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

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ABSTRACT: This is the first report on an ongoing study conducted to collect data on the specific insects that 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 open wooded area. Data were collected daily throughout the entire decay cycle on the various insect populations that frequented each cadaver. Analysis of the data shows that there is a direct correlation between the rate of decay and the succession of insect families and species found in association with a decaying cadaver. Application of this entomological information can contribute to a more accurate estimation of "time since death" of an individual.

KEYWORDS: pathology and biology, decomposition, insects, postmortem changes, time of death

A decomposing corpse, 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 questions 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 of previously known cases. This results 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 decaying corpse. This method is based on entomological and seasonal factors.

Decay rates of human cadavers have a direct relationship to the successional pattern of carrion frequenting insects. Application of this method 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 [*1*] proposed seasonal dating of prehistoric Amer-

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ican 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 [2], 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, and rodents).

Probably the best study on insects and their relationship to decay rates was reported in 1958 by Reed [3]. Reed made observations on the various insects that attack decaying dog carcasses in Knoxville, TN. 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 [3] 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 nonwooded areas but that decomposition proceeded more rapidly in open areas (possibly as a result of higher temperature exposure). Most importantly Reed [3] 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, SC by Payne [4]. 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 [4] "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 [5], arthropod succession and decomposition of buried pigs [6], Coleoptera associated with pig carrion and with insect succession and decomposition of pig carcasses in water [7], and on Hymenoptera associated with pig carrion [8].

The lack of knowledge on human decay rates has initiated research by forensic scientists to devise methods that 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, and so forth) that had been exposed to the environment over various time periods. Such studies have been reported by Daily [9] as well as by Morse and Stoutamire [10]. Another approach was reported by Warren [11] in which plants and related decomposition vectors of human skeletal remains were examined.

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 a result of 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.

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 at 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. This facility is located in an open-wooded area of Knoxville, TN. The decay research facility consists of a large concrete slab 406.4 by 406.4 mm (16 by 16 in.) bordered by a small storage room. Both the concrete floor and storage room are completely enclosed by a chain link fence with chain link across the top forming a chain link cage.

Each cadaver was placed in a specially designed wire coffin which sits approximately 63.5 mm (2.5 in.) above the concrete floor. Each coffin consists of a 1828.8- by 609.6- by 914.4-mm (72- by 24- by 36-in.) lumber frame constructed from 0.61- by 1.22-mm (2- by 4-in.) planks. Covering the coffin on all sides is 9.9-mm (0.39-in.) 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.

All articles of clothing were removed from the cadavers before placement in coffins. Cadavers were placed on their backs with the face up or facing skyward, 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, a 73-year-old male placed 5-13-81; Subject 2-81, a 73-year-old male placed 6-5-81; Subject 3-81, a 72-year-old male placed 10-12-81; and Subject 4-81, a 35-year-old 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 1 to 3 h, 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 h 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 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 for identification purposes. Flying insects were collected using an aerial insect net and crawling insects were collected with dissecting forceps. Insects collected for identification were taken from various areas of the cadaver and nearby soil.

Identification of insects was established using various taxonomic manuals. Microscopic examination and various dissecting techniques were used to determine the sex and species of certain insect forms. All insects collected were preserved in a solution containing 85 cm^3 of 90% alcohol, 10 cm^3 of 40% formalin, and 5 cm^3 of glycerin.

Results

During the interval of 13 May 1981 through 13 May 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 of writing.

The cadavers were observed undergoing successional stages of decomposition. These stages were defined using the criteria set forth by Reed [*3*]. 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. 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.

During the decay stage the skin cracked in several areas, allowing the entrance of air, which facilitated the processes of aerobic protein decomposition. Reed [3] 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 because of the lack of 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. However, one cadaver was considered to be in the dry stage although it contained small amounts of moisture that 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, the cadaver remains become a shelter for insect fauna that are not normally associated with a decaying body. This was taken into consideration when collecting insects during this stage.

The decompositional rate of each cadaver observed varied. Variation in the decay rates were caused by 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 degradation 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 degradation of the cadavers.

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

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

TABLE 1—*Approximate duration of decompositional stages for each cadaver.*[a]

Subjects And Placement Dates	Stages of Decomposition			
	Fresh, days	Bloated, days	Decay, days	Dry, days
Subject 1-81 5/13/81	10	5	19	27
Subject 2-81 6/5/81	4	3	6	13
Subject 3-81 10/12/81	14	7	still in progress	...
Subject 4-81 11/11/81	36	19	112	still in progress

[a] Total observation period for decay rate study was one full year (13 May 1981 to 13 May 1982).

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 [3].

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 [3]. Also the various insect species observed in this study were found to be the same as those reported by Reed.

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 carcasses 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 [6] and Payne and King [7,8]. Similarities were found to exist between the decompositional stages and insect families observed. Many of the particular insect species reported on by Payne and King were also observed in this study. Payne and King 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. Toward the end of the fresh stage eggs were deposited in the area of the scrotum or vagina. 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.

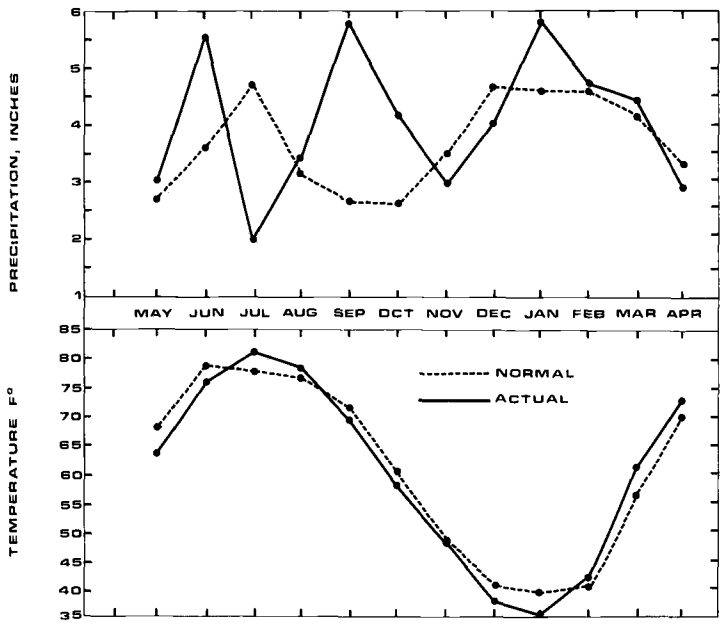


FIG. 1—*Normal temperatures, normal precipitation, and deviations from normal for the period May 1981 to April 1982. 1 in. = 25.4 mm and* t°C = (t°F −32)/1.8.

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, sap and rove beetles only remained with the addition of dermestid, checkered, and lamellicorn beetles. These beetles were observed feeding on the remaining dry tissue, hair, and fungus on the cadavers.

Figure 2 lists the ten major insect families observed and their approximate spring/summer distribution during the stages of decay. These insect families can be found throughout the United States, however, there are some differences in geographical ranges among various genus and species. A representative adult member of each arthropod family observed is illustrated in Fig. 3. 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. Because of 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 lists the various families observed and their approximate spring/summer distribution. Distribution of the larvae in this study were fairly consistent with those described by Reed [*3*].

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 2 or 3 h after placement at the decay facility. Shortly afterwards the female blow flies were observed depositing eggs in the various facial cavities.

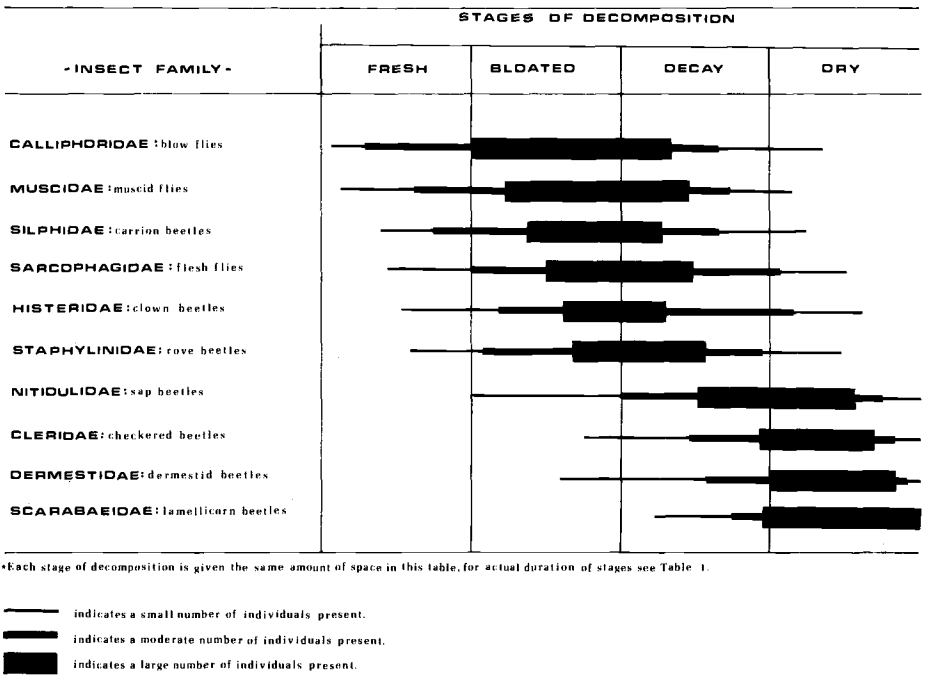
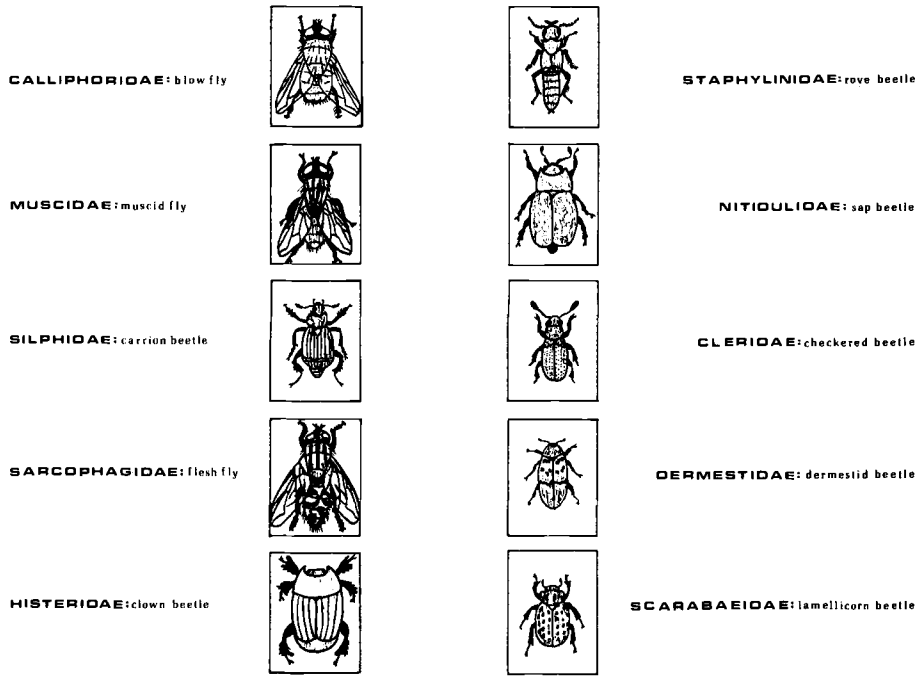


FIG. 2—*Approximate distribution of adult arthropods frequenting cadavers in spring/summer.*



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

FIG. 3—*Illustration of the various arthropods that were observed frequenting the cadavers during decomposition.*

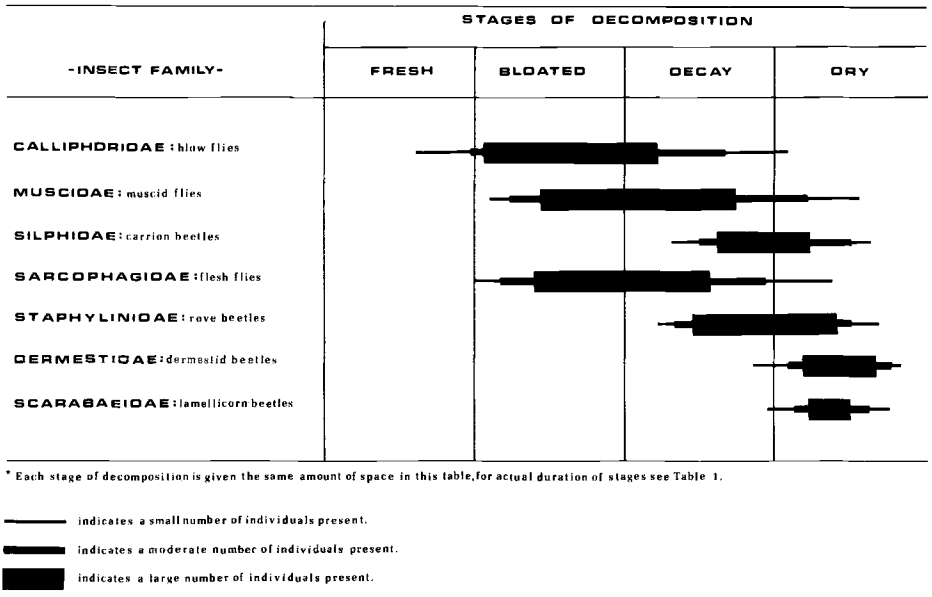


FIG. 4—*Approximate distribution of larvae frequenting cadavers in spring/summer.*

Hatching of the blow fly eggs occurred within 6 to 40 h, at which time the emerging larvae began feeding on the cadaver tissues. The growing larvae fed on decaying flesh for three to ten days. Upon reaching maximum growth the larvae migrated off the cadavers in great numbers and buried into the nearby soil.

Once buried the larvae began to pupate and this lasted between 6 to 18 days after which the adult fly forms would hatch out from the puparium and dig to the surface. The time period required for each of the previously mentioned developemental 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 [*12*] in 1948, using aged meat baits to capture blow flies.

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 phases have been termed the fresh, bloated, decay, and dry stages. 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 that 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 that fed on the cadavers were also observed to occur at rates previously established by entomologists.

This study has shown the importance for forensic science investigators to collect and record insect specimens found on and around a cadaver. Upon initial examination of human remains in the field, the forensic science investigator should collect as many different insect specimens as possible. Specimens should be collected from several areas of the body as well as the surrounding soil. The soil surrounding the cadaver will most likely contain many fly larvae which have either pupated or have begun pupation.

If the deceased individual is in the earliest stages of decomposition it is very important that fly larvae be collected. In this case the largest larvae specimens observed should be collected since they represent the earliest insect in the successional pattern.

During the earliest period after death no fly larvae may be observed on the cadaver; however, investigators should collect fly eggs which will be present in the entrance of the nose, ears, eyes, mouth, or open wounds. Half of the insect specimens (adults, pupae, larvae, and eggs) should be placed in collection vials containing a preservative solution as noted in this paper or a 70 to 90% alcohol solution will suffice. The remaining insect specimens should be placed in containers that are ventilated to allow the insects to remain alive. Some of the live insect specimens, particularly fly larvae and pupae which are taken to a consulting entomologist, will be allowed to complete development so that accurate species identification can be made.

If the cadaver is fully clothed the feeding carrion insects will not be highly visible, and in this case the forensic science investigator is advised to collect insect specimens once the clothing is removed. Once removed, the clothing itself should be thoroughly examined for insect specimens. In many instances fly larvae and particularly pupae can be found in between clothing or clothing layers such as a cuff, waist band, collar, and so forth rather than in the surrounding soil.

Once a deceased individual becomes fully skeletalized very few, if any, insect specimens will be observed. Those few observed will probably be dermestid beetles which are one of the last insect families to feed on animal remains. However, it was observed in this study and in numerous forensic science cases involving only skeletal remains that early successional insects can be found upon close examination in skeletal crevices or foramen.

Examination of various skeletal cavities, particularly inside the cranial vault, may produce remains of early successional insects. Gentle probing or washing of these cavities will remove these earlier insect remains for examination and identification. For example, certain carrion beetles that might be recovered can provide information pertaining to time since death because of their active seasonality. In any case, all insects collected on or around a decaying cadaver or skeleton should be taken immediately to a knowledgeable entomologist for identification and determination of how long the insects have been feeding on the human remains.

It is evident that the investigation of the active seasonality and successional pattern of various carrion insects could provide a method by which time interval since death can be established. Present and future analysis of these insect data collected in this study will be used to develop a chart of the various insect species along with their seasonality and duration of successional patterns. A forensic science investigator comparing this chart with entomological data collected at the site of a decaying corpse hopefully will be able to make a reasonably accurate determination of time since death.

It must be noted that there are many other variables that affect the relationship between the decay rates of human cadavers and insect activity. The presence of clothing on the remains is one variable which can be expected to affect this relationship. Other important variables to consider are the physical size and body build of an individual and the type of environment in which the body is found (open sun or shade, and so forth). This initial study only tested a few of these variables. Additional research, testing other variables, and experimental conditions are in progress and planned for the future.

Based on the information acquired in this study, it can be concluded that there is a close correlation between human decay rates and carrion insect activity. Knowledge and better understanding of this relationship can be an aid in establishing the "time interval since death" of a decayed corpse.

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 observed 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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