8-1982

Insect Activity and Its Relationship to Decay Rates of Human Cadavers in East Tennessee

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To the Graduate Council:

I am submitting herewith a thesis written by William C. Rodriguez III entitled "Insect Activity and Its Relationship to Decay Rates of Human Cadavers in East Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

William M. Bass, Major Professor

We have read this thesis and recommend its acceptance:

Richard Jantz, Fred H. Smith

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Accepted for the Council:

Vice Chancellor
~~Graduate Studies~~s and Research

INSECT ACTIVITY AND ITS RELATIONSHIP TO DECAY RATES OF HUMAN CADAVERS IN EAST TENNESSEE

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

William C. Rodriguez, III
August 1982

DEDICATION

I dedicate this thesis to my wife, Karleen, whose love and support through the years have made the goals I seek possible.

ACKNOWLEDGMENTS

A special thanks is given to my committee chairman, Dr. William M. Bass, for his continual guidance and support. He served me not only as a professor, but as a personal friend. Sincere appreciation is extended to the other thesis committee members: Dr. Richard L. Jantz and Dr. Fred H. Smith. Both of these individuals have encouraged my studies and have assisted me in numerous ways.

I would like to thank my fellow student, Mr. Steve Symes, whose interest and assistance in this project aided my research in every way. The author also wishes to thank Dr. Patrick Willey for his helpful suggestions.

Much appreciation goes to Dr. Neal Greenberg of the Department of Zoology whose teachings have greatly broadened my knowledge in experimental methodology.

I am indebted to John and Nancy Katz, and Emily and Karl Krohn for their moral support and strong interest in my graduate studies.

Lastly, a special thanks to my parents for their love and understanding throughout the years.

ABSTRACT

The purpose of this study was to collect data on the specific insects which are found in association with decaying human cadavers. Four nude unembalmed human cadavers were each placed, at various times of the year, within a decay research facility located in an open wooded area. Data were collected daily throughout the entire decay cycle on the various insect populations which frequented each cadaver. Analysis of the data shows that there is a direct correlation between the rate of decay and the activity of carrion insect families found in association with a decaying cadaver. Application of this entomological and decompositional information can contribute to a more accurate estimation of "time since death" of an individual.

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CHAPTER I

INTRODUCTION

A decomposing corpse or skeleton, which has been discovered lying in a wooded area, secluded lot or in an open field, presents the forensic scientist with many questions to be answered. One of the most important is the "time interval since death." The answer to this question is, in many cases, crucial to establishing the identity of the individual. Forensic scientists faced with this question must rely on their experience from previous cases. This can result only in a rough estimation of time since death, based on nonspecific criteria.

The purpose of this research was to provide a more reliable method for determining the time interval since death of a decayed or skeletalized individual, on the basis of entomological and seasonal factors.

Decay rates of human cadavers have a direct relationship to the activity and seasonality pattern of carrion frequenting insects. Investigation of the details of this insect activity and rates of human decomposition can provide forensic scientists with a defined criterion for determining the time interval since death.

Previous Studies on Decay Rates

Most research concerning decay rates has employed an entomological approach. In the anthropological literature Gilbert and Bass (1967) proposed seasonal dating of prehistoric American Indian burials from the presence of fly pupae. However, the great majority of literature dealing with decay rates and insect activity appears in the entomological journals.

One of the earliest entomological studies was conducted by Motter (1898), who reports on the various insect fauna observed in association with 150 human disinterments. Other entomological studies report on the insect fauna associated with decaying animal carcasses (dogs, pigs, rodents).

Probably the best study on insects and their relationship to decay rates was reported by Reed (1958). Reed made observations on the various insects that attack decaying dog carcasses in Knoxville, Tennessee. His study of 45 dog carcasses, placed at intervals of about two weeks in hot weather and less frequently in cooler weather, revealed much information on the ecological process and stages of decomposition.

Reed (1958) found that the total arthropod populations were greater in summer, however, certain species reached their maximum populations during the cooler periods of the year. He also discovered that insect populations in general were larger in wooded areas than in the non-wooded areas but that decomposition proceeded more rapidly in open areas (possibly due to higher temperature exposure). Most importantly Reed (1958) made excellent records of all insect species, both adult and larvae, observed in association with each carcass.

A later study concerned with the carrion insects which attack decaying carcasses of baby pigs (Sus scrofa) was conducted in Tipton, South Carolina by Payne (1965). From this study six stages of decomposition were noted for carrion exposed to arthropods: flesh, bloated, active decay, advanced decay, dry and remains. He also noted that a carcass free of insects decomposed and dried slowly.

According to Payne (1965) "... a definite ecological succession occurred among the fauna of carrion. Each stage of decay was characterized by a particular group of arthropods, each of which occupied a particular niche. Their activities were influenced by physical properties of carrion, rapidity of putrefacation, time of day, and weather."

Several other carrion insect studies conducted by Payne and his associates have been reported in the literature. Publications include reports on Hemiptera associated with pig carrion (1968); arthropod succession and decomposition of buried pigs (1968); Coleoptera associated with pig carrion and with insect succession and decomposition of pig carcasses in water (1970); and on Hymenoptera associated with pig carrion (1972).

The lack of knowledge on human decay rates has stimulated research by forensic scientists to devise methodologies which could determine the time interval since death. Some forensic scientists have approached this problem by studying the degree of deterioration of associated material (clothing, leather items, paper, etc.) which had been exposed to the environment over various time periods. Such studies have been reported by Daily (1982) as well as by Morse and Stoutamire (1980). Another approach was reported by Warren (1980), in which plants and related decomposition vectors of human skeletal remains from Southeast Asia were examined.

CHAPTER II

MATERIALS AND METHODS

The cadavers of three adult White males and one adult White female were used in this study. All four cadavers were donated to the University of Tennessee, Department of Anthropology for the purpose of scientific research. Information concerning the age, weight, stature and cause of death of each individual was recorded. The three male cadavers were completely intact and in each case, death was due to natural causes. However, the female cadaver had been autopsied with the brain and vital organs removed. Her death was attributed to multiple fractures of the skull and massive internal injuries received in an automobile accident.

Subjects and Collection of Data

The three males were placed in the decay facility within two days of their death, and the female within four days of her death. Between the time of death and commencement of data collection, the cadavers were stored in morgue coolers. An identification code number, representing the experimental subject and year of experimental trial, was assigned to each cadaver.

Experimental studies were conducted at the Department of Anthropology's decay research facility (Figure 5, Appendix). This facility is located in an open-wooded area of Knoxville, Tennessee. The decay research facility consists of a large concrete slab, 16' by 16', bordered by a small storage room are completely enclosed by a chain-link cage.

Each cadaver was placed in a specially designed wire coffin which sits approximately 2.5" above the concrete floor. Each coffin consists of a 72" by 24" by 36" lumber frame constructed from 2" by 4" planks. Covering the coffin on all sides is a .39" mesh hardware cloth; this provides easy access to the cadaver for insects, but prevents the destruction and loss of skeletal material by rodents. To allow for better observations and photography, the wire coffin lids were hinged. The research facility and a cadaver positioned in a coffin are shown in Figures 5 and 6, Appendix.

All articles of clothing were removed from the cadavers prior to placement in coffins. Cadavers were placed on their backs with the head facing forward, arms positioned to the sides and legs spread slightly apart.

The cadavers were placed in the decay facility at separate times of the year, this being dependent upon time of death. Placement dates at the facility are as follows: subject 1-81, an old male (placed 5-13-81); subject 2-81, an old male (placed 6-5-81); subject 3-81, an old male (placed 10-12-81); and subject 4-81, a middle aged female (placed 11-11-81).

Data concerning climatic conditions, body decomposition and insect activity were recorded daily. Each daily observational period began at noon and lasted from one to three hours, depending on the degree of insect activity. During warmer weather periods, additional observations were made at night to check for nocturnal insect activity.

Climatic data consisted of air temperature, relative humidity, rainfall and local sky conditions. Temperature and relative humidity were measured 24 hours a day using a Belfort continuous temperature/ humidity recorder. Rainfall was measured with the aid of a plastic rain gauge, and local sky conditions were judged by means of visual observation.

Data on the daily decompositional state of each cadaver were recorded by means of photographs and written documentation. Kodak 400 a.s.a. Ektachrome slide film was used for photographing the cadavers and insects. Photographs were taken with an Olympus OM-10 quartz camera in conjunction with wide angle, telephoto and macro lenses.

Insect Collection and Identification

Insect data consisted of daily observational records on the insect types, abundance, feeding and reproductive activity. Photographs of the various insects and their activities were also taken.

In addition to written and photographic records, insect specimens were collected from various areas of the cadaver and nearby soil. Adult Diptera (flies) forms were collected using an aerial insect net and larvae were collected with the aid of dissecting forceps. Both adult and larvae Coleoptera (beetles) forms were collcted with forceps or aspirator bottles. The number and type of insect specimens collected was arbitrarily decided on at each observation period. This decision, however, was based on the number of particular insects present and whether or not certain specimens could be easily identified in the field.

Determination of the abundance of insect species observed on the cadavers was very difficult. Some insect forms occurred in numbers too large to permit accurate counts. Other insect forms which were present in numbers small enough to count were sometimes hidden under decaying tissue or debris and were omitted during counting. Also many species could not be identified in the field, thus estimates of these species were based on the number of individuals collected.

A standard method for estimating the abundance of all insect forms could not be applid due to the different collection methods. For example, six individuals of a species of rove beetle might be collected on a cadaver and at the same time a netted sample of six individual blow fly might be collected, yet it would not be correct to assume that these two species were present in equal numbers.

The problem of making quantitative determinations of adult fly populations was particularly difficult. This was attributed to the differences in rapidity of flight and alertness of different fly species. Some species of blow fly like Calliphora vomitoria are slow fliers and not very alert, as where most flesh fly species are alert and fast fliers, making capture difficult or impossible. Other factors such as wind and high temperatures also increased the difficulty of collecting representative fly samples.

The number of insects and particular species were recorded in the field when possible. A five term scale developed by Reed (1958) was used to record the number of insects which were present in numbers too large to count. "The terms of this scale, arranged in order of increasing abundance are: rare, scarce, medium numbers, common and abundant." Use of this scale was also employed to estimate the number of individuals of certain insect families present.

Identification of insects was established using various taxonomic manuals by Arnett and Downie (1951), Borror and White (1970), Chu (1949), Curran (1934), Dillion and Dillion (1962), Hall (1948), James and Harwood (1971), Peterson (1951), and Swan and Papp (1970). Microscopic examination and various dissecting techniques were employed to determine the sex and species of certain insect forms. All insects collected were preserved in a solution containing 85cc of 90% alcohol, 10cc of 40% formalin and 5cc of glycerin.

CHAPTER III

OBSERVED STAGES OF DECOMPOSITION

During the interval of May 13, 1981 through May 13, 1982 observations of the four cadavers yielded significant information concerning the relationship of insect activity to human decay rates. It must be noted that subjects 3-81 and 4-81 are still undergoing the last stages of decomposition at the time this thesis is being written.

The cadavers were observed undergoing successional stages of decomposition. These stages were defined using the criteria set forth by Reed (1958). The first stage observed was the "fresh stage." This stage began upon the death of the individual and continued until the early stages of bloating. During warm weather bloating was observed to begin within a few days.

The second stage of decomposition observed was the "bloated stage." This stage began with the onset of bloating and ended with the cessation of bloating. Duration of this stage continued for approximately three to seven days during warm weather.

The third stage observed was the "decay stage." Commencement of this stage began when bloating ceased and ended when most of the cadaver remnants were relatively dry. Duration of the decay stage was approximately six to nineteen days during warm weather. During this "decay stage" the skin cracked in several areas, allowing the entrance of air, which facilitated the processes of aerobic protein decomposition. Reed (1958) stated that "... this process is referred to as decay by some bacteriologists in distinction from putrefacation, or anaerobic protein decomposition."

The final stage of decomposition observed was the "dry stage." This particular stage was more difficult to define than the previous stages, due to the lack of easily detectable events marking the beginning and completion of the stage. Generally defined, this stage began when only small amounts of tissue remained, and ended when no carrion insects remained. During warm weather this stage lasted for approximately 13 to 27 days. It must be noted that one cadaver was considered to be in the dry stage although it contained small amounts of moisture which was gained from climatic precipitation. Also during this stage small quantities of viscous putrefying material occasionally dripped off the cadavers.

If large patches of dry tissue remain on the cadaver during the dry stage, it becomes a shelter for insect fauna which are not normally associated with a decaying body. This was taken into consideration when collecting insects during this stage. Examples of each stage of decomposition are shown in Figures 7-11, Appendix.

CHAPTER IV

CARRION INSECT POPULATIONS OBSERVED

Numerous insect families and species were observed throughout the decompositional cycle of the cadavers. The majority of these insects can be basically classified as carrion insects. Carrion insects are those insects which feed on decomposing flesh or other insects at the site of a decaying organism. The feeding and reproducing insect families observed in association with a decaying organism represent a unique ecological system.

Once death occurs in an animal, that is exposed to the environment, the process of decomposition begins. As decomposition takes place, enzymatic and bacterial breakdown of the body tissues occur. The breakdown of body tissue in turn releases various odors which attract the carrion insects.

The highly developed sense of chemo-reception in carrion insects allows detection of a decaying organism. During each stage of decomposition specific odors are released into the environment at different concentrations. Specific insect families and species are attracted to the decaying organism during the particular periods when odors are released. This differential odor release is chiefly responsible for insect succession patterns that occur at an exposed and decomposing organism.

In the discussion of the carrion insects observed frequenting the human cadavers, the data are presented in a format which is similar to that described by Reed (1958). Use of this format provides a condensed yet informative presentation of the insect data. An example of this information which is abbreviated, is as follows:

Genus species[1]: Adults abundant (21 maximum), fresh and bloated, 2 cadavers, May 12, 1981 - September 9, 1981; larvae abundant, decay and dry, May 26, 1981 - October 2, 1981.

The data given in the previous abbreviations are as follows, in the order presented: 1. Recognition of the adults made in the field denoted by a small number "one" above species listed and those recognized in the laboratory denoted by a small number "two;" 2. Abundance of adults according to the five term scale; 3. Maximum number of individuals observed at (or collected and later identified from) a cadaver during one visitation; 4. Decompositional stage or stages when adults were observed in greatest numbers; 5. Number of cadavers from which adult insects were observed; 6. Seasonality pattern, with the first date representing teh earliest time of appearance for adults during active seasonality and the last date represents the latest such record. Seasonality is noted as "entire year" for some species, however communities of these species were much smaller in winter than during the other seasons; 7. Larva data, with the abbreviations following the semicolon denoting the same information as listed for adults, except for the exemption of item "1" in the sequence.

Order Diptera

During the fresh and bloated stages of the human cadavers, the insect order Diptera (the flies) were the most dominant insect form observed. The major Diptera families observed were the Calliphoridae (blow flies), Muscidae (house flies) and Sarcophagidae (flesh flies).

Members of the family Calliphoridae were the first insect forms to be observed on the cadavers. It was also observed that the female flies belonging to these families, greatly outnumbered the males, due to their reproduction strategy.

Family Calliphoridae (blow flies): Adults abundant, bloated, spring through fall, larvae abundant, bloated and decay, entire.

Blow flies range in size from approximately 5 to 13mm in length. These flies range in color from metallic blue or green to copper. The blow flies were the most abundant fly form present during the fresh and bloated stages. Enormous numbers of larvae were present during the bloated and early decay stages. During the decay stage migrating larvae and pupae were found in large numbers in the soil near the cadavers. The various species observed in this study are as follows:

Calliphora livida[2]: 56 adults, 4 cadavers, May 19, 1981 - November 19, 1982.

Calliphora terrae-novae[2]: 2 adults, 1 cadaver, November 21, 1981 - November 24, 1981.

Calliphora vincina[2]: 23 adults, 2 cadavers, October 14, 1981 - November 20, 1981.

Calliphora vomitoria[2]: 31 adults, 1 cadaver, October 16, 1981 - December 3, 1981.

Callitroga macellaria[1]: adults medium numbers, 4 cadavers, May 22, 1982 - November 18, 1981.

Cynomopsis cadaverina[2]: 43 adults, 3 cadavers, May 24, 1981 - June 11, 1981; and October 19, 1981 - October 27, 1981.

Lucilia illustris[2]: 24 adults, 2 cadavers, May 13, 1981 - July 6, 1981.

Phanecia caeruleiviridis[2]: 64 adults, 4 cadavers, May 14, 1981 - November 23, 1981.

Phanecia pallescens[2]: 47 adults, 2 cadavers, July 19, 1981 - October 16, 1981.

Phanecia sericata[2]: 39 adults, 4 cadavers, May 13, 1981 - November 17, 1981.

Phormia regina[1]: Adults abundant, found entire year.

Family Muscidae (house flies): Adults common, bloated and decay, all seasons; larvae common, bloated and decay, all seasons.

Flies belonging to the family Muscidae range in size from approximately 5-9mm in length. Muscids lack bright coloring and are usually a dull colored grey. The adult and larvae were observed on the cadavers in numbers considerably less than members of the family Calliphoridae. The various species observed in this study are as follows:

Fannia canicularis[2]: 2 adults, 1 cadaver, October 24, 1981 only.

Fannia incisurata[2]: 1 adult, 1 cadaver, October 15, 1981 only.

Musca domestica[1]: 29 adults, 3 cadavers, May 18, 1981 - November 5, 1981.

Muscina assimilis[2]: 5 adults, 1 cadaver, November 17, 1981 - December 3, 1981.

Muscina stabulans[2]: 2 adults, 1 cadaver, June 2, 1981 only.

Family Sarcophagidae (flesh flies): Adults medium numbers, bloated and decay, entire year; larvae scarce.

Flies belonging to the family Sarcophagidae range in size from approximately 7 to 15mm in length. These flies look similar to Muscidae flies but are distinguished by the checkerboard pattern on their abdomen. Most frequently these flies are observed breeding in animal excrement or flesh of dead animals. Sarcophagids are very alert and fast fliers making collection and determination of population size difficult. The various species observed in this study are as follows:

Sarcophaga haemorrhoidalis[1]: 8 adults, 2 cadavers, May 27, 1981 - August 28, 1981.

Sarcophaga sarraceniae[2]: 3 adults, 2 cadavers, September 11, 1981 - December 6, 1981.

Order Coleoptera

During the decay stage, the insect order Coleoptera (the beetles) competed with Diptera for dominance of the cadaver insect community. However, during the later period of the decay stage and on into the dry stage, Coleoptera were the dominant forms. The major Coleoptera families observed were the Silphidae (carrion beetles), Histeridae (clown beetles), Staphylinidae (rove beetles), Nitidulidae (sap beeltes), Cleridae (checkered beetles), Dermestidae (dermestid beetles) and Scarabaeidae (scarab beetles).

Family Silphidae (carrion beetles): Adults abundant, bloated and decay; larvae abundant, decay and dry.

Carrion beetles range in size from approximately 10 to 24mm in length. Some carrion beetles are brightly colored where as others are not. The adults feed on both decaying flesh and fly larvae. Eggs deposited by the female beetles are buried in a decaying animal or in nearby soil. Once the larvae hatch they will feed only on the decaying flesh, but later as mature larvae will feed on fly larvae. All carrion beetles have the ability to fly as well as crawl. The various species observed in this study are as follows:

Silpha surinamamensis[1]: Adults abundant, 3 cadavers, April 15, 1981 - September 12, 1981; larvae abundant, April 17, 1982 - September 21, 1981.

Silpha americana[1]: Adults common, 3 cadavers, April 5, 1982 - September 23, 1981; larvae common, April 2, 1982 - September 25, 1981.

Silpha inqequalis[1]: Adults common, 2 cadavers, February 24, 1982 - July 7, 1981; larvae abundant, February 26, 1982 - July 2, 1981.

Silpha noveboracensis[1]: Adults common, 3 cadavers, February 20, 1982 - June 28, 1981; larvae abundant, March 10, 1982 - July 9, 1981.

Necrophorus tomentosus[1]: Adults scarce, 2 cadavers, May 22, 1981 - September 18, 1981; larvae not observed.

Family Histeridae (clown beetles): Adults abundant, bloated and decay; larvae abundant, decay and dry.

Clown beetles range in size from approximately 1.5 to 10mm in length. These beetles are usually ovoid in shape, dark black in color with a polished appearance. Adult beetles frequent carrion where they feed on other small insects such as fly and beetle larvae. The various species observed in this study are as follows:

Atholus sedecemstriatus[2]: 6 adults, 2 cadavers, May 29, 1981 - September 2, 1981.

Hister abbreviatus[2]: 23 adults, 2 cadavers, May 18, 1981 - October 4, 1981.

Hister coenosus[2]: 9 adults, 1 cadaver, June 18, 1981 - August 23, 1981.

Phelister vernus[2]: 4 adults, 1 cadaver, June 27, 1981 - August 25, 1981.

Saprinus assimilis[2]: 37 adults, 3 cadavers, June 14, 1981 - August 9, 1981.

Saprinus conformis[2]: 7 adults, 2 cadavers, June 5, 1981 - September 11, 1981.

Saprinus lugens[2]: 3 adults, 2 cadavers, June 20, 1981 - October 28, 1981.

Family Staphylinidae (rove beetles): Adults abundant, bloated, decay and dry, all seasons; larvae abundant, decay and dry.

Rove beetles range in size from approximately 2 to 27mm in length. Most speices are black or brown in color with pubescent markings. These beetles are also very slender with short elytra which are squared at the posterior ends and cover two or three of the dorsal abdominal segments. The larvae look much like the adult form, but do not possess wings. Both adults and larvae have long, sharp mandibles which cross in front of the head. Adult rove beetles are very strong fliers and are capable of flying long distances. When caught or disturbed they elevate the abdomen in a threat stance much like a scorpion, as if they were preparing to sting. However, these beetles cannot sting but large specimens can inflict a painful bite. Various species can be found on carrion, manure or rotting logs. Adults and larve are predaceous, feeding on fly larvae and ants. Females deposit eggs in the soil near the available food source. The various species observed in this study are as follows:

Aleochara lata[1]: Adults common, 4 cadavers, January 23, 1982 - October 26, 1981.

Baryodma bimiculata[2]: 23 adults, 4 cadavers, May 20, 1981 - January 3, 1982.

Creophilus maxillosus[1]: 19 adults, 4 cadavers, May 22, 1981 - December 1, 1981.

Gyrophyphus hematus[1]: 2 adults, 2 cadavers, May 19, 1981 - July 30, 1981.

Ontholestes cingulatus[1]: 10 adults, 3 cadavers, May 23, 1981 - October 29, 1981.

Philonthus blandus[1]: 3 adults, 3 cadavers, May 24, 1981 - October 28, 1981.

Philonthus cyanipennis[1]: Adults scarce, 3 cadavers, May 23, 1981 - October 21, 1981.

Quedius capucinus[1]: 26 adults, 4 cadavers, May 22, 1981 - December 18, 1981.

Staphylinus maculosus[1]: 12 adults, 3 cadavers, May 17, 1981 - October 26, 1981.

Rugilus angularis[2]: 14 adults, 4 cadavers, May 18, 1981 - January 5, 1982.

Tachinus fimbriatus[2]: 4 adults, 4 cadavers, May 20, 1981 - November 27, 1981.

Tachinus flavipennis[2]: 16 adults, 2 cadavers, June 16, 1981 - October 27, 1981.

Family Nitdulidae (sap bettles): Adults common, late decay and dry; no larvae observed.

Sap beetles range in size from approximately 2 to 6mm in length. These beetles are usually brown, black or grey in color. Diet consists of decaying plant material and fungus associated with drying animal bones. The various species observed in this study are as follows:

Nitidula bipunctata[2]: 5 adults, 2 cadavers, April 12, 1982 - June 17, 1981.

Omostia colon[2]: 58 adults, 3 cadavers, February 3, 1982 - December 10, 1981.

Family Cleridae (checkered beetles): Adults medium numbers, dry stage; no larvae.

Checkered beetles range in size from approximately 4 to 10mm in length. These beetles are cylindrical in shape and are often brightly colored. The adults are predacious, feeding on dermestid and cheese skipper larvae. They are most common on the dried carcasses of dead animals. The various species observed in this study are as follows:

Necrobia violacea[1]: Adults scarce (10 maximum), 3 cadavers, May 30, 1981 - November 27, 1981.

Necrobia ruficollis[1]: Adults scarce (7 maximum), 3 cadavers, June 23, 1981 - November 19, 1981.

Necrobia rufipes[1]: Adults scarce (3 maximum), 3 cadavers, June 4, 1981 - October 23, 1981.

Family Dermestidae (dermestid beetles): Adults abundant, dry stage, entire year; larvae abundant, dry stage, entire year.

Dermestid beetles range in size from approximately 3 to 7mm in length. These adult beetles are robust and usually covered with dull or brightly colored scales. The larvae are long and cylindrical in shape and covered densly with fine hairs. Both the adult and larvae can be found feeding upon materials such as, dry skins, bones, feathers or hair. The only specie observed in this study is as follows:

Dermestes caninus[1]: Adults abundant (maximum 80), 3 cadavers, March 13, 1982 - December 6, 1981; larvae abundant (over 100), 4 cadavers, March 19, 1982 - October 25, 1981.

Family Scarabaeidae (Scarab beetles): Adults common, dry stage; larvae common, dry stage.

Scarab beetles range in size from approximately 6 to 18mm in length. These beetles are usually black or brown in color with oval or elongated bodies. Species of this family feed on dung, excreta, feathers, skin and carrion. The various species observed in this study are as follows:

Ateuchus histeriodes[1]: Adults scarce (3 maximum), 3 cadavers, June 1, 1981 - October 27, 1981.

Geotrupes blackburnii[1]: 2 specimens, 3 cadavers, February 2, 1982 - December 7, 1981.

Geotrupes splendidus[1]: Adults scarce (2 maximum), 3 cadavers, March 9, 1982 - December 4, 1981.

Trox monachus[1]: Adults common (10 maximum), 4 cadavers, February 3, 1982 - December 17, 1981; larvae common, May 29, 1981 - December 12, 1981.

Trox suberosus[1]: Adults scarce (3 maximum), r cadavers, June 2, 1981 - November 27, 1981.

CHAPTER V

RESULTS

Rate of Decay

The decompositional rate of each cadaver observed varied. Variation in the decay rates were due mainly to the climatic differences during each season. Subjects 1-81 and 2-81, which were placed at the decay facility in the spring (5-13-81) and summer (6-5-81), decayed at a much faster rate than subjects 3-81 and 4-81, which were placed at the facility in the fall (10-12-81) and winter (11-11-81).

Warmer temperatures during the spring and summer increased the number and types of carrion insects found in association with the cadavers. This in turn produced faster decomposition of the cadavers. During the cooler temperatures of the fall and winter there was a decrease in the number and types of carrion insects thus producing slower decomposition of the cadavers.

Table I, Appendix, shows the amount of time required for each cadaver to proceed through the various stages of decomposition. Normal and actual monthly temperatures and precipitation during the period of study are shown in Figure 1, Appendix.

Insect Successional Patterns

Insects belonging to the orders Diptera (flies) and Coleoptera (beetles) were found to be the two major insect groups frequenting the decaying cadavers. Of these two orders, ten insect families were represented. Insect data analysis showed that there was a definite successional pattern of insect families frequenting each cadaver throughout the decay process. The successional patterns observed in this study are consistent with those described by Reed (1958).

This successional pattern was marked by the presence of a particular insect family or families during each stage of decomposition. The succession of insect families observed in this study were found to be consistent with those described by Reed (1958). Also the various insect species observed in this study were found to be the same as those reported by Reed (1958).

However, there are variations in the minimum time for particular insect species to begin frequenting the decaying subjects. These variations can most likely be attributed to the different decompositional rates of dog and human cadavers, which is to be expected considering the differences in body size and composition.

Insect and decompositional data collected in this study were also compared with that reported by Payne (1965, 1970, 1972). Similarities were found to exist between the decompositional stages and insect families observed. Many of the particular insect species reported on by Payne, were also observed in this study. Payne did not greatly elaborate on the specific insect successional and seasonality patterns observed, ruling out an accurate comparison of results.

During the "fresh stage" of decay, blow flies and muscid flies were the primary insect types observed. Their basic activities were feeding and reproduction on the cadavers. Egg laying by adult flies, first occurred in the area of the face; eggs being deposited in the nasal openings, ears, mouth and eyes (Figures 12 and 13, Appendix). Toward the end of the "fresh stage" eggs were deposited in the area of the scrotum or vagina (Figure 27, Appendix). Hatching of the eggs occurred shortly afterwards, with newly hatched fly larvae feeding on the flesh. Fly activity continued until the "dry stage" of decomposition.

At the onset of the "bloated stage" carrion beetles followed by rove and clown beetles were observed in association with the cadavers. These beetles were observed feeding on the young fly larvae, however the carrion beetles were also observed feeding on the decomposing flesh of the cadavers. In addition to the continued presence of blow and muscid flies, flesh flies were observed feeding and depositing eggs on the cadavers.

During the "decay stage" sap beetles were observed in association with the cadavers. All previously mentioned insect types continued to frequent the cadavers during this stage. The latter part of this stage was characterized by the decline of all insect types other than the sap and small rove beetles.

With the onset of the "dry stage" only sap and rove beetles remained and were joined by dermestid, checkered and lamellicorn beetles. These beetles were observed feeding on the remaining dry tissue, hair and fungus on the cadavers.

Figure 2, Appendix, lists the ten major insect families observed and their approximate spring/summer distribution during the stages of decay. A representative adult member of each arthropod family observed is illustrated in Figure 3, Appendix. Fall and winter insect distribution varied in the number of individuals and particular species present.

It must be noted that insect groups other than those listed were also observed frequenting the cadavers. Due to the great variation of their distribution during the decay stages, they were not included in this study.

Various larvae insect forms were observed on the decaying cadavers. The larvae represented seven insect families. Figure 4, Appendix, lists the seven insect larvae families observed and their approximate spring/summer distribution during the stages of decay. Distribution of the larvae in this study were fairly consistent with those described by Reed (1958).

The insect family observed frequenting the cadavers in the greatest numbers were blow flies. These flies belong to the family Calliphoridae and were the major vector in the degradation of the cadavers. Adult blow flies were observed on the cadavers within 1 to 2 hours after placement at the decay facility. Shortly afterwards the female blow flies were observed depositing eggs in the various facial cavities.

Hatching of the blow flies eggs occurred within 6 to 40 hours, at which time the emerging larvae began feeding on the cadaver tissues. The growing larvae fed on decaying flesh for 3 to 10 days. Upon reaching maximum growth the larvae migrated off the cadavers in great numbers and buried into the nearby soil (Figure 35, Appendix).

Once buried, the larvae began to pupate, this lasted between 6 to 18 days after which the adult fly forms would hatch from the appuariums and dig to the surface. The time period required for each of the previously mentioned developmental stages was dependent on temperature and fly species.

Another interesting observation made was that a successional pattern existed for flies as a group. The first flies observed to frequent the cadavers were species of the genus Phaenicia. Several days later, species of the genus Callitroga began frequenting the cadavers.

In a few more days species of the genus Calliphora and Cynomyopsis were observed on the cadavers. The last fly group attracted to the cadavers were species of the genus Sarcophaga. This same successional pattern was reported by Hall (1948) using aged meat baits to capture blow flies. Various examples of insects frequenting the cadavers are shown in Figures 12-40, Appendix.

CHAPTER VI

DISCUSSION AND CONCLUSIONS

The decomposition of human cadavers was found to occur most rapidly during the spring and summer. Carrion insect populations found on the cadavers were at their greatest during these two seasons. During the fall and winter when carrion insect populations were at their minimum, decomposition of human cadavers was found to occur slowly. This correlation between the rate of decay and number of carrion insects, indicates that insects are a major factor responsible for decomposition.

It was very apparent in this study that a decaying human cadaver undergoes four basic decompositional stages. These stages have been termed the fresh, bloated, decay and dry stage. The succession of each decompositional stage was found to be well correlated with the successional patterns of various carrion frequenting insect groups.

Many of the carrion insects which frequented the cadavers were found to be active only during particular months of the year. Also minimum and maximum time limits were established for the appearance of various carrion insect families and individual species on the cadavers. The growth and development of particular fly species which fed on the cadavers were also observed to occur at rates previously established by entomologists.

Other Factors Affecting Decomposition

Climatic conditions and insect activity are basically responsible for the rate of decomposition in human cadavers, however they are not the only factors. Another important factor observed in this study was the body build of a cadaver.

It was very evident that no one human cadaver decomposes at the same rate as another. A deceased individual who is very fat or muscular will decompose at a much slower rate than an individual who has a very lean body build. So the rates of decomposition observed in this study can serve only as generalized time sequences. Perhaps with the additional study of a greater number of cadavers the maximum and minimum rates of decomposition can be more accurately determined.

As noted before, there are many variables which in some was affect the rate of decomposition. Some of the variables include whether a cadaver is dressed or nude, placed on top of the soil or below, and/or placed in the shade or in direct sunlight. This initial study only tested a few of these variables. Additional research testing other variables and experimental conditions is either in progress or planned for the future.

Anthropological Applications

Information acquired in this study can be of definite value to archaeologists and physical anthropologists. Archaeologists, in their study of historic and proto-historic people, try to answer many questions concerning cultural patterns. One group of cultural patterns or ceremonies that are of interest to archaeologists are mortuary practices.

Mortuary practices are basically the various methods utilized by different peoples to inter their dead. In certain geographical regions of the United States preservation at grave sites are exceptionally good.

Human skeletal material recovered in such instances might also contain the dried remains of various insects in the skeletal cavities.

The preserved insect remains would most likely be that of fly pupariums and beetle elytra. This has been reported in studies conducted by Gilbert and Bass (1967) as well as by Ubelaker and Willey (1978).

Recovery and identification of these remains could then be compared to the findings of this present decay study. After careful comparison, the determination of the seasonality of a burial could be estalbished in certain cases. Determination of the seasonality of a burial can also be of great use to physical anthropologists who might be studying some spect of mortality rates.

The most important and accurate use of the data collected in this decay study is in the field of forensic anthropology. Forensic investigators, particularly forensic anthropologists, are often called upon by law enforcement officials to determine the time interval since death of a decaying corpse. Until now, few studies have been conducted to devise methodologies by which this determination could be made.

Information obtained in this study, on the active seasonality and successional pattern of various carrion insects could provide a measure for establishing time interval since death. Present and future analysis of these insect data will be used to develop a chart of the various insect species along with their seasonality and duration of successional patterns. A forensic investigator comparing this chart with entomological data collected at the site of a decaying corpse hopefully fill be able to make a reasonably accurate determination of time since death.

Based on the information acquired in this study, it can be concluded that one of the major contributors human decay rates are carrion insect activity. Knowledge and better understanding of this relationship can be a valuable tool for anthropologists and forensic scientists.

CHAPTER VII

SUMMARY

Four unembalmed human cadavers were placed in an open, wooded area of east Tennessee and allowed to decay naturally. Each cadaver was placed at the study area during a particular season. Daily observations and photographs of the decompositional process and insects involved were made.

It was observed that an unembalmed cadaver allowed to decompose naturally, undergoes four separate decay stages named fresh, bloated, decay, and dry, respectively. The rate at which these stages occur is mainly dependent on climatic conditions and carrion insect populations.

Also observed was that decomposition of the cadavers occurred most rapidly during the spring and summer when temperatures were warm and carrion insect populations were the greatest. Insect types frequenting the cadavers were observed to change in succession with the stages of decay.

This study has shown that data on the successional pattern and seasonality of particular carrion insects species can be an aid in determining "the time interval since death" of a decaying corpse.

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APPENDIX

TABLE I

AMOUNT OF TIME REQUIRED FOR EACH CADAVER TO PROCEED THROUGH THE VARIOUS STAGES OF DECOMPOSITION

SUBJETS AND PLACEMENT DATES	STAGES OF DECOMPOSITION			
	FRESH	BLOATED	DECAY	DRY
SUBJECT 1-81 5/13/81	10 DAYS	5 DAYS	19 DAYS	27 DAYS
SUBJECT 2-81 6/5/81	4 DAYS	3 DAYS	8 DAYS	13 DAYS
SUBJECT 3-81 10/12/81	14 DAYS	7 DAYS	still in progress	
SUBJECT 4-81 11/11/81	38 DAYS	.18 DAYS	112 DAYS	still in progress

Total observation period for decay rate study was one full year (May 13, 1981 – May 13, 1982).

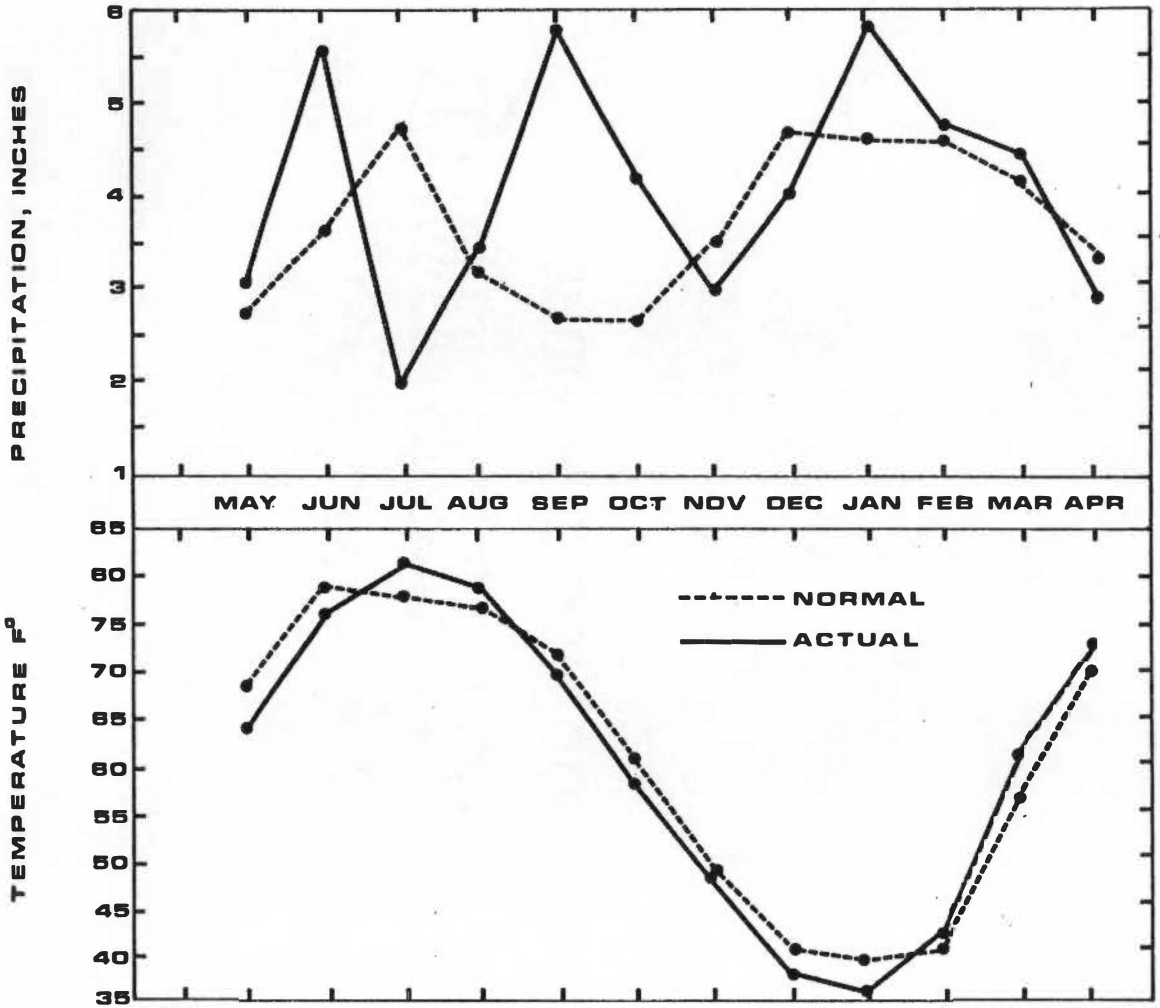


Figure 1. Normal and Actual Monthly Temperatures and Precipitation During the Period of Study.

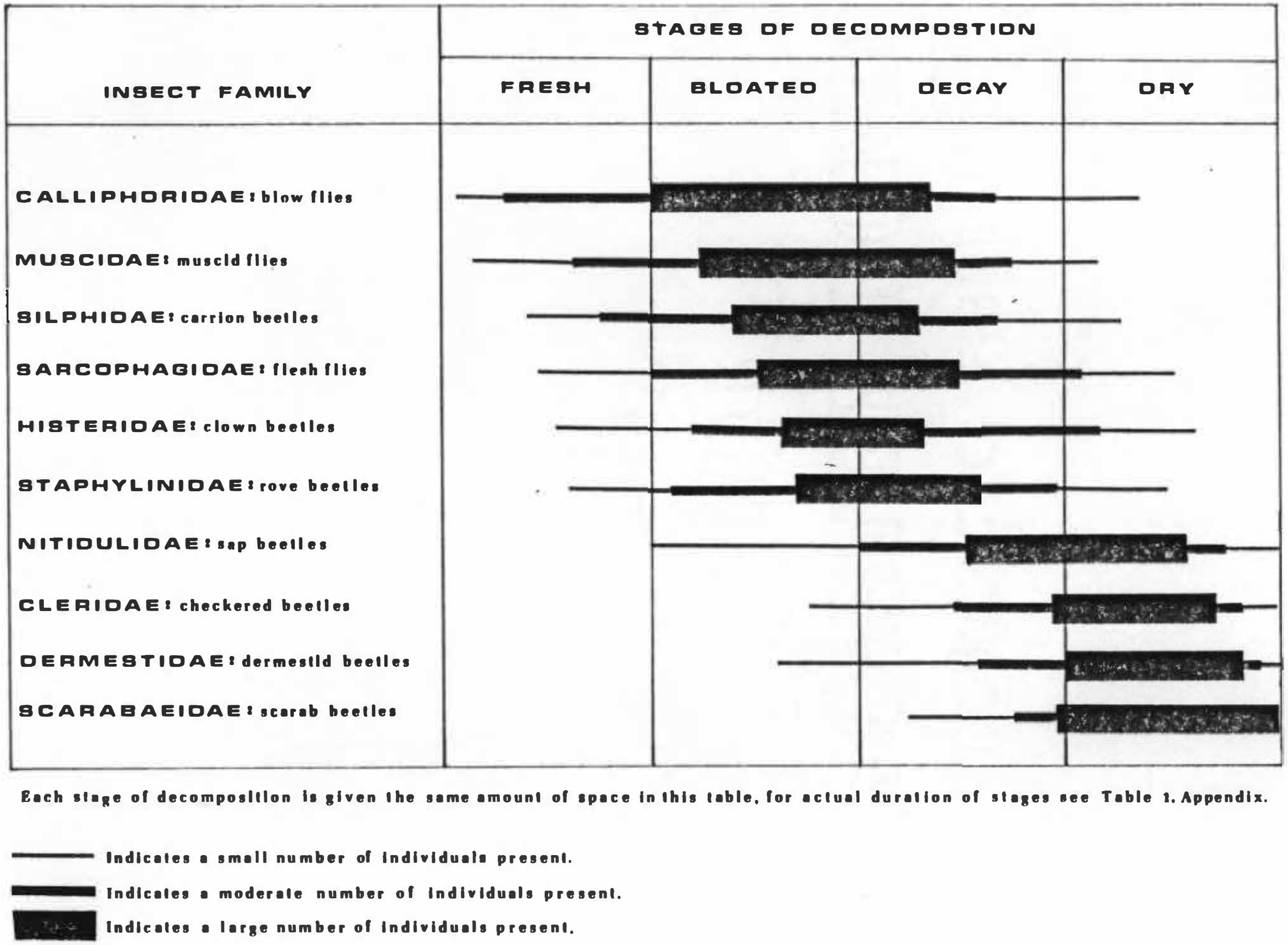
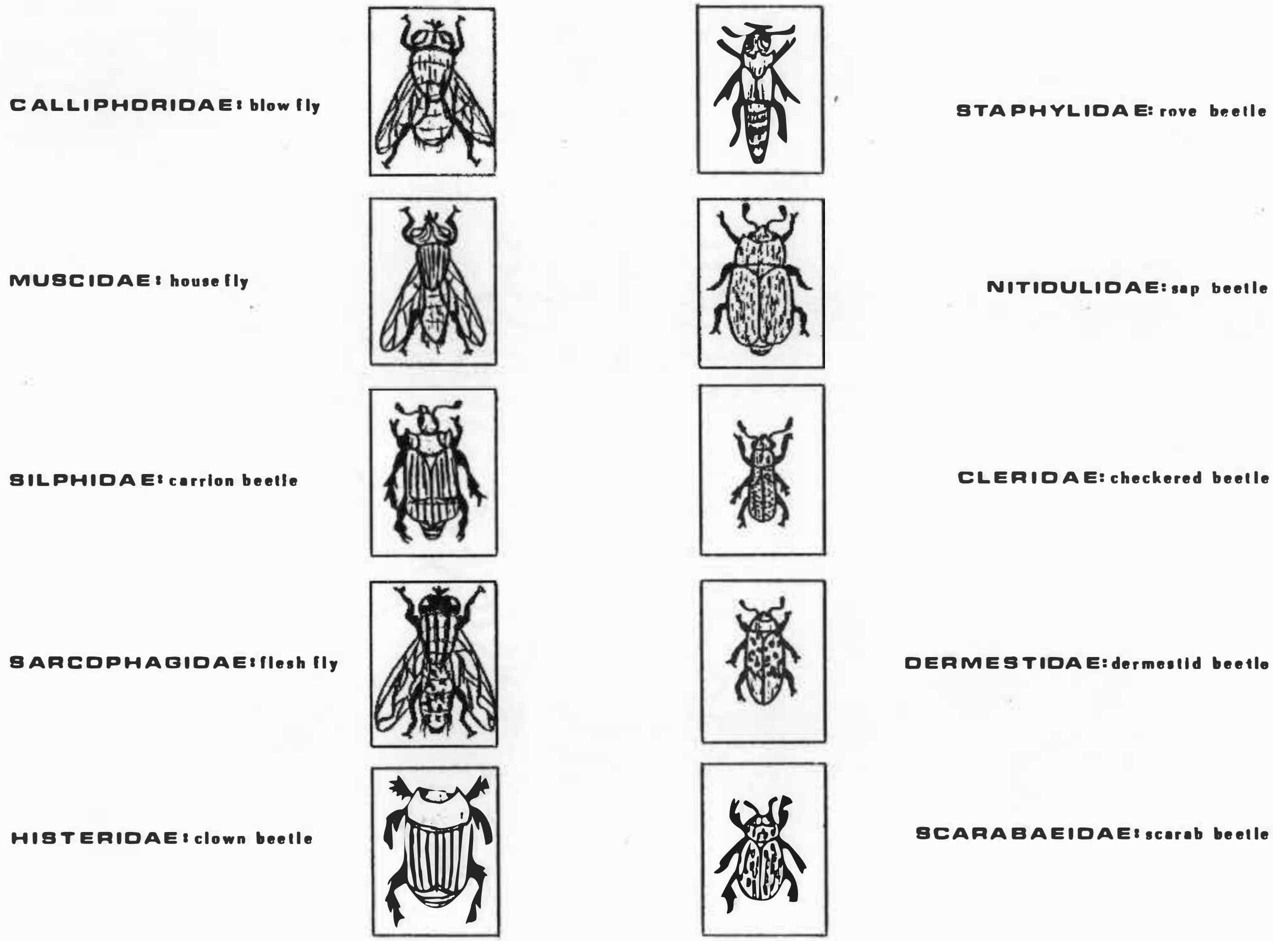


Figure 2. The Ten Major Insect Families Observed and Their Approximate Spring/Summer Distribution During the Stages of Decay.



The insects illustrated are not drawn to scale and do not represent any particular genus or species.

Figure 3. A Representative Adult Member of Each Arthropod Family Observed.

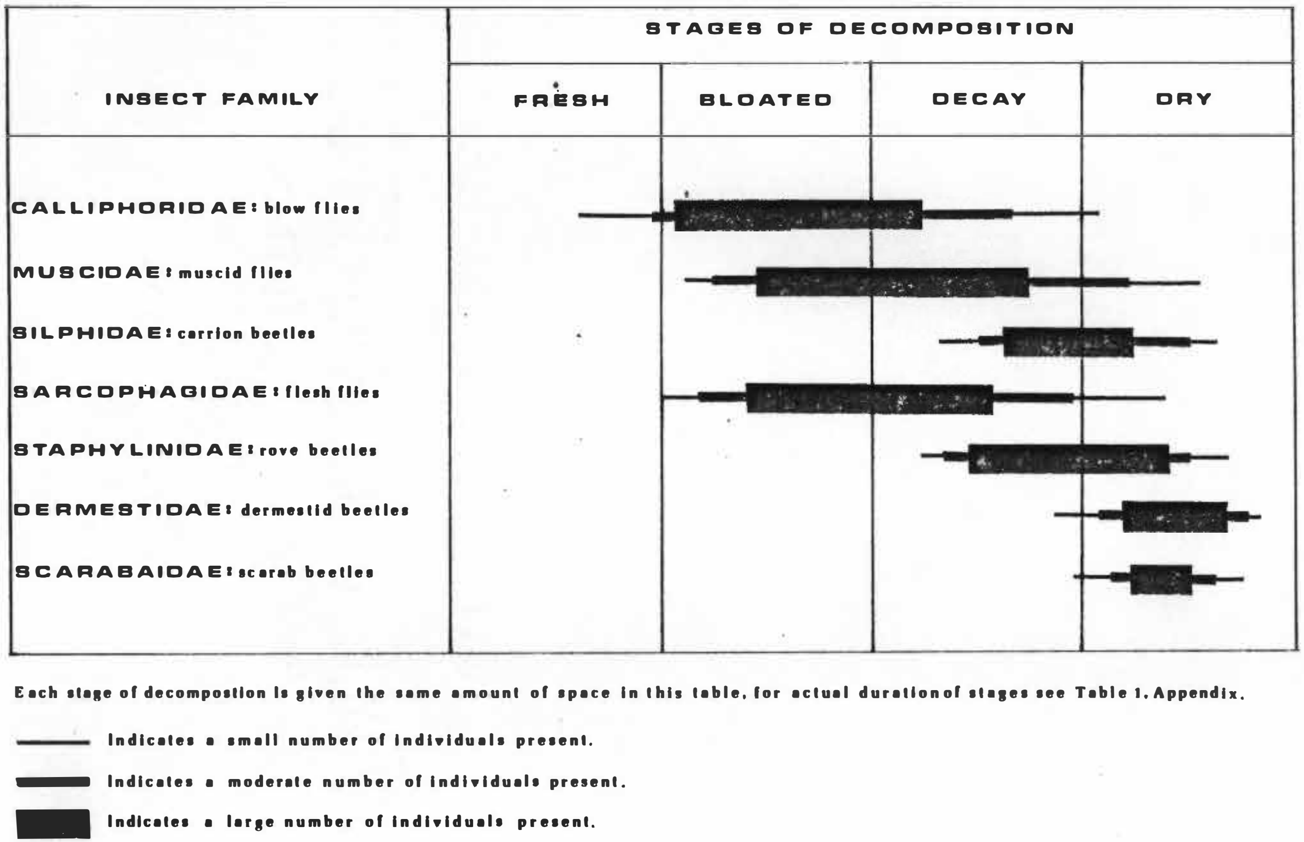


Figure 4. The Seven Insect Larvae Families Observed and Their Approximate Spring/Summer Distribution During the Stages of Decay.

Figure 5. Anthropology Decay Research Facility.

Figure 6. Cadaver Lying in Coffin.

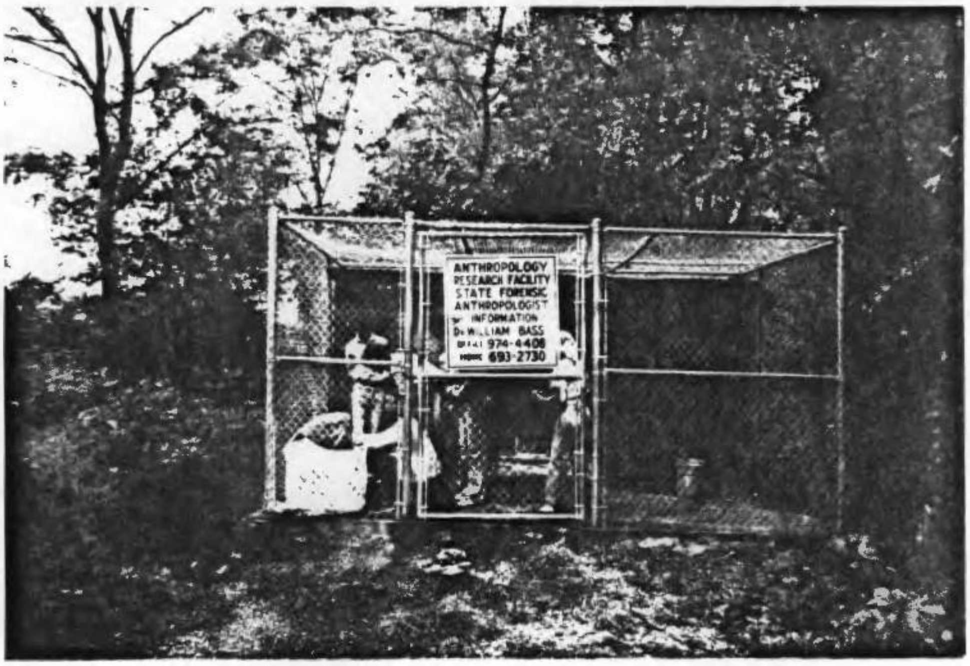


Figure 5

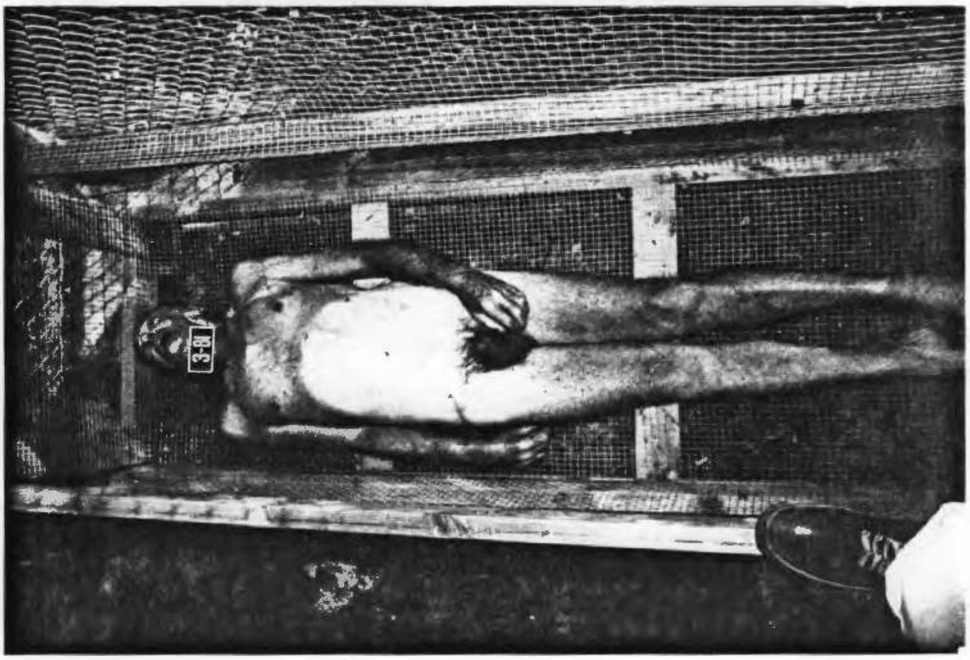


Figure 6

Figure 7. Side View of a Cadaver During the "Fresh Stage."

Figure 8. Side View of a Cadaver During the "Bloated Stage."

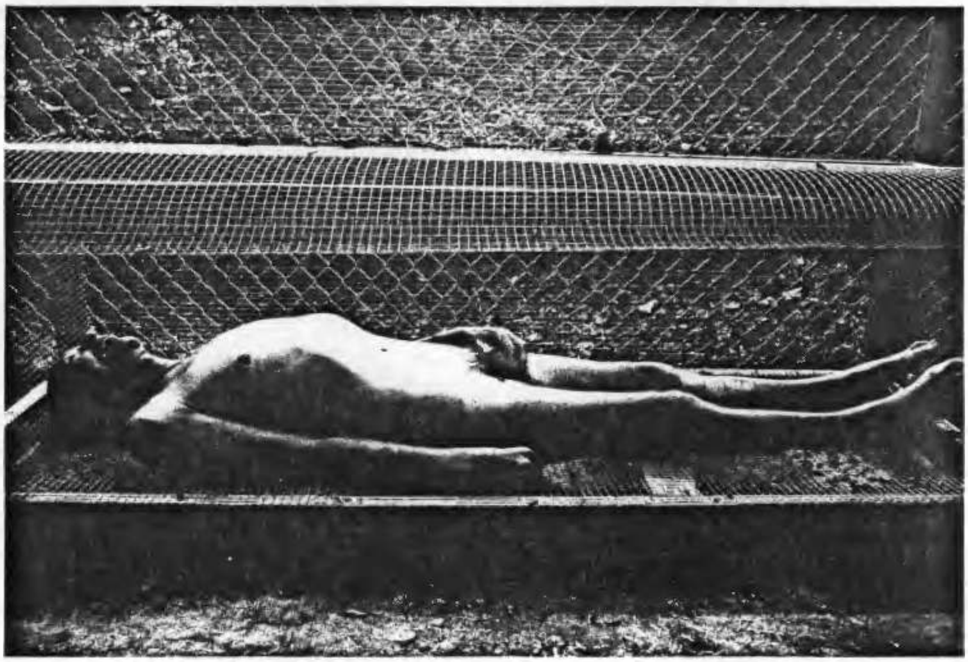


Figure 7

Figure 8

Figure 9. Side View of a Cadaver During the "Decay Stage."

Figure 10. Side View of a Cadaver During Advanced Decay.

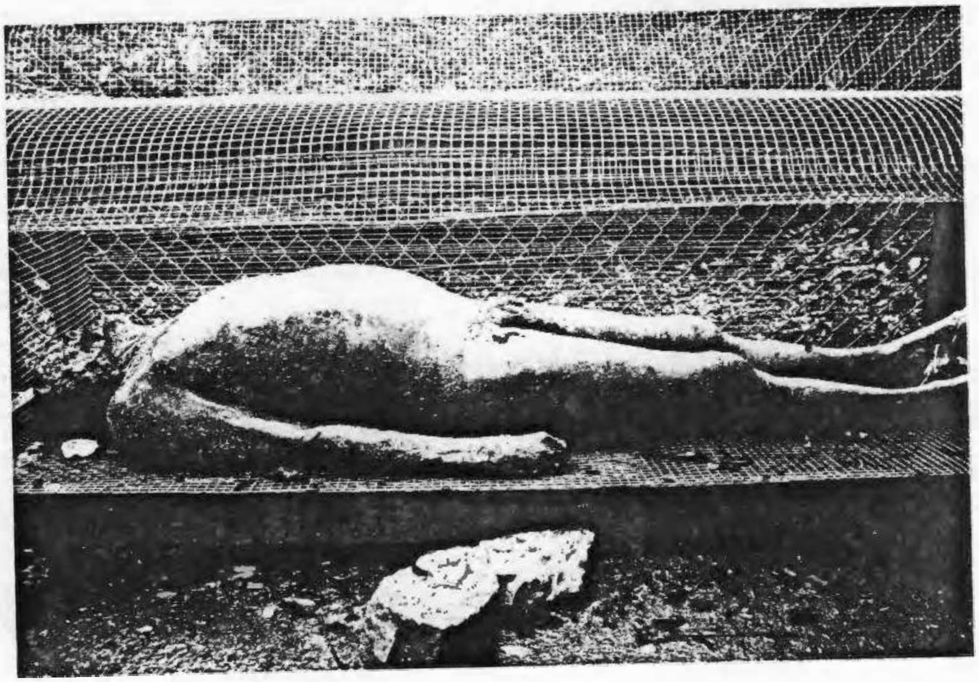


Figure 9

Figure 10

Figure 11. View of a Cadaver in the "Dry Stage."

Figure 12. Blow Flies Laying Eggs in the Mouth and Eyes of a Cadaver One Hour After Placement at Facility.

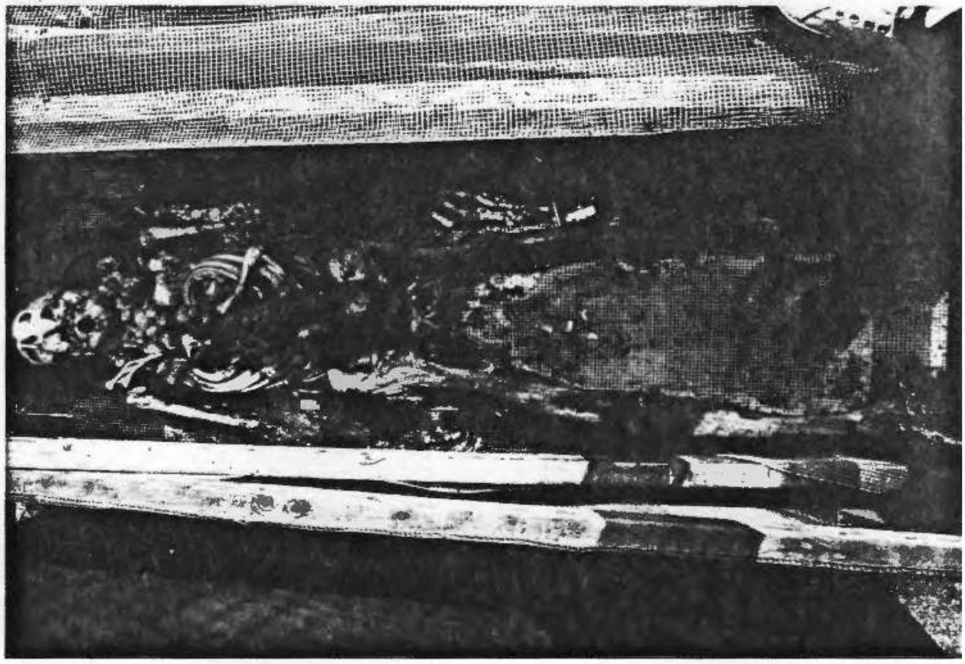


Figure 11

Figure 12

Figure 13. Two Blow Flies Beginning to Lay Eggs in the Left Nostril of a Cadaver.

Figure 14. View of Face Showing a Number of Fly Eggs in the Left Nostril.

Figure 13

Figure 14

Figure 15. View of Face Showing Large Egg Masses in Both Nostrils.

Figure 16. View of Face Showing Egg Masses Around Left Eye and Newly Hatched Larvae at the Base of the Nose.

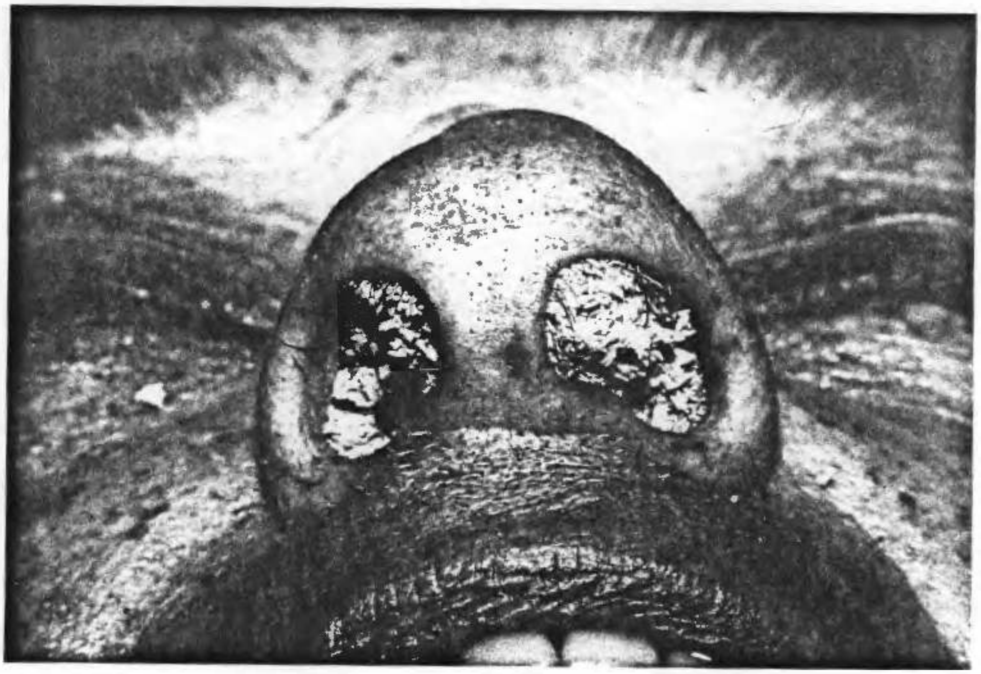


Figure 15

Figure 16

Figure 17. View of Face Showing Increased Decomposition and Larvae Activity.

Figure 18. View of Face Showing Many Blow Flies, Young Larvae and New Egg Mass in Right Eye.

Figure 17

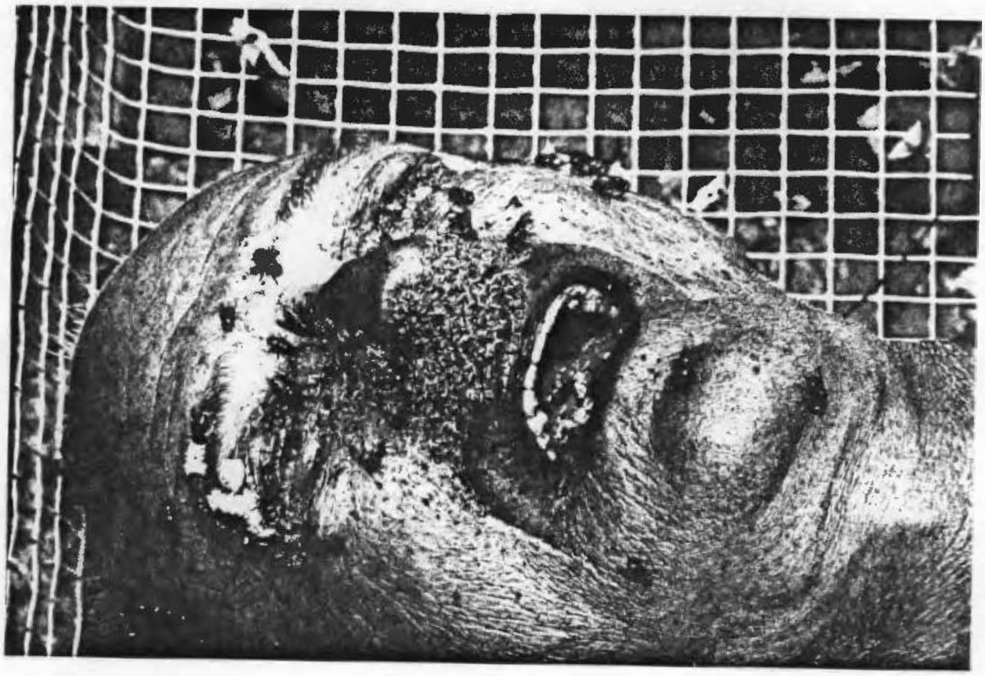


Figure 18

Figure 19. View of Face Photographed Late in the Evening, All Fly Larvae Have Migrated for the Night Down into the Nasal Passages.

Figure 20. Side View of Face Showing Enlargement of Nose and Upper Lip Which Are Covered With Fly Larvae.

Figure 19

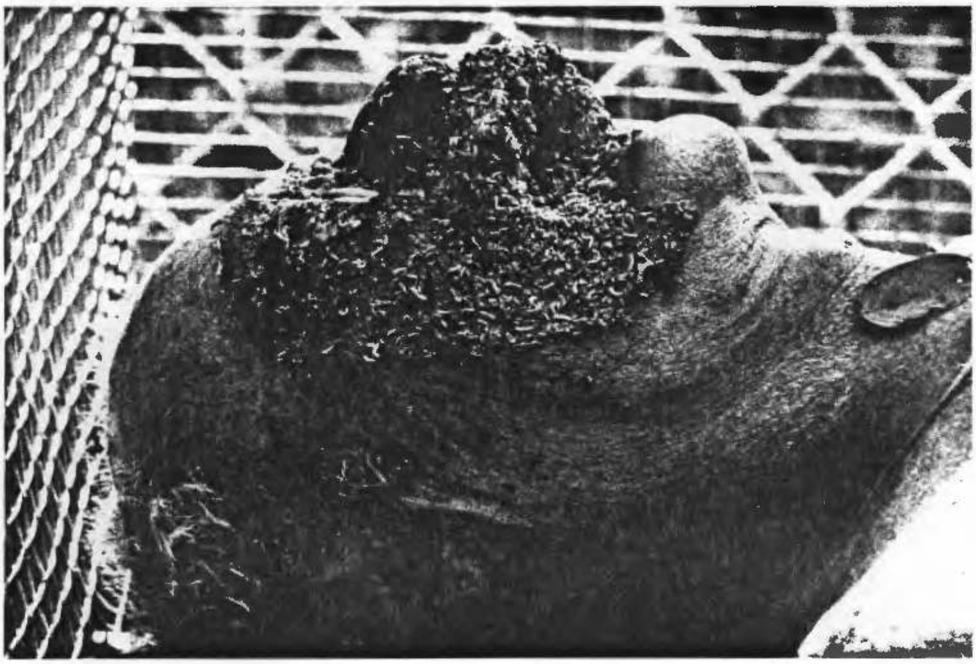


Figure 20

Figure 21. View of Face Showing Swollen Nose and Numerous Fly Larvae.

Figure 22. View of Face Showing Extensive Decay and Displacement of Maxillary Dentures.

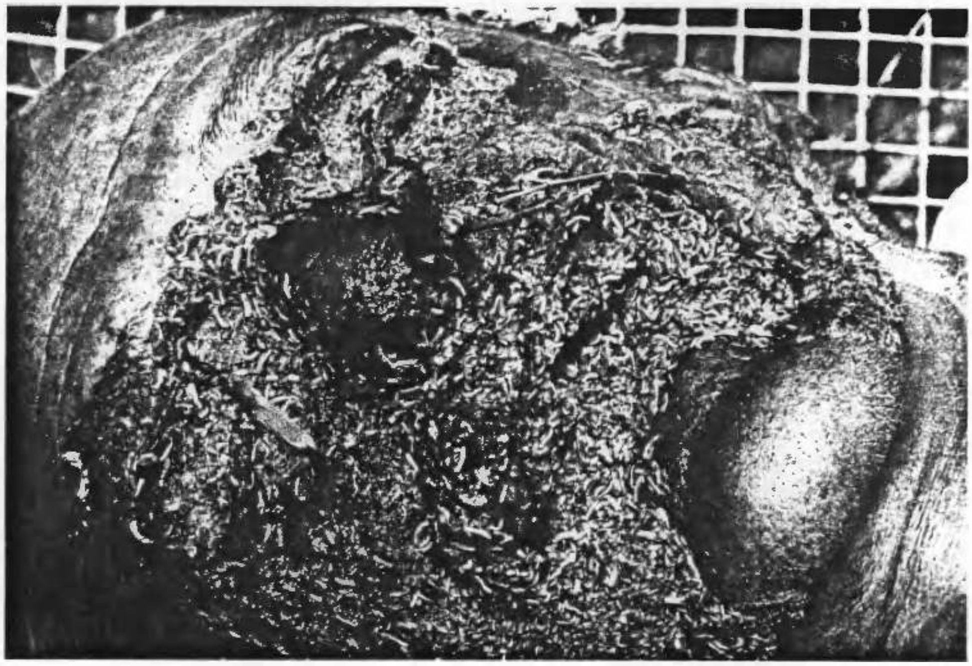


Figure 21

Figure 22

Figure 23. Extensive Degradation of Cadavers Face by Fly Larvae, Also Large Adult Rove Beetle on Chin in Search of Prey.

Figure 24. View of a Cadavers Abdominal Section Showing Fly Larvae Boring In and Out of Skin.

Figure 23

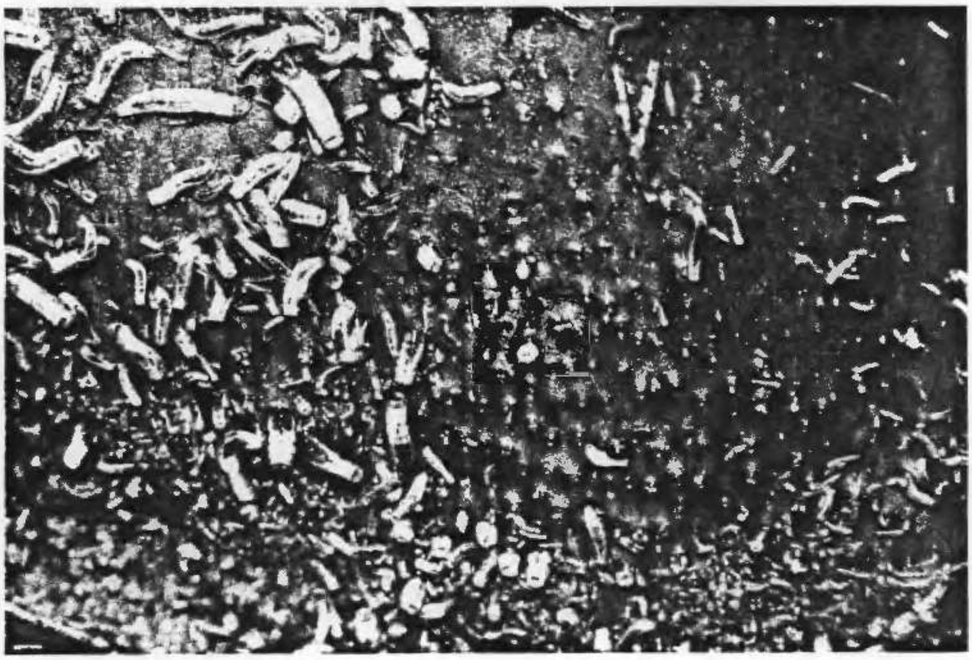


Figure 24

Figure 25. Marked Area Next to Facility Where Insect Samples Were Collected From the Soil.

Figure 26. Side View of Upper Torso Showing the Extent of Bloating and Larvae Activity.

Figure 25

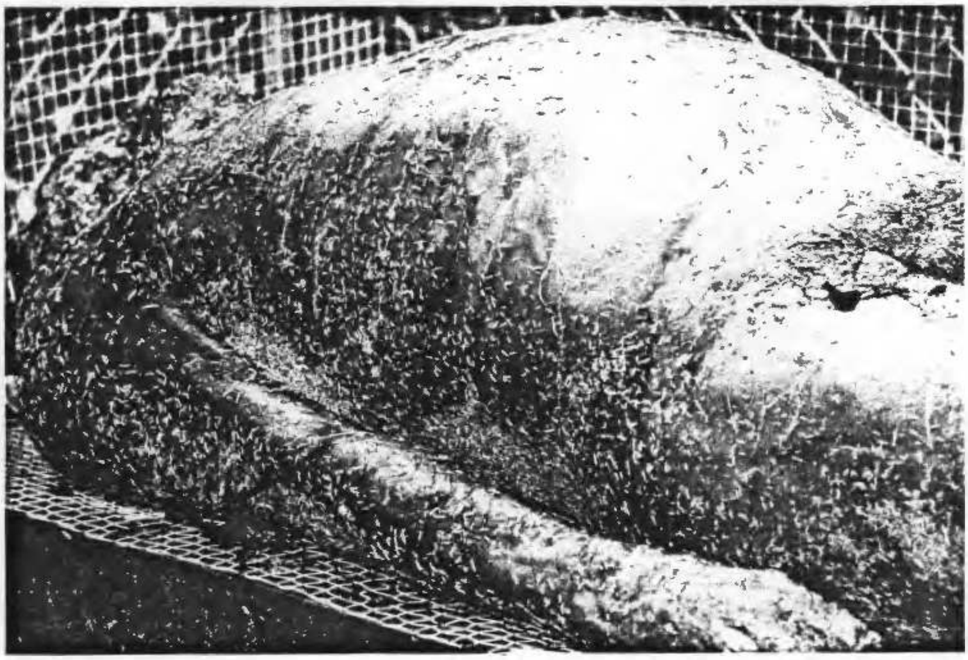


Figure 26

Figure 27. View of Swollen Scrotum with Large Larvae Blisters at the Base of the Penis.

Figure 28. View of Cadavers Face Showing Two Black Carrion Beetles Feeding on Decaying Flesh Below the Nose.

Figure 27

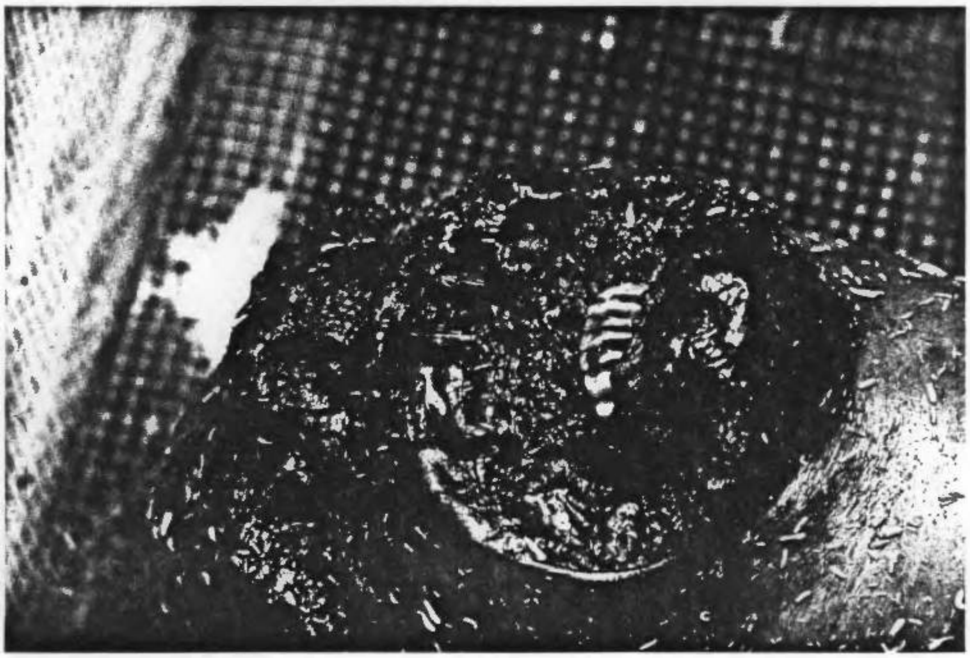


Figure 28

Figure 29. Close up View of Two Carrion Beetles Feeding on the Decayed Face of a Cadaver.

Figure 30. View of Genitals with Small Egg Masses Scattered Throughout the Pubic Hair.

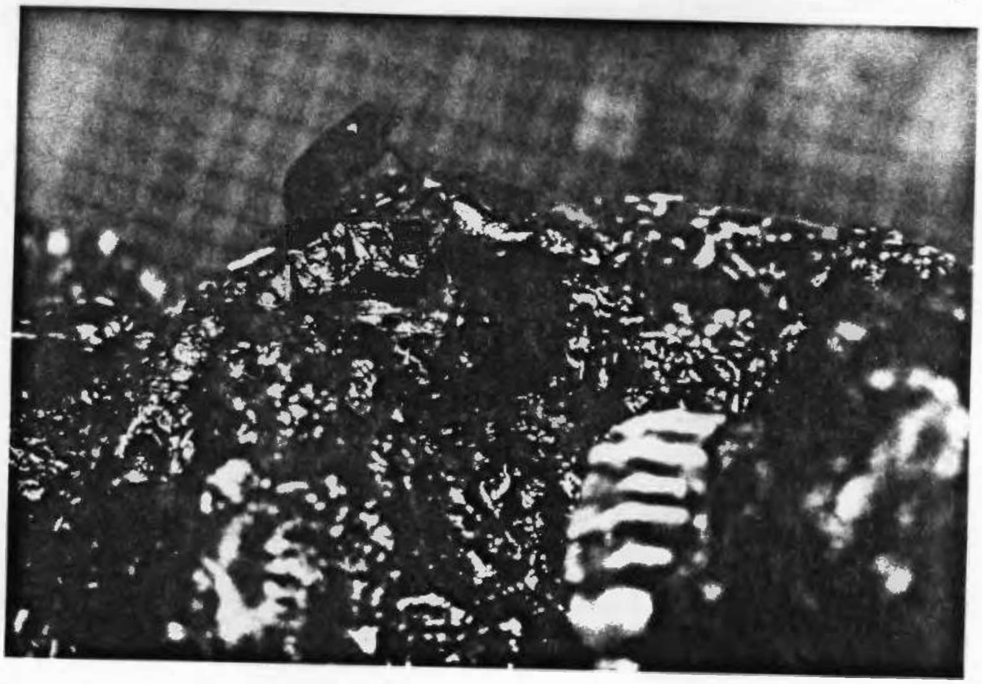


Figure 29

Figure 30

Figure 31. Close up View of Face Showing Extensive Decomposition and Exposure of Maxillary Dentures.

Figure 32. View of the Lower Legs Showing Large Larvae Blisters.

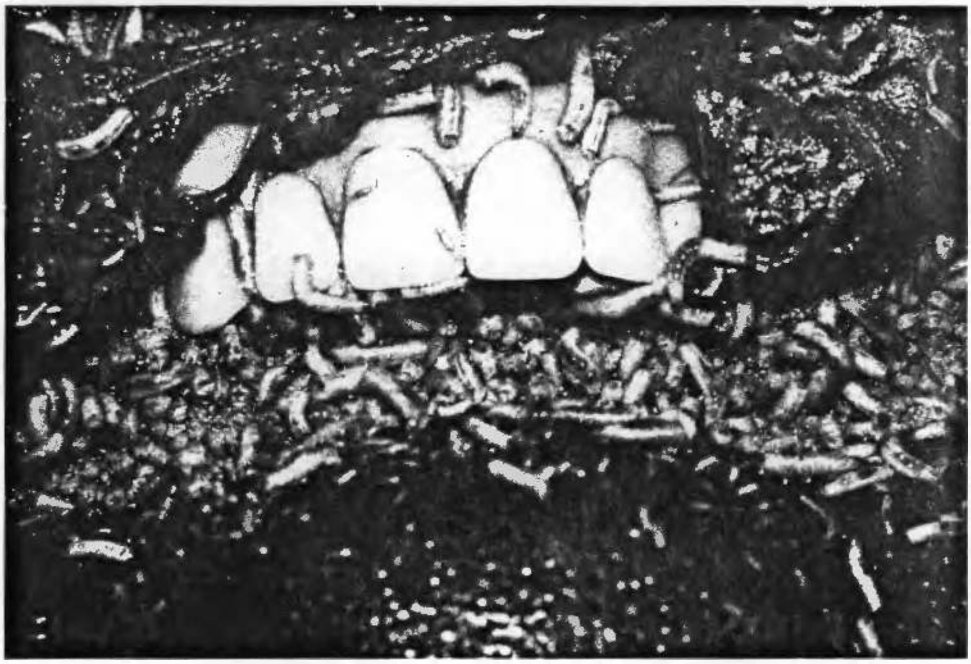


Figure 31

Figure 32

Figure 33. Mass of Maturing Fly Larvae in Abdominal Cavity.

Figure 34. View of the Genitals with Large Egg Masses at the Sides of the Scrotum.

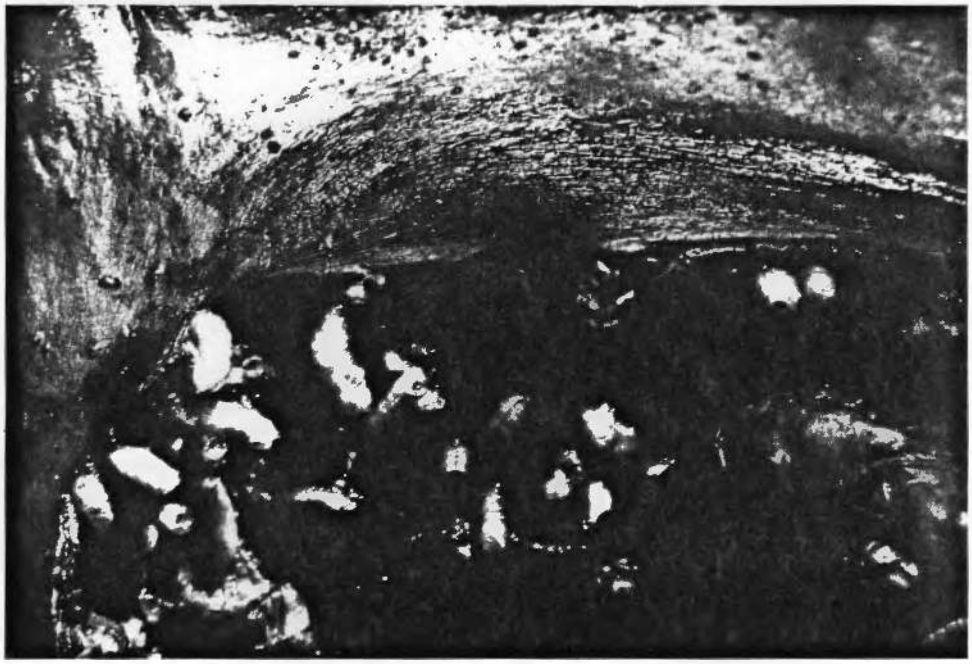


Figure 33

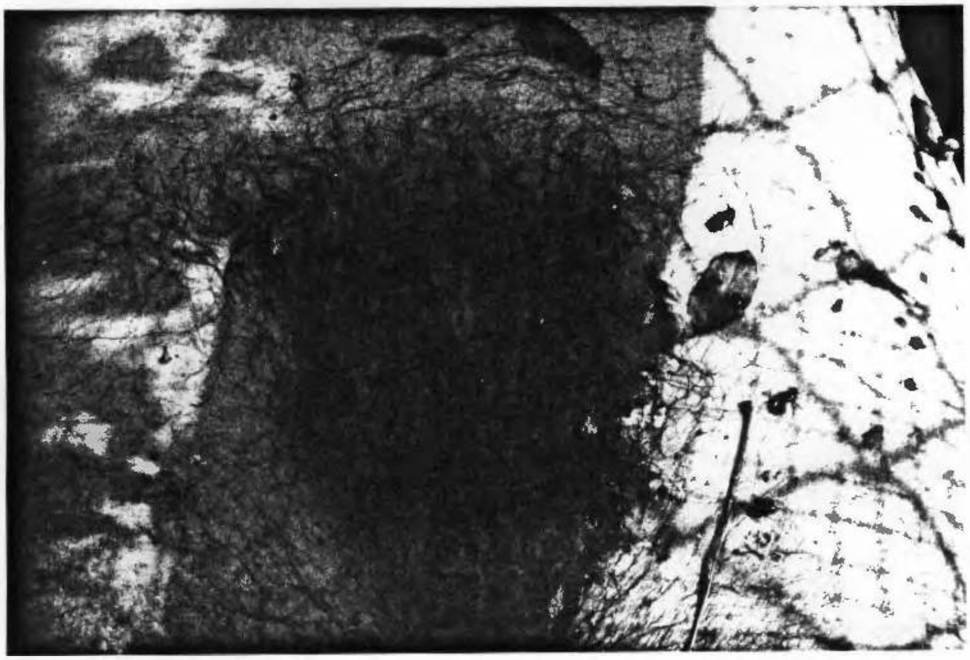


Figure 34

Figure 35. Larvae Migration on the Soil with Penny in Background.

Figure 36. Exposure of Frontal Portions of the Skull During Decay Stage.

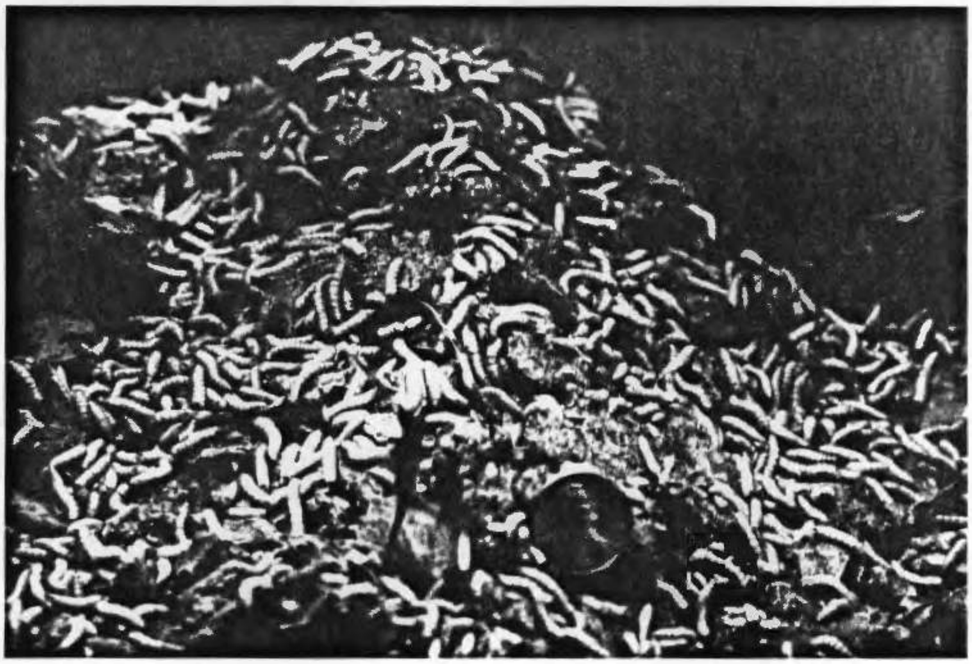


Figure 35

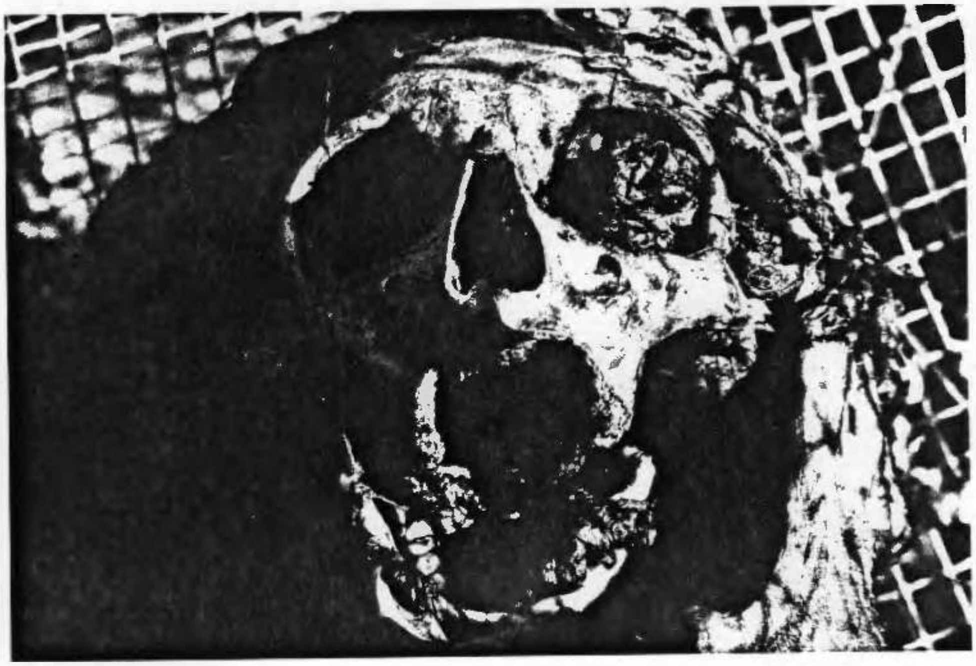


Figure 36

Figure 37. Glove Form next to Left Hand due to Skin Slippage.

Figure 38. Dermestid Beetle Feeding on Exposed Skull.

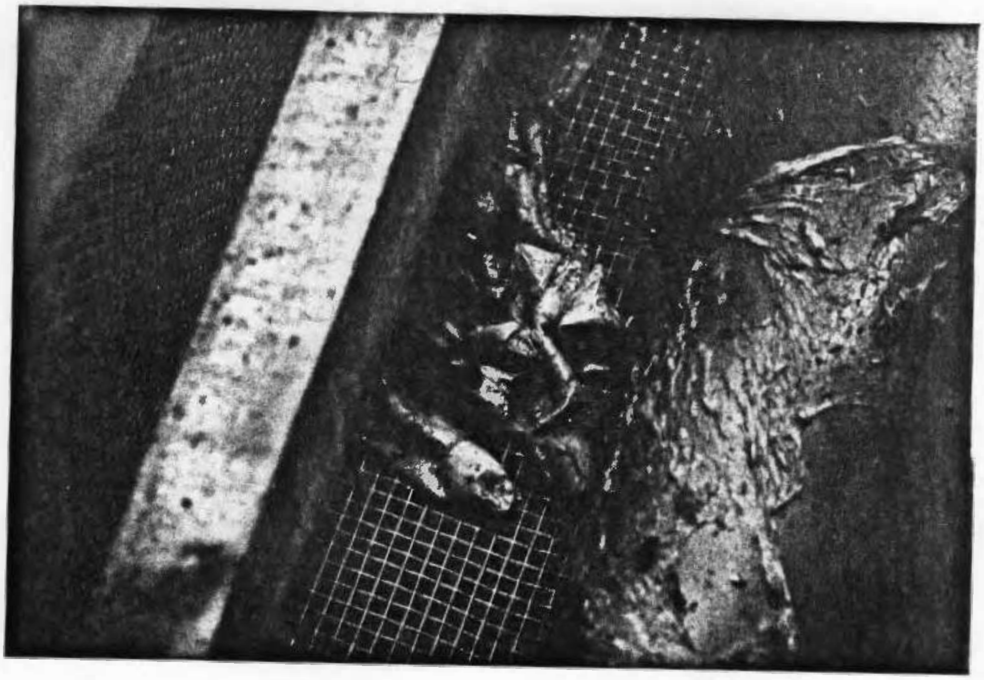


Figure 37

Figure 38

Figure 39. Checkered Beetle Feeding on Dry Tissue of Exposed Skull.

Figure 40. Collecting Insects at Research Facility.

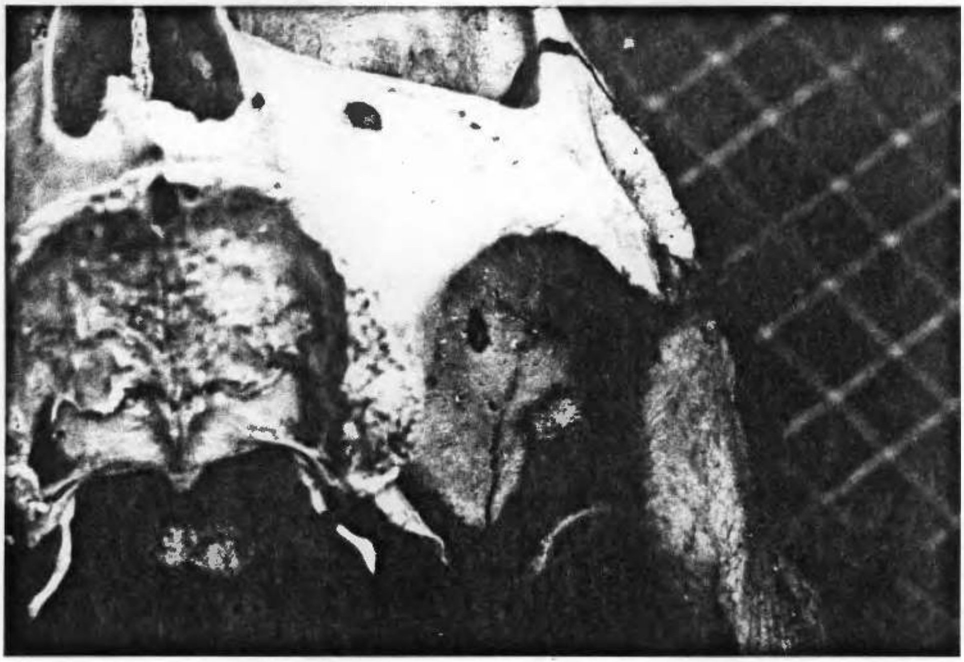


Figure 39

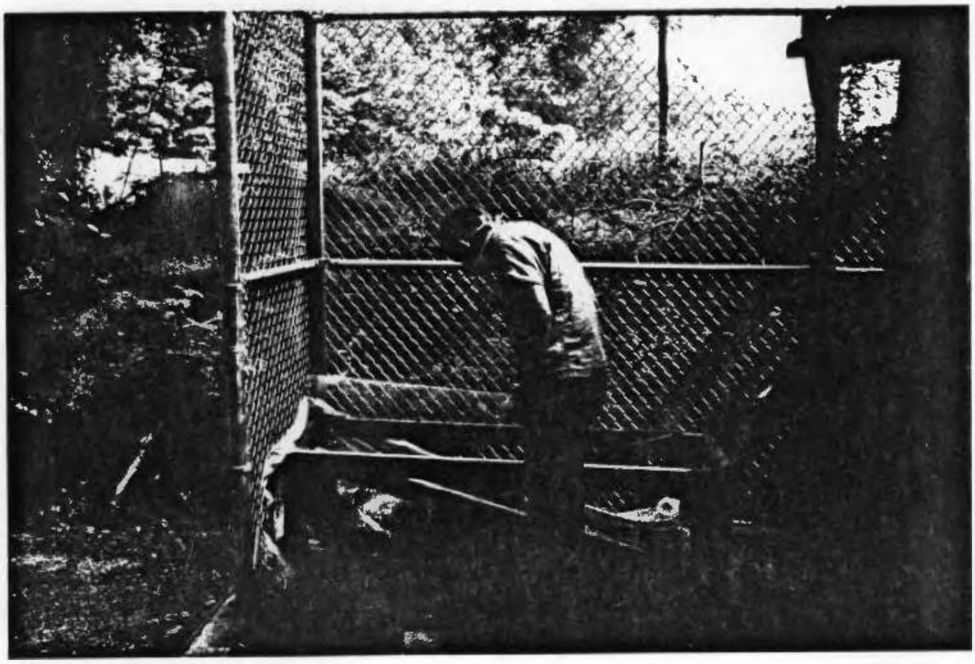


Figure 40

VITA

William Cesar Rodriguez, III was born in Altoona, Pennsylvania on August 4, 1954. He attended elementary schools in Memphis, Tennessee, and was graduated from Overton High in May 1973. The following September he entered The University of Tennessee, Knoxville. After two years of study he left the university to work in research at The University of Tennessee Medical School.

In September 1978 he returned to The University of Tennessee, Knoxville, and in March 1981 he received a Bachelor of Arts degree in Anthropology. In the spring of 1981 he started graduate school at The University of Tennessee, Knoxville, and began study toward a Master's degree. This degree was awarded in August 1982.

He is married to the former Karleen Katz of Nashville, Tennessee.