through the winter and those who hatched in warmer weather but then again witnessed cold or snowy conditions.

Humans might experience a very similar situation during the decomposition process in cold, arid climates where significant freeze-thaw cycles occur. As previously mentioned, wolves and humans have obvious physical distinctions that might affect the comparable rates of decomposition. However, the presence of insects during these cold, arid conditions is undeniable. As long as there are materials available for insects to feed, they will be present regardless of temperature. Insects are capable of retreating to areas within and around a body that are most accommodating during undesirable weather conditions. They can generate heat and are able to survive temperatures well below freezing as observed at the Lubrecht Forest. Where insects go when conditions are unfavorable is a question that unfortunately cannot be answered in these pages. However, if insects are capable of surviving in wolf carcasses during phases of warm and cold weather, they are certainly capable of the same behavior in humans.
The summer wolves in this study decomposed at completely different rates than did wolves placed in the fall. However, two specimens that were set out at identical times decomposed differently. It is difficult to state whether or not humans could decompose at the same rates as summer wolf specimens and fall wolf specimens. If a human were to decompose beginning in the summer months, the rate of decay would be similar to that of wolves 1 and 2, which experienced standard transitions from stage to stage within 3 to 4 months. It is likely that humans would also experience the same types of freezing and thawing that occurred in this project if exposed to conditions such as those typical of a northwestern Montana climate. For wolves 1 and 2 the winter months assisted in preserving enough tissue to allow for insect survival, even if most of the soft tissue has been removed. Periods of freezing and thawing might have actually aided in the continuance of arthropod generations. Humans would most likely experience the same arthropod survival, that is if barriers existed to protect species from environmental factors thus providing a food source and a place to retreat.

Wolves 3 and 4 are comparable to human specimens, as well. While wolves 1 and 2 progressed from the active stage of decomposition to the advanced stage of decomposition in as little as 2-3 weeks, wolves 3 and 4 took nearly twice as long to reach the advanced stage of decomposition at nearly one month. Humans, regardless of their structural differences with wolves, would most likely witness very similar decomposition patterns where humans exposed in June would more quickly reach the advanced stage than humans exposed in September. In turn, this would cause a series of differentiating insect occupation based on the availability of adhering tissue. When exposed during winter months, humans might decompose at a faster rate due to more exposure of skin
and an absence of a thick coat of fur to assist in protecting from the elements. However, it is important to note here that human skin is composed of three layers - the epidermis, dermis, and hypodermis, which provides a thick barrier. Also, obviously not all people are the same size. Somatotyping is a method of categorizing humans into three different categories based on size: ectomorphs (thin-bodied), endomorphs (thick-bodied), and mesomorphs (in between). These differences exist not only in body form but also in internal anatomy of structures. The variations in size among human organisms could also affect the rate of decomposition. Variables such as clothing might also affect the rate at which a human would decay in a climate such as northwestern Montana. The condition in which the body was disposed of, if applicable, such as covered in plastic where some type of barrier is present, might also alter this process. It is not until more advanced studies involving these types of scenarios take place that this information can be confirmed.

Wolf foot pads are surrounded by stiff, bristly hair, which acts as insulation. Also, wolves tend to have much narrower chests than most canines their size, and the growth of a winter coat obviously provides an even thicker barrier to the elements. All of these physiological traits could affect the rate of decomposition.
CHAPTER 5: CONCLUSIONS

With the use of animal carcasses as subjects to scientific experimentation, we were able to observe the changes a specimen endures during the decomposition process. Furthermore, we were able to use that information as a paradigm for inferring patterns of decomposition for human beings. Although wolves 1 through 4 decomposed at a rate comparable to past studies of decomposition stages, these specimens told a unique story about the climate of northwestern Montana. From fluctuations in odor to variations in insect activity, it is obvious that decomposition of the carcasses proceeds during the winter months, where temperatures and weather conditions frequently change and can be extreme.

Observations of entomological activity yielded perhaps the most valuable information concerning the decomposition process, more specifically the freeze-thaw process as it occurs in northwestern Montana. Insect activity on carcasses that were covered in snow was observed. Insect activity on the foot pads of wolf 1 and on the gums of wolf 4 were observed even when current temperatures were at freezing. This solidified the hypothesis that carcasses can remain active throughout Montana winter weather conditions.

However, there is much more research that needs to be extended for a project of this caliber. It is still somewhat of a mystery as to the activity that takes place inside a carcass during not only winter months but during the entire decomposition process. As we discovered, insect larvae can emerge and re-emerge depending on food availability but where do they come from and where do they go when those conditions are not
suitable? This question can be answered through a future study where close surveillance of insect behavior is examined. The observance of internal aspects of a carcass would be the best way to do this, possibly with the use of cameras. A method of placing cameras inside a carcass without disturbing the decomposition process is a challenging one. Another aspect of decomposition studies that needs attention is temperature beneath carcasses on the surface of the soil in order to record temperatures of air space and also to explore possibilities of insulation from snow (Gonder, 2007). Wolves 1 and 2 had polished and cracked teeth as of March 28, 2007 while wolves 3 and 4 still displayed pink teeth at that time. Studies examining details of this process are necessary, since this, too, can yield information concerning the time since death interval.

Of course, an expansion of this type of project is necessary in other parts of the country, since no two climates are exactly alike. And finally, a transition from carnivores and ungulates to Sus Scrofa, or pig specimens, and eventually human specimens is ideal in order to fully examine the process of human decay in a climate such as northwestern Montana. Although the specimens used in this study contributed characteristics dissimilar from human beings, such as the prevalence of fur, the information they provided can still be appropriately applied to humans.

Up until my final site visit on May 3, 2007 wolves 1 through 4 were still in the dry stage and were not yet in the remains stage. It is uncertain as to how long these specimens will linger in this phase but this is significant since past research, including that of Pickering and Bachman (1997), has supported the idea that a constant rate of freezing and thawing greatly accelerates decomposition. In fact, the carcasses at
Lubrecht Forest told a different story, where rates of decay and the processes that surround them, are extremely unpredictable.


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