Wintertime Observations on Pig (Sus Scrofa) Decomposition

David Glynn McBride
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WINTERTIME OBSERVATIONS ON PIG
(Sus scrofa) DECOMPOSITION

by

David Glynn McBride

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
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Finally, I must extend my deepest thanks to my parents, Mary Jo and Glynn McBride, whose seemingly limitless support and encouragement has made everything possible, and to my dearest friend, Lisa Ruppert. This project would never have been completed without you.

David Glynn McBride
WINTERTIME OBSERVATIONS ON PIG
(Sus scrofa) DECOMPOSITION

David Glynn McBride, M.A.
Western Michigan University, 1994

Detailed knowledge of the behavior of insects and other arthropods associated with decomposing remains is essential to estimate the time since death. To date, many studies have been conducted on human and animal decomposition rates in warm and/or humid climates, but little is known about decomposition rates in a northern wintertime environment. This study was undertaken to document the progression of decay and arthropod activity under these conditions and provide data that can be utilized for estimating time since death in such climates.

Six stillborn pigs (Sus scrofa Linnaeus) were placed in cages in a woodlot near Western Michigan University from January through May, 1992. Air, soil, and carcass temperatures, decomposition, and arthropod activity were monitored daily. Carcass decomposition was divided into two stages: Stage I was marked by minimal arthropod activity due to periods of freezing and thawing, which also slowed decay rates substantially. Stage II was dominated by the development of large colonies of adult and larval carrion beetles (Coleoptera: Silphidae), which rapidly skeletonized the remains. No other species were observed in sufficient numbers to affect decomposition.
TABLE OF CONTENTS

ACKNOWLEDGMENTS ................................................................. if

LIST OF TABLES ....................................................................... vi

LIST OF FIGURES ..................................................................... vii

CHAPTER

I. INTRODUCTION .................................................................... 1

II. LITERATURE REVIEW ......................................................... 5

III. METHODS AND MATERIALS .............................................. 11

   Preparation ........................................................................ 11

   Observation Techniques ...................................................... 14

   Specimen Collection and Preservation ............................... 16

   Equipment .......................................................................... 17

   Cages ................................................................................ 17

   Thermometers .................................................................... 18

IV. STUDY AREA ..................................................................... 20

V. STUDY RESULTS ................................................................. 23

   Stage I: Weeks 1-14 .......................................................... 26

   Stage II: Weeks 14-20 ........................................................ 30

VI. DISCUSSION OF STUDY RESULTS

   AND SPECIES COLLECTED .............................................. 35
Table of Contents—Continued

CHAPTER

VII. SUMMARY AND CONCLUSIONS ......................................................... 44

APPENDICES ......................................................................................... 48

A. Taxonomic List of Species Collected, Showing Approximate
   Duration and Proportion of Species’ Presence at Study Site .................. 49

B. Summary Data for Air, Soil and Carcass Temperatures
   and Precipitation .............................................................................. 52

BIBLIOGRAPHY ..................................................................................... 59
LIST OF TABLES

1. List of Some Vertebrate Species
   Commonly Seen in Study Area................................................................. 22

2. Temperature Interstices of Stage 1.......................................................... 26

3. Recorded Carcass Weights and Lengths..................................................... 28

4. Observed Minimum Temperature Tolerances and Activity
   Threshold Ranges for Six Arthropod Species (Celsius)................................. 43
LIST OF FIGURES

1. View of the Study Site ................................................................. 13

2. Group 1 (Pigs 1-3) on Date of Placement:
   January 9, 1992 ........................................................................ 24

3. Group 2 (Pigs 4-6) on Date of Placement:
   February 11, 1992 ..................................................................... 25

4. Silphid Colony on Pig 5:
   April 21, 1992 .......................................................................... 31
CHAPTER I

INTRODUCTION

Human remains discovered in wooded areas, fields, or other locations present forensic scientists with many questions about the identity of the deceased, possible cause of death, and the time interval since death (Rodriguez and Bass 1983, 1985). Forensic anthropologists and entomologists are often uniquely qualified to provide information in this regard through professional experience with skeletal or decomposing remains and reference to data acquired from previously described cases.

Forensic anthropology typically focuses on estimation of the age, stature, and identity of the deceased, as well as the estimation of postmortem interval and possible cause of death, through examination of the skeletal remains. The objective of forensic entomology is primarily to assess postmortem interval through examination of arthropod activity on, or associated with, remains at all stages of decomposition. Forensic anthropology and forensic entomology are therefore closely related by the mutual objective of the estimation of postmortem interval. It is on the basis of this relationship that the present research was undertaken.

This study is designed to provide fundamental data from which to anticipate the nature of decay and faunal succession in subsequent studies of human or large animal remains under environmental conditions similar to those outlined below. By
examining the progression of decomposition and arthropod inhabitants of baby pig 
(*Sus scrofa* Linnaeus) carcasses for a known postmortem interval from winter to 
spring, this study adds to the overall body of knowledge applicable to both anthropol­
ogy and entomology.

In order to make estimates of postmortem interval more accurately, it is essen­
tial that forensic scientists have a broad database from which to draw their conclu­
sions. The most effective way to add to the available data is by conducting controlled 
studies in natural, as opposed to laboratory, settings because of the wide range of vari­
ables that affect decomposition, such as temperature, precipitation, and insect activity 
(Mann, Bass, and Meadows 1990).

Human cadavers are, of course, the ideal subjects for such field studies, and 
have been used by Haskell (personal communication 1994), and Rodriguez and Bass 
(1983, 1985) in studies at the University of Tennessee, Knoxville. The Consortium of 
American Forensic Entomologists (C. A. F. E.) has sanctioned the use of domestic 
pigs (*S. scrofa*) as the most appropriate substitute (Goff 1989). The recommendation 
calls for pigs of fifty pounds or larger to be used, to approximate the size and weight 
of human cadavers and permit the most direct extrapolation of data to human cases.

Payne (1963) used several species in preliminary studies, including toads, dogs, 
chickens and rabbits collected from roadsides. All were found less than ideal for sys­
tematic study due to thick fur or feathers (which made observations difficult), lack of 
uniformity in body size, and indeterminable time of death. He finally settled on baby 
pigs (*S. scrofa*) as the most satisfactory species. Baby pigs that died perinatally of
natural causes were selected for this study based on their availability and the criteria outlined by C. A. F. E. and Payne.

Numerous studies have documented the decomposition of plant and animal remains under varying conditions of exposure. Most were conducted from an entomological or ecological viewpoint (Fuller 1934; Chapman and Sankey 1955; Payne 1963, 1965; Johnson 1975). In the last few years, there has been an increase in the number of studies that focus on insect succession as it relates to forensic science. This shift in perspective has led researchers to examine human and animal remains, with emphasis on the insects which play a direct role in the decay process.

Smith (1986) points out the need to conduct studies in as many geographical areas as possible, since there is considerable variation in environmental factors and insect species distribution. Catts and Haskell (1990) also stress the significance of the local environment, noting that insect activity and development are closely tied to temperature and humidity. Smith (1986:33) noted a near absence of decomposition studies conducted in wintertime, especially in cold climates. Consequently, there are limited data from which to infer the nature of decomposition and faunal succession (if any) for human remains deposited after the onset of cold weather.

On January 9, 1992, the first three of a total of six baby pigs were placed in a one hectare (2.4 acres) woodlot approximately 1.5 kilometers from the campus of Western Michigan University to describe decompositional progression and insect succession on remains in a cold-climate, wintertime setting. The second group of three pigs was placed on February 11, 1992.
The study area was chosen for its seclusion, to ensure that the carcasses were not disturbed by human activity, and for its accessibility, since inspections were to be made at least once daily. Carcasses were placed in three separate cages, two of which were adjacent to one another. The third cage was located approximately five meters away to reduce the possibility that arthropods attracted to one group were drawn from the other, as suggested by Reed (1958).

Carcass decomposition was divided into two major stages. Stage I was largely free of insect activity and marked by several alternating periods of freezing and thawing. Stage II began on April 15, and was characterized by the destruction of the carcasses by large, intermingled colonies of two species of carrion beetles, *Silpha inaequalis* Fabricius and *Silpha noveboracensis* Forster (Coleoptera: Silphidae). Ten other species were present in small numbers and were not significant to the progression of carcass destruction.
CHAPTER II

LITERATURE REVIEW

Previous studies of arthropod activity related to decomposition have focused on the description of environmental microseres (Payne 1963). This term refers to the narrow range of conditions that comprise individual species' required or preferred habitats. Much of this material is published in entomological journals and does not involve carrion, which are studied as a model of the human decomposition process.

Earlier studies tend to be purely observational, as exemplified by Morley (1907), a British coleopterist who reported the presence of 113 species of Coleoptera on vertebrate carrion he encountered randomly over a ten-year period. Similarly, Holmquist (1926) examined the hibernation preferences of arthropods in wooded areas near Chicago, Illinois over a period of three years. The study demonstrated that most of the 329 species found overwintered in or under decaying wood and detailed which species were found in adult, larval or pupal stages of development.

Later studies are more systematic in design. Graham (1925) investigated the effects of temperature and moisture on insect activity in rotting logs. He considered each log as a separate ecological unit, or microclimate, and organized his results on the basis of the insects' food requirements. Mohr (1943) studied cattle droppings with a similar objective, using the term, microhabitat, to describe the small, transient envi-
ronments that appeared in successive stages as the dung decomposed. He identified seven phases through which dung passes during decomposition. Kaufmann (1937) devised a series of buried traps baited with meat and poultry scraps for the purpose of collecting and identifying species of carrion beetles. The species collected are not listed or otherwise described, but he does mention that the beetles appeared to be attracted to the bait primarily by its odor, an observation later tested and substantiated by Shubeck (1968), who determined radii of odor perception for several silphid species. By releasing marked adults at various, known distances from a food source (chicken legs), Shubeck found that some species perceived odor and returned directly to the food source from far greater distances than others.

The above studies, though valuable in their own right, are not, nor were they intended to be, directly applicable to forensic science. *The Washing Away of Wrongs*, a frequently cited thirteenth century Chinese story by Sung Tz’u (Catts and Haskell 1990; McKnight 1981), has come to be recognized as the earliest recorded example of the application of entomological knowledge in a forensic context. In the story, a villager was murdered by slashing. Efforts to solve the crime by questioning the villagers were to no avail, and the investigator had everyone bring their sickles to be examined. All were unremarkable except one, which attracted flies to the remnants of tissue or blood which stained the blade. Faced with the weight of evidence, the murderer confessed.

In 1894, Mégnin (cited in Payne 1963; Smith 1986; Catts and Haskell 1990) published *La Faune des Cadavres: Application l’entomologie à la Médecine Légale*
[The Fauna of Cadavers: Application of Entomology to Forensic Medicine], a long-term study of the inhabitants of human cadavers that established many of the descriptive criteria and research methods used in decomposition studies today.

Mégnin described eight successive waves of arthropods on human cadavers over a period of three years and detailed the taxonomy of species from each wave (Smith 1986). The arthropod succession was correlated with seven decompositional stages and the duration of each was identified. Also described was a succession of four waves of arthropod invasion on buried corpses over a period of two years (Smith 1986:16).

Although Mégnin devised the basic descriptive framework for decomposition studies, nearly every subsequent researcher adapted the interpretation of decay stages to their particular data. Fuller (1934), in a four-year study of various animal carrion, focused on the competition between and among arthropod species, with particular attention given to blow fly species. She described only three decay stages, the third of which combined the later stages outlined by Mégnin. Chapman and Sankey (1955), in a study of rabbit carcasses in England, followed the precedent set by Fuller by organizing their results into three decay stages. A similar study by Bornemissza (1957) found five stages of decay using guinea pig carcasses.

It is important to note that the concept of decomposition stages is subjectively based on each researcher's specific objectives and results (Smith 1986), and mainly serves to separate the discussion into manageable sections. Environmental factors such as temperature and precipitation can vary sufficiently within a very short distance
to deliver substantially different results between otherwise similar carcasses (Catts and Haskell 1990). Though the gross progression of decay will lead eventually to skeletal remains, the major uniformity in decompositional stages from one study to another is that each describes a progressively greater degree of carcass degeneration and soft tissue clearing. This is evident from a comparison of the insect-open and insect-proof environments discussed by Payne (1963) and the anaerobic, underwater environment described by Payne and King (1972).

Payne (1963) examined the decomposition of ten baby pigs, two of which were placed in tightly screened cages that prevented intrusion by insects. He distinguished six decomposition stages for the pigs open to insects and five for the pigs free of insect activity. He emphasized the distinctions as follows (Payne 1963:37):

Pigs free from insects underwent a type of decomposition and disintegration very different from that of pigs exposed to insects. With the carcasses free from arthropods it was very difficult to divide decomposition of the carcass into well-defined stages. The influence of the insects was completely missing. Five stages were recognized with some certainty in all carcasses.

The six stages observed by Payne and King (1972) for submerged pig carcasses are biologically analogous to the stages described by Payne (1963), but are based on periods of floating or submersion, which determined the extent of insect activity. Similar results have been reported from studies not involving animal remains. Walker (1957) collected and identified the inhabitants of traps baited with cantaloupe, cornmeal or fish. The baited traps, along with unbaited traps were placed in three dis-
tinct habitat regions and displayed marked divisions in arthropod activity, which Walker attributed to differences in temperature and rainfall between the sites.

Reed (1958), utilizing forty-three dog carcasses in several microhabitats, clearly stressed the importance of environmental conditions, as well as the possible significance of carcasses placed in close proximity to one another. No carcass was placed within fifty feet of another, to ensure that arthropods collected from one carcass were neither attracted by, nor drawn away from, another. Four stages of decay were described, each longer in duration than the preceding stage, though Reed states that he did so for convenience of description. Additionally, Reed recognized the possibility that the strychnine used to kill some of the dogs might affect insect behavior and demonstrated that it did not.

Wintertime studies of decomposition are few. Most of the published works were conducted in regions where winter is not severe. Deonier (1940), studied remains ranging in size from rabbits to cattle and horses, and found substantially more arthropod activity on the larger carcasses. Deonier attributed this to the greater susceptibility of smaller carcasses to temperature fluctuations. The small carcasses froze solidly in cold weather, whereas the large carcasses never froze completely, registering far greater internal temperatures throughout the study. The studies were conducted during two consecutive winters in southwestern Texas and southern Arizona, and although temperatures occasionally dropped below freezing, extended cold periods did not take place. Micozzi (1986) demonstrated the effects of freezing-thawing on Wis-
tar rats, utilizing histologic and microbiologic methods to compare tissue decomposi-
tion in the thawed animals to others that were never frozen.

Rodriguez and Bass (1983) studied the decomposition of human cadavers near
Knoxville, Tennessee during the period of May 13, 1981 through May 13, 1982.
Though part of the study was conducted during wintertime and freezing temperatures
were recorded, it began well before the onset of cold weather and ended well after,
although the temperature never reached the low extremes that were common in this
study. Several case studies are summarized in Smith (1986), Goff (1989), and Catts
and Haskell (1990), which involve bodies either deposited or discovered during cold
weather in a number of locations. Smith (1986), and Catts and Haskell (1990) also
provide excellent references for the physical characteristics and taxonomic identifica-
tion of arthropod species associated with decomposing human and animal remains.
Additional, as yet unpublished, studies have been conducted (Haskell, personal com-
munication 1994) that will undoubtedly add greatly to an understanding of carcass de-
composition in cold weather.
CHAPTER III

METHODS AND MATERIALS

Preparation

An outdoor, observational study of carcass decomposition cannot be a controlled experiment in the strictest sense of the term since climatic and environmental variables can never be duplicated or controlled (Mann, Bass, and Meadows 1990). If, however, study data are to be useful to forensic entomology, an effort should be made to regulate as many factors as possible. To the extent made possible by availability, subjects should be of uniform size and weight, have verifiable and similar times of death, and, unless the intent is to examine the effects of mechanical trauma, should be free of external perimortem injury (Payne 1963). Baby pigs (Sus scrofa Linnaeus) were selected as subjects for this study based on the above criteria. Standards established by the Consortium of American Forensic Entomologists (C. A. F. E.) (Goff 1989) favor the use of much larger pig carcasses (50 pounds), since they more closely approximate human body size and weight. Larger carcasses are slower to freeze and thaw and will usually display greater distinctions in the decomposition process (Deonier 1940; Haskell, personal communication 1994). Also, large carcasses will typically be host to more diverse insect populations, because the greater body mass tends to decrease the interspecific and intraspecific competition for food (Deonier
(1940; Reed 1958; Smith 1986). However, large carcasses that would have met the recommendations of C. A. F. E. were not available at the time of the study.

The carcasses were not frozen prior to placement because, although Payne stored his carcasses in a freezer before use, Micozzi (1986) found that Wistar rats subjected to freezing and thawing decomposed faster than those that were never frozen, albeit in the same sequence. Preventing the pigs from freezing before placement ensured that any measurable effects of freezing/thawing were attributable to conditions during the study.

Baby pigs that meet the above criteria can usually be obtained from pig farms throughout the year, as were the animals in this study. Sows typically bear litters of 8-12 young, two or three times per year, and each litter usually has some piglets stillborn or inadvertently suffocated by the sow shortly after birth (McBride, personal communication 1992). Pigs obtained in this manner satisfy the criteria outlined above without the legal and ethical concerns inherent in the use of initially live subject animals.

Pigs 1-3 were received on January 9, 1992. They were numbered and placed in the first two cages according to the procedures described below. Neither of the first two cages was large enough to accommodate all three carcasses without crowding. Consequently, one carcass (Pig 2) was selected randomly and placed alone in Cage 1, and pigs 1 and 3 were placed in Cage 2, immediately adjacent to the first. Three additional carcasses were obtained on February 10, and were placed in Cage 3 on February 11. Cage 3 was located approximately five meters from the first two cages. Figure 1 illustrates the layout of the site at the time of placement of Cage 3.
Figure 1. View of the Study Site.
Observation Techniques

Carcasses were monitored from the date of placement until May 28, by which
time all remains were skeletonized and invertebrate activity directly related to the re­
 mains was no longer distinguishable. Observations were concerned primarily with de­
scription of decomposition stages and collection of associated invertebrate fauna.

Selected carcasses were initially subjected to supplementary weight measure­
ments, in order to precisely gauge the rate of decomposition. However, the effort was
 discontinued after March 27 because it was decided that, given the proximity of the
carcasses to one another and the small number of available test subjects, repeated re­
moval of some carcasses for weight measurement could alter the successional pattern
for all. The behavior of burrowing insects and their larvae would be affected by a
physical barrier, such as cloth, plastic or mesh, which must remain under the carcass to
enable its removal in later stages. Evaluation of decomposition rates was subsequently
based on carcass area, rather than mass.

In addition to the above, the following procedures were observed for place­
ment and subsequent examination of all carcasses:

1. Carcasses were placed at the study site within 24 hours of death. During
the time interval between death and placement, all pigs were enclosed in plastic bags
and stored in an outdoor shed. As noted earlier, they were not allowed to freeze.

2. Each pig was tagged, weighed on a triple-beam balance, then measured on
a sliding caliper board. Tail lengths varied considerably (2-5cm) among otherwise
similarly sized pigs. Therefore, measurements were taken from the nose to the base of
the tail in order to provide a more accurate representation of body size. Carcass
weights and measurements are provided in Chapter V.

3. The physical condition of each pig was noted. This examination focused
on evidence of internal or external trauma such as bleeding from the mouth or anus, or
invasive injury, which could enhance arthropod activity.

4. The carcasses were then placed in their respective cages, as stated earlier.
All pigs were positioned in the cages roughly equidistant from one another and from
the cage frames.

5. The site was visited at 9 a.m. and 6 p.m. daily for one week after placement
to ensure the equipment was functioning properly and internal carcass temperatures
were stabilized. Thereafter, a visual inspection was made at 9 a.m. each day. Air, soil
and carcass temperatures were recorded at 3 p.m. daily, to allow ambient air tempera­
tures to have reached their maximum, and were charted along with National Weather
Service maximum and minimum temperatures and precipitation data. Supplemental
observations were made on days when there was no snow cover, or when initial in­
spection indicated carcass temperatures above freezing.

6. Weekly photographs were taken of the site and carcasses as a supplemen­
tary record. A Nikon FM-2, 35mm camera body was used with a 55mm macro or
28mm wide angle lens. Kodak Ektachrome 100 or Kodachrome 64 slide films were
used for all exposures. An electronic flash was used when available light was poor.
Specimen Collection and Preservation

Arthropod specimens were collected on first observance and whenever a previously unrecorded species appeared. Collection was held to the minimum necessary for identification in order to avoid undue alteration of the successional pattern. In addition to daily inspections of the site and exposed surfaces of each pig, the undersides of pigs 2 and 4 were inspected weekly and small soil samples were taken at two week intervals. Nighttime inspections were made weekly.

Surgical gloves were worn during collection and examination of carcasses. Small specimens, such as ants (Formicidae), were collected in a bulb-and-syringe aspirator. Larger specimens were collected with forceps or by hand, and aerial specimens were captured in a sweep net. Soil samples were collected with a small mason's trowel.

All specimens were placed in a killing jar containing a cotton ball moistened with 1,1,1, trichloroethane (methyl chloroform). In addition to being safer than traditional, cyanide-based killing jars, trichloroethane rapidly paralyzes and kills any of the insect species. This is especially helpful when handling potentially dangerous specimens, such as the stinging Hymenoptera (wasps, bees and hornets), since the jar can be placed directly over the fabric of the aerial net and held against the ground, eliminating the need to transfer the insect to the killing jar manually. Nevertheless, caution should be exercised; trichloroethane is mildly narcotic and hepatotoxic with prolonged expo-
sure. Direct exposure to flame or strong ultraviolet light will decompose 1,1,1, tri-chloroethane to produce phosgene gas (Shaw and Rossol 1991:156).

Specimens were removed from the killing jars and placed in vials containing Hood's Solution (Catts and Haskell 1990:120) for preservation. Soil samples were placed directly into jars containing 95% ethanol and any arthropods found were transferred to Hood's solution (5ml glycerine added to 95ml of 75% ethanol) after sorting. All containers were labeled with date, time, and location of capture.

Equipment

Cages

Cats, dogs, raccoons, crows, and many other opportunistic feeders are known to frequent the study area and could be expected to disturb the carcasses (Morley 1907; Fuller 1934; Reed 1958; Payne 1963). Therefore, it was necessary to house the carcasses in cages to ensure only arthropod species had access.

Due to the potential for chemicals, such as paint or varnish, to act as mild insect repellents, the cages were constructed of kiln-dried, untreated, unpainted lumber that had been stored outdoors for several months prior to the study.

Lumber for cages 1 and 2 was standard-grade, 1×4-inch pine stock. The frames were 91.4cm (36 inches) square with butted joints and nails at the corners. Both the tops and bottoms were covered with 6.4mm (0.25 inch) mesh galvanized hardware cloth. The top was raised when collecting specimens and was otherwise
held in place by a wooden crosspiece and weighted with concrete blocks. These cages had been previously used for informal decomposition studies and for skeletonization of specimens for laboratory reference use.

Cage 3 was constructed specifically for this field study. It was longer and narrower than the others, which allowed placement of three carcasses within the same cage, spaced somewhat further apart than pigs 1 and 2 had been in Cage 2. Outside dimensions were 122×76 cm (48×30 inches). The frame was constructed of 1×4-inch tongue-in-groove pine planks, stacked in two sections, for an overall height of 14cm (5.5 inches). The joints were butted and nailed, as in the first cages. The bottom covering of hardware cloth was omitted and the carcasses were placed in direct contact with the ground. The top of Cage 3, also 6.4mm mesh galvanized hardware cloth, was stapled to the frame and the entire cage was raised when collections were made. Cage 3 was anchored in the same manner as cages 1 and 2 when not open for inspection.

Thermometers

Eight thermometers were used in the study. Each was a dual-bulb design, having one independent bulb and the other connected, by way of a thin copper conduit, to a 7×25mm copper thermocouple probe. Six of the eight thermocouples were inserted anally into the carcasses, to a depth of five centimeters. The remaining two, one by pigs 1-3 (Group 1) and the other by pigs 4-6 (Group 2), were buried in the soil at a depth of ten centimeters. The thermometers were mounted on stakes next to the
cages so that readings could be taken without disturbing the carcasses. The independent bulbs were used to measure ambient air temperature at the site. Readings from the independent bulbs were compared with others from the same group as an additional control for consistency.

Prior to the study, each thermometer was tested for uniformity and accuracy. Thermocouples were frozen in distilled water and checked against the independent, ambient temperature bulbs and two commercial-grade freezer thermometers. Those which showed variation greater than 1° Fahrenheit were exchanged for other units. Every unit had an integral Celsius scale, but most were found to be improperly calibrated by two to three degrees, even on units with accurate Fahrenheit scales. Therefore, all temperature readings were recorded in degrees Fahrenheit. This facilitated comparison with National Weather Service data, which are also provided in degrees Fahrenheit.

During the first week of the study, ice and snow buildup on the units made readings impossible. To prevent reoccurrence, each unit was covered with either a clear plastic container, open at the bottom, or a 0.5 mil plastic bag (equivalent to household plastic wrap). Both methods were effective, without providing insulation which would affect temperature readings.
CHAPTER IV

STUDY AREA

The field study portion of this project was conducted in a wooded area of Kalamazoo, Michigan, approximately 1.5 kilometers east of Western Michigan University's West Campus, and one kilometer south of the East Campus. The overall area of the woodlot is roughly one hectare (2.4 acres). Like many woodlots in Kalamazoo, the study area is privately owned and bounded by long-established residential areas. The area is nearly devoid of human traffic, since all publicly accessible sections are fenced and none of the property owners appear to make any use of it. Stray cats and dogs are common, as are a number of nonnative plant species, which have spread from deliberate plantings around the forest periphery. Pesticides or chemical fertilizers are not known to be used in significant quantity near the test area.

Sutton and Sutton (1985) place Southwestern Lower Michigan in the northern tier of the Mixed Deciduous forest region. Barnes (1991) defines the area somewhat more narrowly as the Beech-Maple forest region of the Central Lowland physiographic province. The latter is essentially a subdivision of the former and the terms are often used interchangeably, without indication of their relationship to one another.

The forest canopy at the placement site is dominated by mature growth (up to one meter in diameter) Sugar Maple (*Acer saccharum*), American Elm (*Ulmus*
americana), and Black Walnut (*Juglans nigra*). Sugar Maples are by far the most numerous, followed by elm and walnut. Red Oak (*Quercus rubra*), White Pine (*Pinus strobus*), and Black Maple (*Acer nigrum*) are less numerous, but nearly as large.

The intermediate canopy is mainly composed of seedlings and saplings of *A. saccharum* and *U. americana*, and is of medium density. Ground cover consists of Boston Ivy (*Parthenocissus tricuspidata*), Periwinkle (*Vinca minor*), Black Raspberry (*Rubus occidentalis*), Pokeweed (*Phytolacca americana*), and several species of Bluebells (*Campanulaceae* spp.) near the perimeter of the woodlot. The periwinkle and bluebells yield to Virginia Creeper (*Parthenocissus quinquefolia*) and an occasional outcropping of Poison Ivy (*Rhus radicans*) as one goes toward the center of the lot, but reappear where breaks in the canopy provide sunlit clearings. Overall, these species are evenly distributed and none are obviously dominant. At the time of the study, the woodlot floor was covered with an average 2-3 centimeter layer of decomposing leaves and branches, broken occasionally by patches of exposed soil.

Much of the area is hilly, due to the proximity of the Kalamazoo moraine and other features formed by the Wisconsinan glaciation during the Pleistocene (Barnes 1981). The hills are not severe, and do not exhibit any rocky outcroppings or extreme water runoff. The soil is a uniformly dark loam, rich in organic matter, which slows drainage from the hills and is able to retain a substantial amount of moisture during periods of little precipitation (Barnes 1981).

No systematic effort was undertaken to capture and/or identify individual vertebrate species since the carrion cages were made inaccessible, as described in the pre-
following chapter. However, several species were frequently seen in the study area. They are listed in Table 1, in approximate order of abundance, from greatest to least.

Table 1

List of Some Vertebrate Species Commonly Seen in Study Area

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aves</strong></td>
<td></td>
</tr>
<tr>
<td>American Robin</td>
<td><em>Turdus migratorius</em></td>
</tr>
<tr>
<td>Blue Jay</td>
<td><em>Cyanocitta cristata</em></td>
</tr>
<tr>
<td>Northern Cardinal</td>
<td><em>Cardinalis cardinalis</em></td>
</tr>
<tr>
<td>American Crow</td>
<td><em>Corvus brachyrhynchos</em></td>
</tr>
<tr>
<td><strong>Mammalia</strong></td>
<td></td>
</tr>
<tr>
<td>Fox Squirrel</td>
<td><em>Sciurus niger</em></td>
</tr>
<tr>
<td>Domestic Cat</td>
<td><em>Felis domestica</em></td>
</tr>
<tr>
<td>Domestic Dog</td>
<td><em>Canis familiaris</em></td>
</tr>
<tr>
<td>Eastern Chipmunk</td>
<td><em>Tamias striatus</em></td>
</tr>
<tr>
<td>Eastern Cottontail</td>
<td><em>Sylvilagus floridanus</em></td>
</tr>
<tr>
<td>Raccoon</td>
<td><em>Procyon lotor</em></td>
</tr>
<tr>
<td>Woodchuck</td>
<td><em>Marmota monax</em></td>
</tr>
<tr>
<td>Gray Squirrel (black variant)</td>
<td><em>Sciurus carolinensis</em></td>
</tr>
<tr>
<td><strong>Marsupialia</strong></td>
<td></td>
</tr>
<tr>
<td>Virginia Opossum</td>
<td><em>Didelphis virginiana</em></td>
</tr>
</tbody>
</table>
CHAPTER V

STUDY RESULTS

This chapter describes the environmental conditions, faunal succession, and progression of carcass decomposition during the study and is divided into two major decompositional stages, based upon the absence or presence of insect activity. Beginning with the initial placement of the carcasses, Stage I lasted for fourteen weeks. The dates spanned from January 9 to April 14 for pigs 1-3, and from February 11 to April 14 for pigs 4-6, as noted in Chapter I. Figure 2 and Figure 3 show the pigs at the time of placement. Stage II begins with the appearance of the silphid colonies on April 15 and continues until the termination of the field study on May 28. Summary data are provided in Appendix A. Raw data are available from the Department of Anthropology, Western Michigan University.

Because the vigorous silphid colonies were the only arthropods to have discernible impact on carcass decomposition, other species collected will not be discussed in great detail. A complete description of all arthropod activity, its influence and dates of arthropod appearance is presented in Chapter VI.
Figure 2. Group 1 (Pigs 1-3) on Date of Placement: January 9, 1992.
Figure 3. Group 2 (Pigs 4-6) on Date of Placement: February 11, 1992.
Stage I: Weeks 1-14

This stage was characterized by the predominance of freezing temperatures and at least partial snow cover for approximately eight of the fourteen weeks and was subdivided into six phases of varying length in which the pigs alternately froze and thawed. All carcasses were free of insect activity when frozen and/or snow covered. A few insects did appear during warmer phases of Stage I, but as indicated below, their presence was sparse and did not influence the progression of decomposition. Table 2 shows the sequence of cold and warm periods during stage one. Snow depths were measured adjacent to the cages.

Table 2

<table>
<thead>
<tr>
<th>Corresponding Week of Study</th>
<th>Dates (1992)</th>
<th>Carrion Status</th>
<th>Snow Cover (Maximum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-6</td>
<td>1/9 to 2/19</td>
<td>Frozen</td>
<td>18-23cm (7-9&quot;)</td>
</tr>
<tr>
<td>7-9</td>
<td>2/20 to 3/9</td>
<td>Thawed</td>
<td>None</td>
</tr>
<tr>
<td>10</td>
<td>3/10 to 3/16</td>
<td>Frozen</td>
<td>7-10cm (3-4&quot;)</td>
</tr>
<tr>
<td>11</td>
<td>3/17 to 3/21</td>
<td>Partly Thawed</td>
<td>Trace</td>
</tr>
<tr>
<td>11</td>
<td>3/22 to 3/25</td>
<td>Frozen</td>
<td>18cm (7&quot;)</td>
</tr>
<tr>
<td>12-14</td>
<td>3/26 to 4/14</td>
<td>Thawed</td>
<td>None</td>
</tr>
</tbody>
</table>
Pigs 1-3 were solidly frozen to the ground within 24 hours of placement and remained so until the initial thaw began on February 20. Pigs 4-6 froze similarly to the earlier group but responded more quickly to the rise in air temperatures, reaching a maximum internal temperature of 13.3°C (56°F) by March 7. Carcasses 1-3 only reached a high of 11.1°C (52°F) by the same date. Group 1 (pigs 1-3) was slightly more sheltered than Group 2 (pigs 4-6) and registered consistently cooler temperatures throughout the study, which may account for the more rapid thawing of the second group. Carcass temperatures rarely rose above the ambient temperature during Stage I, however.

Visually, changes in the carcasses were minimal until near the end of Stage I. Prior to the final thaw of March 26, some distention was evident in the pigs' abdomens and legs when ambient temperatures were above freezing, but it was never pronounced and was abruptly arrested when the carcasses re-froze. By March 26, the eyelids of all the carcasses had become sunken and the heads were slightly desiccated. A faint odor of putrefaction was noticeable within 50-60cm of the cages, but the dominant smell remained that of damp leaves with traces of barnyard mash (trampled hay, mud and manure), which still clung to some of the pigs.

Supplemental weight measurements were made twice during this stage, as noted in Chapter III. On February 19, pigs 2 and 3 showed no measurable weight change and Pig 1 had lost only 14g. Pig 4 gained 57g, which may be attributed to absorption of moisture from the snow cover. On March 27, Pig 2 showed a net loss of
56g since placement. Pig 4 had lost 29g since the previous measurement, but still weighed 28g more than when it was placed. Table 3 shows all carcass measurements recorded during the study.

Table 3

Recorded Carcass Weights and Lengths

<table>
<thead>
<tr>
<th>Carcass Number</th>
<th>Date (1992)</th>
<th>Weight (g)</th>
<th>Length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1*</td>
<td>1/10</td>
<td>1134</td>
<td>27.9</td>
</tr>
<tr>
<td>2*</td>
<td>1/10</td>
<td>1389</td>
<td>33.0</td>
</tr>
<tr>
<td>3*</td>
<td>1/10</td>
<td>1673</td>
<td>34.9</td>
</tr>
<tr>
<td>4*</td>
<td>2/11</td>
<td>1049</td>
<td>31.8</td>
</tr>
<tr>
<td>5*</td>
<td>2/11</td>
<td>1503</td>
<td>35.6</td>
</tr>
<tr>
<td>6*</td>
<td>2/11</td>
<td>1531</td>
<td>36.5</td>
</tr>
<tr>
<td>1</td>
<td>2/19</td>
<td>1120</td>
<td>27.9</td>
</tr>
<tr>
<td>2</td>
<td>2/19</td>
<td>1389</td>
<td>33.0</td>
</tr>
<tr>
<td>3</td>
<td>2/19</td>
<td>1673</td>
<td>34.9</td>
</tr>
<tr>
<td>4</td>
<td>2/19</td>
<td>1106</td>
<td>31.8</td>
</tr>
<tr>
<td>2</td>
<td>3/27</td>
<td>1333</td>
<td>32.1</td>
</tr>
<tr>
<td>4</td>
<td>3/27</td>
<td>1077</td>
<td>30.5</td>
</tr>
</tbody>
</table>

(* indicates placement date and initial measurements)

There was a nominal presence of Little Black Ants (*Monomorium minimum* Buckley; Hymenoptera: Formicidae) during the thaw of weeks 7-9. Since the ants did not appear every day and only ten individuals were observed and/or collected during the entire three week phase, their presence was regarded as noteworthy, but insignificant to the overall faunal succession. Also, the ants did not reappear during the second warm phase. Their next recorded presence was April 6, near the end of Stage I.
The final warming trend of Stage I began on March 26, by which time, most of the carcasses displayed some bloating, and a moderately strong odor of putrefaction was noticeable within approximately two meters of each cage. All of the carcasses had undergone repetitive freezing and thawing which made it difficult to distinguish between slight bloating due to putrefaction and the onset of the desiccation that is characteristic of post-putrefaction stages, as described by Payne (1963) and Smith (1986).

By March 28, sparse patches of mold and several areas of blue-black discoloration were evident on the surfaces of pigs 1, 3, 4 and 6, which had light body coloration. Dark body color obscured similar observations of pigs 2 and 5. All carcasses exhibited slight bleeding from the nose and anus, as well as a small discharge of fluid from the mouth.

Air temperatures were consistently near 4.4°C (40°F) from March 26 to April 5. All six pigs were fully thawed, though there was no discernible change in appearance during the period. Ambient temperatures rose sharply on April 6, remaining near 15.6°C (60°F) through April 9, when they again fell to near 4.4°C (40°F).

Soil temperatures remained below 0°C (32°F) until March 2, when there was an eight-day increase during the first warming phase. On the last day of this period, March 9, the maximum ambient temperature was 14.4°C (58°F) and the maximum soil temperature was 5.6°C (42°F). Ambient temperatures fell dramatically the next day, reaching only -6.1°C (21°F) and soil temperatures abruptly dropped to 0°C (32°F). However, a ten-degree drop in soil temperature overnight may reflect a residual influ-
ence of the ambient air temperature on the thermometer, since soil temperatures typi-
cally changed more slowly. The last date that soil temperatures were recorded at or
below 0°C (32°F) was April 5.

_Silpha noveboracensis_ Forster and _Silpha inaequalis_ Fabricius (Coleoptera:
Silphidae) were first observed on April 9, when seven to ten adults were visible on
each carcass. The beetles were active, but it was not clear if they were feeding on the
carcasses or searching for other food. The return of colder weather forced a retreat of
all insects to an undetermined location by April 10. Silphids, ants and blowflies were
collected for identification near the end of Stage I and are discussed in detail in Chap-
ter VI. Otherwise, all arthropods were observed and collected during Stage II.
Careful examination of the pigs revealed no visible changes attributable to insects,
prior to April 15.

Stage II: Weeks 14-20

The beginning of Stage II was marked by the reappearance of silphid adults
and the initial appearance of silphid larvae on April 15. Figure 4 shows the early de-
velopment of the silphid colony on Pig 5. The insects were very active both inside and
on the surfaces of all six carcasses. There were intermittent periods of cold tempera-
tures and/or rain during which the adults sought shelter under the carcasses. Larvae
secluded themselves underneath and inside the carcasses. Both adults and larvae re
Figure 4. Silphid Colony on Pig 5: April 21, 1992.
mained active and exposed during rainy periods if the temperature was warm enough, but cool temperatures forced the disappearance of all insects, regardless of precipitation. The threshold of tolerance appeared to be from 12.8-13.9°C (55-57°F), although some individuals were seen moving sluggishly at slightly cooler temperatures. No silphids were seen when ambient temperatures were below 11.1°C (52°F).

Internal carcass temperatures closely mirrored ambient temperatures, as in the first stage, but unlike Stage I, exceeded air temperatures on several occasions. Elevated carcass temperatures were never consistent, however.

By April 28, odors of decomposition had subsided and a somewhat damp and stale smell, similar to that of a wet dog, persisted for the remainder of the study. The week prior to April 28 was cool and rainy, with little evident insect activity. A warming trend began thereafter and prompted a rapid increase in the silphids’ activity. The rate of carrion deterioration increased accordingly.

By May 4, five of the six carcasses were partially skeletonized. The temporomandibular joints had become disarticulated and the skulls were exposed in several places. The pigs’ bodies appeared desiccated and the skin was leathery, but not dry. Silphid larvae had eaten several holes, both small and large, through the skin, exposing several ribs and other bones. Internally, most of the liquefied viscera had been removed or consumed, possibly by larvae since the adult beetles were not readily observed entering the carcasses. Pig 2 took approximately three days longer to reach a similar condition of clearing. Pig 2 was alone in the first cage and was the most shel-
tered, usually registering the lowest carcass temperatures, as noted earlier. This may have retarded silphid activity in the early portion of Stage II.

Growth of the silphid colony peaked by May 10. At that time, each carcass was host to a densely packed mass of adult silphids approximately 100cm² in area. An adult silphid occupies roughly 1cm² and, since many of the insects were mating and otherwise crawling on top of one another, each colony could have numbered 150-250 individuals. Larvae were as numerous as adults and were scattered throughout the carcasses. After May 10 the colonies began to disperse, but some adults and larvae remained until the pigs were fully skeletonized.

All carcasses except Pig 2 were mostly skeletonized by May 13. In general, pigs 4-6 were slightly more advanced in decomposition than pigs 1-3. Pig 2 still lagged behind the others by two or three days. All remains were damp and had acquired the odor of the surrounding soil and leaf litter. Some desiccated flesh remained on the shoulders and hindquarters of most of the carcasses. Bits of hair and skin still remained on the skeletal remains in several places. Vertebrae and pelvic bones were clearly visible except on Pig 2. Ribs and the uppermost limbs were disarticulated and had collapsed onto the bones beneath.

By May 28, pigs 4-6 were completely skeletonized and were difficult to discern from the surrounding leaves and ground cover. Slightly more soft tissue remained on pigs 1-3. The forest canopy had filled in above the cages, leaving all six carcasses fully shaded during the daytime.
Temperature readings were not taken from the carcasses after May 16. Since the pigs were nearly skeletonized, the internal thermocouples merely indicated the ambient temperature and were no longer useful. Ambient temperatures registered 18.3-21.1°C (65-70°F) through the end of the field study.

Ten isopods (pillbugs) were counted on May 23 and were gone the following day. They were the last arthropods recorded. The study was terminated on May 28, based upon full skeletonization of the carcasses and the absence of discernible arthropod activity within the cage perimeters.
CHAPTER VI

DISCUSSION OF RESULTS AND COLLECTED SPECIES

Previous studies of carcass faunal communities, with the exception of the insect-inaccessible remains discussed by Payne (1963), have demonstrated the initial blow fly succession to be the most influential arthropod activity relative to tissue clearing. Blow flies were nearly absent in this study, however. Instead, carrion beetles (Silphidae) were without question the most significant arthropods. A taxonomic list of all species recorded is provided in Appendix A.

Ambient temperature and seasonality at the test site were the most influential environmental factors. The fortuitous arrival of the silphids during cool weather, before blow flies or any other carrion insects gained a foothold, may have enabled them to establish a colony based on an abundance of food and absence of competition (Cashatt, personal communication 1992). The carcasses may also have been too decomposed by mid-April to be an attractive breeding ground for blow flies (Haskell, personal communication 1994).

Blow fly species were unique in this study by their conspicuously low numbers. The two species collected, Phaenicia sericata Meigen and Calliphora vomitoria Linnaeus (Diptera: Calliphoridae), commonly called greenbottle and bluebottle flies, respectively, were seen only between April 7 and April 21. At no time were any dip-
terous eggs, larvae or pupae observed on, in, or near any of the carcasses, though adult flies frequently landed on the carcasses. It is possible that blow flies laid eggs on the carcasses, only to have them quickly consumed by the predaceous silphids, which appeared two days after the first calliphorids were observed.

Because blow flies usually play a major role in the breakdown of remains, additional efforts were made to verify these findings. Carcasses were inspected more closely for several days after the initial appearance of the blow flies. Particular attention was given to the openings of the head and anus, as well as any ruptures of the skin, the most likely areas for blow flies to lay eggs (Deonier 1940; Johnson 1975; Smith 1986; Catts and Haskell 1990).

A Malaise trap (Arnett, Downie and Jaques 1980:13), was positioned above pigs 4-6 on April 13, and baited with tissue from the pigs in an effort to determine if blow flies were visiting the site in greater numbers than indicated by the daily inspections. A Malaise trap works by directing flying insects up through a funnel-shaped opening to a collection vessel containing bits of flesh or other material attractive to the desired insects. Inspections of the trap were not productive, yielding only one specimen of *C. vomitoria*. Catts and Haskell (1990) suggest the use of sticky traps or fly paper as an alternative method for collection of flying insects.

Carrion beetles, *Silpha inaequalis* Fabricius and *Silpha noveboracensis* Forster (Coleoptera: Silphidae) first appeared on April 9, disappearing along with all other insects until April 15, most likely due to cold temperatures. Goe (1919), Balduf (1935), Dorsey (1940), and Cole (1942) note that both *S. inaequalis* and *S. noveboracensis*
lay eggs in the soil beneath the host carcass. Adults seen and collected on April 9, along with their first brood, may have come from beneath the carcasses when temperatures rose above the minimum threshold for activity. The number of generations or total population of silphids cannot be determined conclusively since there was no control to assess the original population and the soil under the pigs was not closely examined. Consequently, the estimate of total colony size in Chapter V should not be interpreted as a statement of fact that the beetles observed on April 9 bred the entire colony. For them to have done so is possible, based on estimates of adult and larval populations, as well as observations of frequent mating and colony growth, but confirmation cannot be made from the data collected in this study.

There is little consensus about silphid behavior or life cycles. Based on the research of Goe (1919), Steele (1927), Balduf (1935), Dorsey (1940), and Cole (1942), larvae progress through a series of three instars (growth stages) over a period of fourteen to twenty one days, depending on ambient temperatures. A pupal stage follows and lasts from ten to twenty days and is also temperature-dependent. Adults of *S. inaequalis* live approximately fifteen to twenty days while *S. noveboracensis* lives twenty to twenty-four days in the adult stage. Interestingly, Goe (1919:254) noted that prior to entering the soil to pupate, third instar larvae behave in an unusual manner:

> They would dash frantically across the jar in which they were kept, suddenly stop and curl up on their sides, lie so a second, then roll over on their backs, then up and dash away again. These actions were repeated many times showing the unrest at the time this transformation was about to begin.
The behavior is not reported elsewhere, nor was it observed consistently enough in this study to confirm Goe's findings. Only Balduf (1935) mentions specific temperatures in conjunction with incubation or pupation, reporting incubation periods of seven to nine days at temperatures near 20°C (68°F), which is substantially warmer than the temperatures recorded during most of this study.

Reports of feeding behavior are even less clear. Reed (1958) observed that adult silphids fed only on maggots (dipterous larvae), while silphid larvae fed on both carcasses and maggots. Steele (1927) went further, stating that adult silphids could not survive if deprived of maggots. Goe (1919), Dorsey (1940), and Cole (1942) found that adults and all larval stages of *S. inaequalis* and *S. noveboracensis* did well on infested or uninfested carcasses. There is similar disagreement on the preference of silphid species for sunlight, shade, degree of dampness, or tolerance for disturbance, but the differences may result from geographic and climatic variability.

This study supports the findings of the latter group. Both adults and larvae fed vigorously on the carcasses. Only larvae seemed to seek cover when collections were made. Rain (very light rain had no effect) or cold temperatures represent the only observed stimuli for interruptions of colony activity.

Little Black Ants (*Monomorium minimum* Buckley; Hymenoptera: Formicidae) were seen on all carcasses as early as February 21. They were the first arthropods of any species to be observed and were present whenever ambient temperatures and skin temperatures of the pigs were above 3.3°C (38°F). At no time were ants nu-
merous, however. Individual counts ranged from one ant on Pig 2 (February 21), to 5-10 ants on each pig during the middle and late stages of the study.

Usually, the ants were seen feeding on the surface of a carcass near the nose and eyes, or at the base of the tail where ruptured capillaries allowed a small amount of blood and fluid to escape. Occasionally, they were simply wandering across the surface of the pig and did not stop to feed. Their movement was noticeable, but sluggish, when temperatures were near freezing. No ants remained visible when temperatures fell below freezing.

Payne (1963) stated that ants were the dominant species on the carcasses in his study. In contrast, Fuller (1934) only found them on carcasses that were near nests. It is not clear, therefore, why ants did not play a more significant role in this case. No ant nests were observed near the carcasses in this study, so perhaps Fuller was correct in her assessment that ants do not frequent remains more than a few meters from the nest. However, it is likely that weather was also a limiting factor. Internal carcass temperatures were still below 0°C (32°F) for most of the period from February 21 to March 10. From March 10 through March 26, three to five inches of snow covered the site. No activity was again evident until April 6, after which the colony of silphids quickly became established. Had the temperature not dropped after February 21, the presence of *M. minimum* may have been more significant.

Numerous examples of both *Cylisticus convexus* De Geer (pillbugs) and *Trapecheoniscus rathkei* Brandt (Isopoda: Oniscidae) were found within the cages, mostly
on the ground and the cage frames. These crustaceans are the most common isopods in Michigan (Hatchett 1947), and can be found throughout the state. They are typically found in humid locations such as leaf litter, under rocks and fallen logs, and recesses in and around buildings. Payne (1963), citing a personal communication with Henson (1962), states that both species are known to feed on decaying flesh. No other source confirms this, though Judd (1965:201), in stating that specimens of*C. convexus* were often found beneath rubbish piles, lends indirect support to the statement. Both *T. rathkei* and *C. convexus* were occasionally observed directly on the pigs in this study, but it could not be ascertained whether they were feeding on the carcass or the mold that had grown on the pigs’ skin.

The narrow environmental tolerances of the terrestrial isopods may be of use in a forensic context. McQueen (1974, 1976), found that *T. rathkei* and *Porcellio spinicornis* Say will actively seek habitats of 95-100% relative humidity. Conversely, they will quickly leave areas in which the humidity drops below 95%, and will die below 85%. Also, the optimal temperature range for survival and reproduction was found to be 15-25°C (59-77°F). Absolute minimum and maximum temperatures required for survival were not stated.

Millipedes (Diplopoda) are usually found in damp areas of leaf litter and decaying vegetation and feed primarily on plant and animal remains, fungi, and other organic matter (Smith 1986). Millipedes are frequently found in association with animal remains, usually underneath carcasses in the latest stages of decomposition (Payne and
Crossley 1966; Hoffman and Payne 1969), and contribute to the final skeletonization of the remains.

Careful examination during the latter stages of this study yielded only five diplopod specimens. All were collected from inside Cage 3 (pigs 4-6), and were under either the leaf litter or the carcass remains. The first specimen was collected on May 12. Observed behavior was consistent with the above descriptions, though somewhat greater numbers were expected. No diplopods were found within cages 1 and 2. Since the hardware cloth on the bottoms of cages 1 and 2 prevented full contact between the carcasses and the ground, it is possible the millipedes did not find sufficient shelter for them to inhabit.

The two staphylinid species recovered are probably not representative of the total population in the vicinity of the carcasses. The first, a small (8mm), brown specimen, was recovered from a soil sample taken from beneath Pig 4. It has not been identified with certainty beyond family Staphylinidae. The second, *Staphylinus macculosus* Gravenhorst (Coleoptera: Staphylinidae), a large (2.5cm) beetle with yellow abdominal stripes, was recovered while running through leaf litter inside Cage 3.

Staphylinids, commonly known as rove beetles, are entomophagous predators (Smith 1986) usually found in leaf litter and under decaying vegetation. Although they are not believed to feed on animal remains, they are frequently recovered near carcasses since many of the 13,000 species feed on the larvae of silphids, Diptera, and other species associated with decomposition (Fuller 1934; Payne 1963). Many species
invade the nests or burrows of the Silphidae to feed on eggs and larvae before they can emerge (Balduf 1935).

Yellowjackets (*Vespula maculifrons* Buysson; Hymenoptera: Vespidae) were infrequent visitors to the carrion site. They appeared only late in the study, after ambient temperatures were consistently above the freezing mark. Smith (1986), Catts and Haskell (1990), and Kitchings and Walton (1991) describe vespids as both scavenging and predaceous. Payne (1963) observed yellowjackets feeding on blow fly eggs, larvae and adults. Since there were no dipterous eggs or larvae observed in this study, it must be assumed that the vespids were either feeding minimally on the carcasses, or were waiting to capture other insects.

A total of four slugs and one small snail were seen near the carcasses during the latter stages of the study and were not identified to species. They were found inside, but near the edges of cages 2 and 3, so a direct association with the pig remains should not be inferred. However, (Payne 1963, 1965) states that terrestrial gastropods tend to be omnivorous and opportunistic feeders, and their typical habitat is the damp shelter of decaying vegetation or, perhaps, animal carcasses. It is therefore possible that the gastropods were attracted to the pigs, rather than being only incidentally present.

Clearly, all arthropod species encountered in this study were influenced by daily temperature fluctuations near or below the lower extremes of their range of tolerance. Observed minimum temperature tolerances for each species are provided in Table 4.
Table 4

Observed Minimum Temperature Tolerances and Activity Threshold Ranges for Six Arthropod Species (Celsius)

<table>
<thead>
<tr>
<th>Species</th>
<th>Minimum Tolerance:</th>
<th>Threshold Range:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Activity</td>
<td>Minimal Activity</td>
</tr>
<tr>
<td><em>Silpha noveboracensis</em></td>
<td>11.1</td>
<td>12.8-13.9</td>
</tr>
<tr>
<td><em>Silpha inaequalis</em></td>
<td>3.3</td>
<td>5.6-7.2</td>
</tr>
<tr>
<td><em>Monomorium minimum</em></td>
<td>10.0</td>
<td>11.1-12.8</td>
</tr>
<tr>
<td><em>Calliphora vomitoria</em></td>
<td>11.1-12.8</td>
<td></td>
</tr>
<tr>
<td><em>Cylisticus convexus</em></td>
<td>13.3-14.4</td>
<td></td>
</tr>
<tr>
<td><em>Tracheoniscus rathkei</em></td>
<td>11.7</td>
<td>13.3-14.4</td>
</tr>
</tbody>
</table>

There was no discernible impact on the carcasses as a result of the arthropods observed in Stage I, though decomposition progressed whenever the pigs thawed slightly. Ambient temperatures and the degree of carcass decomposition reached by April 9 (Stage II) were observed to be conducive to silphid activity, and may have been unfavorable for Diptera and other observed species. Consequently, most species typically associated with carcass decomposition may have been discouraged from exploiting the remains by the aggressive silphid colonies. *Silpha noveboracensis* and *S. inaequalis* greatly accelerated the process of skeletonization, which was complete by May 28, seven weeks after their first appearance.
CHAPTER VII

SUMMARY AND CONCLUSIONS

The purpose of this study was to contribute to the body of basic research that is applicable to forensic entomology by recording the succession of carcass fauna during wintertime in a cold climatic region. Although data collected from observations of small carcasses cannot be expected to directly predict the succession that would take place on human remains, even under similar circumstances, there is a stated need for studies of insect succession under cold weather conditions (Smith 1986).

This study has presented the faunal succession on six perinatal domestic pig (Sus scrofa Linnaeus) carcasses as observed from January through May of 1992. Two stages of decomposition were distinguishable by the absence or presence of arthropod activity. Tissue degeneration progressed slowly despite several periods of freezing and thawing but initial arthropod activity was dictated by temperatures near the minimum levels of tolerance. Dominance of the silphid colonies was most likely the result of their arrival at the carcasses during a window of opportunity created by suitably warm temperatures and favorable advancement of decay. Blow flies may have been prevented from exploiting the carcasses by the numerous and predaceous silphids.

Although the silphids were directly responsible for clearing most of the soft tissue from the remains, the pivotal factor in the study was found to be the relationship
of insect activity to temperature. Subsequent studies undertaken in cold weather may anticipate arrival of the first arthropods as temperatures of the air, soil and remains converge in the range of 4.4°C-12.7°C (40°F-55°F). Several earlier studies (Fuller 1934; Deonier 1940; Johnson 1975; Smith 1986; Mann, Bass and Meadows 1990) have also discussed similar temperature ranges as the point of separation between arthropod activity and dormancy. Minimum threshold temperatures required for activity were distinguished for four species, representing four orders in two classes. It should be noted however, that the temperatures at which insects become active may also be substantially affected by site characteristics such as foliage, topography and soil type, as well as sunlight and precipitation.

Larger carcasses, as recommended by C. A. F. E., may develop a different faunal succession under the same general climatic circumstances. Small carcasses tend to decompose rapidly and often show little distinction from one decay stage to the next (Haskell, personal communication 1994). In addition to making the description of decomposition more difficult, small carcasses may offer only narrow opportunities for some insect species to exploit when ambient temperatures permit, thus favoring the opportune arrival of those species and perhaps, delaying or precluding the development of others. Had larger pigs or human remains been used in this study, they would likely have remained frozen longer and responded more slowly to daily temperature increases (Fuller 1934; Deonier 1940). The resulting delay could then have shifted the window of opportunity, as well as the progression of decomposition, to a point that would have favored species other than silphids. Additionally, large carcasses are likely
to host a more diverse arthropod population, due to greater body mass and the possibility that different areas of the remains may decompose at different rates, thus providing a wider range of microhabitats for species to inhabit (Fuller 1934; Mann et al 1990; Rodriguez and Bass 1983; Smith 1986).

Discussion of the decomposition of human or large animal remains is speculative in this context and is intended to be suggestive of issues that must be addressed by future studies in order to fully understand the faunal succession on remains deposited in sub-freezing temperatures. Another point noted in this study as potentially relevant to forensic entomology is that, as stated in Chapter VI, terrestrial isopods require a humid environment in order to survive. This characteristic may be valuable to forensic entomology if their presence in association with human remains is established as common or typical. Presently, little published information is available regarding the behavior of either *Cylisticus convexus* or *Tracheoniscus rathkei* as it relates to decomposition of human and animal remains.

There is also a need to accurately establish the life cycle of silphids, especially under marginal temperature conditions and to test whether adult silphids, if given an opportunity, are more likely to breed a colony on a carcass or if most individuals are attracted to the remains from elsewhere. Haskell (personal communication 1994) has encountered similar results in unpublished studies, establishing additional precedent for further study of behavioral and reproductive traits of the Silphidae.

This observational study encompasses several aspects of arthropod behavior that are relevant to forensic science and has established that there is a discernible and
potentially useful faunal succession on carcasses exposed in wintertime. By presenting the results in conjunction with suggestions for further research, this project contributes both data and an overall assessment in an area of forensic entomology for which limited information is available.
APPENDICES
Appendix A

Taxonomic List of Species Collected, Showing Approximate Duration and Proportion of Species’ Presence at Study Site
Taxonomic List of Species Collected, Showing Approximate Duration and Proportion of Species’ Presence at Study Site

<table>
<thead>
<tr>
<th>Name</th>
<th>Decomposition Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>phylum Arthropoda</td>
<td></td>
</tr>
<tr>
<td>class Crustacea</td>
<td></td>
</tr>
<tr>
<td>order Isopoda</td>
<td></td>
</tr>
<tr>
<td>family Oniscidae</td>
<td></td>
</tr>
<tr>
<td><em>Cylisticus convexus</em> De Geer</td>
<td></td>
</tr>
<tr>
<td><em>Tracheoniscus rathkei</em> Brandt</td>
<td></td>
</tr>
<tr>
<td>class Diplopoda</td>
<td></td>
</tr>
<tr>
<td>class Insecta</td>
<td></td>
</tr>
<tr>
<td>order Coleoptera</td>
<td></td>
</tr>
<tr>
<td>family Silphidae</td>
<td></td>
</tr>
<tr>
<td><em>Silpha inaequalis</em> Fabricius</td>
<td></td>
</tr>
<tr>
<td><em>Silpha noveboracensis</em> Forster</td>
<td></td>
</tr>
<tr>
<td>family Staphylinidae</td>
<td></td>
</tr>
<tr>
<td><em>Staphylinus</em> sp.</td>
<td></td>
</tr>
<tr>
<td><em>Staphylinus maculosus</em> Gravenhorst</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Stage I</th>
<th>Stage II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weeks 1-14</td>
<td>Weeks 15-20</td>
</tr>
<tr>
<td>Name</td>
<td>Decomposition Stage</td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>---------------------</td>
<td></td>
</tr>
<tr>
<td>phylum Arthropoda (continued)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>class Insecta (continued)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>order Diptera</td>
<td></td>
<td></td>
</tr>
<tr>
<td>family Calliphoridae</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Calliphora vomitoria</em> Linnaeus</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Phaenicia sericata</em> Meigen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>order Hymenoptera</td>
<td></td>
<td></td>
</tr>
<tr>
<td>family Formicidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Monomorium minimum</em> Buckley</td>
<td></td>
<td></td>
</tr>
<tr>
<td>family Vespidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Vespula maculifrons</em> Buysson</td>
<td></td>
<td></td>
</tr>
<tr>
<td>phylum Mollusca</td>
<td></td>
<td></td>
</tr>
<tr>
<td>class Gastropoda</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weeks 1-14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weeks 15-20</td>
<td></td>
</tr>
</tbody>
</table>

*Stage I* and *Stage II* indicate the decomposition stages for each insect species.
Appendix B

Summary Data for Air, Soil, and Carcass
Temperatures and Precipitation
Actual and Normal Temperatures: Average by Month (1992)
Appendix B — Continued

Actual and Normal Precipitation:
Average by Month (1992)

Average by Month (1992)

Liquid Precipitation (cm)

January  February  March  April  May

3.3  2.5  5.6  8.1  8.6  5.8  3.8
Appendix B—Continued

Group 1 Carcass Temperatures:
Average by Week
Appendix B—Continued

Group 2 Carcass Temperatures:
Average by Week

Week of Study

Temperature (Celsius)

-10 -5 0 5 10 15 20 25

- Pig 4
- Pig 5
- Pig 6
Appendix B—Continued

Group 1 Carcass, Air and Soil Temperatures:
Average by Week

![Graph showing temperature trends over weeks for carcasses, air, and soil]
Appendix B—Continued

Group 2 Carcass, Air and Soil Temperatures:
Average by Week
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