173045

Testing Reliability of Animal Models in Research and Training Programs in Forensic Entomology

NIJ Grant No. 94-IJ-CX-0039

Final Report on Findings

Project Director: R.D. Hall, Ph.D.
with

Kenneth G. Schoenly, Ph.D.

Neal H. Haskell, Ph.D.

In Collaboration with the:

University of Missouri
Lousiana Tech University
University of Tennessee

Duration of Proposed Project: 2 years
Proposed Starting Date: October 1, 1994
Termination Date: September 30, 1996

Report of Findings

NIJ Grant No. 94-IJ-CX-0039
"Testing Reliability of Animal Models in
Research and Training Programs in Forensic Entomology"

A. Introduction

In a death scene investigation, any evidence that helps pinpoint time of death has important implications to suspect identification, establishing cause and manner of death, and other evidence relevant to the case. Insect visitors (and other arthropods) of human remains, whose arrival, residence and exit times recur in a predictable, orderly sequence show promise as indicators for precise determination of the postmortem interval (PMI) in medicolegal investigations. Widespread application of these techniques, however, have not been forthcoming by law enforcement and medical investigation personnel.

One of the living pioneers of forensic entomology, Dr. Pekka Nuorteva (University of Helsinki, Finland) and to whom Kenneth Smith dedicated his Manual of Forensic Entomology (1986), addressed the need for calibration methods of animal and human cadavers during his opening remarks in the "Medicolegal Entomology" workshop of the XIVth Congress of the International Academy of Legal and Social Medicine (Liege, Belgium, 1988):

> "Like scientific methods in general, the method of using blow flies as forensic indicators, is too, loaded with sources of error. It is very important to identify and eliminate these errors now, when we are just refining the method."

> "... it must be noted that a considerable part of the evidence we have at the present is derived from experience obtained with animal carcasses. Clearly there are differences between animal and human carcasses which will result in differences in developmental times, mode of faunal succession and composition of the fauna of sarcosaprophages. Therefore, it is necessary to extrapolate any animal data we have to human data always when possible. The possibilities of doing this are, however, restricted. It has been possible to arrange real field experiments with human cadavers only in Tennessee, USA (Rodriguez 1982, Rodriguez and Bass 1983). These experiments were illustrative as such, but they have not brought to the field of forensic entomology the urgently needed calibrating comparisons with pig and sheep carcasses. This need has become a burning one, because pig and sheep have been chosen to be used as "standards" to replace the use of human bodies in forensic entomology experiments (Hall 1988, Haskell and Williams 1988, Morris 1988, Payne 1965, Payne and King 1970, 1972). The need for calibrations is strengthened by observations that human carcasses are able to attract

Phormia terrae-novae R. D. in situations where other substances are ineffective (Nuorteva 1987)."

The use of human cadavers for field studies is illegal in most U.S. states. Consequently, forensic entomologists have chosen several animal alternatives for the study of insect fauna of decomposing carrion such as: gulls (Lord and Burger 1984); cats (Early and Goff 1986, Tullis and Goff 1987); foxes (Smith 1986); and pigs (Haskell 1989, Schoenly et al. 1991); to carry out baseline field studies. For reasons already stated above, greater attention in recent years has been paid to the use of 50 lb (25 kg) domestic pigs as a model of human postmortem decay. As indicated earlier, it is noteworthy that no human-pig field trials to test that assertion have been done previously. Constraints placed on individuals possessing the necessary expertise (and fortitude) coupled with a lack of resources, are cited as chief reasons why such experiments have not been done. Thus, the urgency to have comparative results on pig and human cadavers for evaluation by the medicolegal community becomes crystal clear. Indeed, side-by-side field experiments represent the only way such a demonstration can be made.

Challenges to the purported reliability of animal results to human remains cases have recently arisen in US courts. For example, in the case of the State of Indiana vs. Pasco in 1989, defense counsel objected to pig-to-human data extrapolations, but was overruled by the deciding judge in the case. The case was eventually appealed to the Indiana State Supreme Court whereupon the lower court ruling was unanimously upheld. Had the deciding judges in this case not possessed an adequate understanding of scientific principles, entomological testimony may have been thrown out and valuable evidence lost. This case and others like it, therefore, argue for more compelling evidence on human/animal comparisons which only field experiments can provide.

B. Research Summary

In response to the need to answer important questions as to the adequacy of the pig as a human decomposition model, forensic entomologist Neal Haskell traveled to the University of Tennessee at Knoxville, in the summer of 1989, to conduct a field study of postmortem decay and arthropod succession in human and pig cadavers.

In collaboration with the Indiana Coroner's Association, the Indiana University School of Medicine, and the Anthropology Department of the University of Tennessee, the study was conducted on the campus of the University of Tennessee (UT) in the only U.S. facility of its kind where human remains can be studied under natural field conditions throughout their entire period of decomposition.

The test units included one unembalmed, unautopsied human subject (male at ca. 175lbs) and three freshly-killed pigs (female at ca. 50 lbs) placed on the UT facility grounds and studied using five collection methods (aerial, pitfall, sticky trap, hand gathered, and larval hand gathered; the hand collection and live larval collections were combined during data analysis). Multiple samples were taken each day for a total of 35 consecutive days. During each of the 35 days, samplings were taken at time periods throughout the day and included: morning, noon, afternoon, early evening for most of the days. This provided a total of 96 time-specific periods with approximately 1370 specific samples containing 10s, 100s or 1000s of individual insect specimens (total estimated specimen numbers could be as high as 100K). For statistical data analysis of these samples, period data were combined into a daily total count so as to compare on a daily basis. Also, due to the vast numbers of samples and individuals, random days spread across the 35 day period were chosen to be included for analysis. Individuals and samples completed to date provide an adequate basis for conclusions in this report, however, as time presents itself, continued data analysis will be conducted. In addition, data are separated in such a way as to conduct data analysis on a period of the day basis, if warranted.

The research questions asked were analyzed by using several quantitative statistical methods with application from community ecology. The primary questions asked were: 1) are species composition, rate of succession and population sizes of forensically important arthropod species statistically indistinguishable across pig and human bodies, or are they highly variable from one test unit to another? 2) which sampling method(s), when used singly or in combination, capture the largest fraction of forensically-important species? 3) how can an understanding of the successional dynamics in carcasses be used to enhance the entomologist's capacity to estimate time of death in medicolegal death investigations?

During analyses of the arthropod data generated from the pig carcasses and human body, the Morisita-Horn (C_{MH}) index was rated the best tool for assessing overall similarity for abundance-type ecological data (Wolda, 1981). C_{MH} calculates an index of similarity between two samples from counts of individual organisms and is nearly independent of sample size except when samples are extremely small. For each pair (Pig A v. Pig B, Pig A v. Human, Pig B v. Human) C_{MH} was calculated in two ways: once for each time-specific sample to obtain day-to-day faunal similarities, and again for all species and individuals, cumulated across all time-specific samples, to obtain overall value or taxonomic similarity. It is calculated as

$$C_{MH} = \frac{2\ \mathrm{sum}(an_i X bn_i)}{(da+db)\ aNXbN}$$

where

aN = number of individual arthropods on subject A
bN = number of individual arthropods on subject B
aN_i = number of individual arthropods in the ith species on subject A
bN_i = number of individual arthropods in the ith species on subject B

$$da = \frac{\text{sum } an_i^2}{aN^2} \quad \text{and} \quad db = \frac{\text{sum } bn_i^2}{bN^2}$$

Rank-abundance curves provide a direct method for examining the distribution of species abundance for one or more faunas (James and Rathbun, 1981). The Spearman rank test was used to assess degree of statistical association in species rank between each carcass pair.

Assessment of sampling methods was accomplished by comparisons of methods singly and then in combination of up to four-way combinations to study the four methods (aerial, hand, pitfall, sticky trap). This assesses the relationship between the efficiency of different sampling methods and the capturability and natural history of different groups of forensically important arthropods.

C. Results and Discussion

The following is a summary of findings and each will be discussed in order.

Summary of Findings:

1. Early Successional Faunas (Days 1 to 10) were More Alike than Mid- or Late- Successional Faunas for All Pairwise Tests.
2. Forensically-important Insects are Among the Most Abundant and Conspicuous Carrion-Frequenting Organisms.
3. Successional Trends of Forensically Important Taxa Mirrored Whole Communities but were More Alike in All Pairwise Tests.
4. Only 1 of 35 Forensically Important Insect Species was Unique to the Human Subject (that is, sampled only from the human subject). None of the 35 Forensically Important Insect Species was Unique to Pigs A and B (sampled only from either Pig A or Pig B).
5. Different Collection Methods Captured 35-100% of the Sampled Forensically Important Taxa and 30-100% of the Forensically Important Individuals.
6. Hand Collection was the Single Best Method for Sampling Forensically Important Taxa Followed by the Aerial Net Method.
7. The Background Fauna Included Small Numbers of Forensically Important Taxa and Individuals.
8. As Decomposition Progressed, the Carrion Fauna began to Resemble the Background Fauna.
9. As Decomposition Progressed, Different Subjects (Human, Pig A, Pig B) Gave Similar Turnover Rates.
10. Calliphorid presence is variable by blow fly species and by time.
11. Sex ratios of Calliphorids present may provide an indication as to 1st generation eclosion.

12. The Diptera families of Sepsidae and Piophilidae were found in high numbers of adults and as multiple species, which may provide important successional information.
13. Vespidae wasps disturbed ovipositing female blow flies and on occasion captured them on the wing for food.

C. 1. Early Successional Faunas (Days 1 to 10) were More Alike than Mid- or Late-Successional Faunas for All Pairwise Tests.

Based upon pairwise comparisons as described in the Research Summary section using the Morisita-Horn Index, it is seen from data comparisons that there is a high degree of similarity from days 1 to 10. Medians of these data for all taxa in days 1 to 10 are 78% similarity and when the forensically important taxa are used a median of 85% similarity is seen (Figures 1 and 2). When all days are compared in similarity, there is a reduction in median values to 38% for all taxa (78% for Days 1-10) and 83% (85% for days 1-10) for forensically important taxa. This suggests then, that there is high similarity between each pair of experimental units during the first 10 days of decomposition, but as decomposition progresses, the similarity between the pigs and the human decrease.

The 50 lb pig will provide an adequate model for comparing the insects which will be attracted to humans after death during the early portion of the decomposition process. This result agrees with the physical appearance of the experimental units in that by days 10-12 both pigs A and B were rendered nearly to skeletal remains. This is in contrast to the human which maintained considerable soft tissue masses in the lower torso areas and the extremities (primarily the legs) for the duration of the study. This result is then the function of body mass and possibly compactness of the organisms themselves. Compactness being the pigs lacking longer extremities as seen in humans with a larger percent body mass in the legs and arms.

C.2. Forensically-important Insects are Among the Most Abundant and Conspicuous Carrion-Frequenting Organisms.

Based upon the rank abundance tests described in the Research Summary section above, it is seen that species abundance identifies the forensically important species as the most abundant taxa collected from all experimental units. Figure 3 rank the most prominent species (total taxa of 72 groups with more than 14,000 individuals) to the least prominent for the Human, Pig A, and Pig B respectively. For the Human unit, 78% of the forensically important individuals and 41% of the forensically important taxa are among the most abundant of the study. For Pig A, 71% of the individuals and 43% of the taxa of forensically important fauna are among the most abundant fauna in the study. Pig B shows lower abundance of forensically important fauna at 58% for the individuals and 34% for the taxa. In Fig. 3 we see that 8 of the first 9 most abundant taxa and individuals are from the forensically important groups for all three experimental units. This suggests that the most important insects used in forensic entomology investigations and as

Figure 1. Pairwise Comparison of Taxonomic Composition: All Taxa

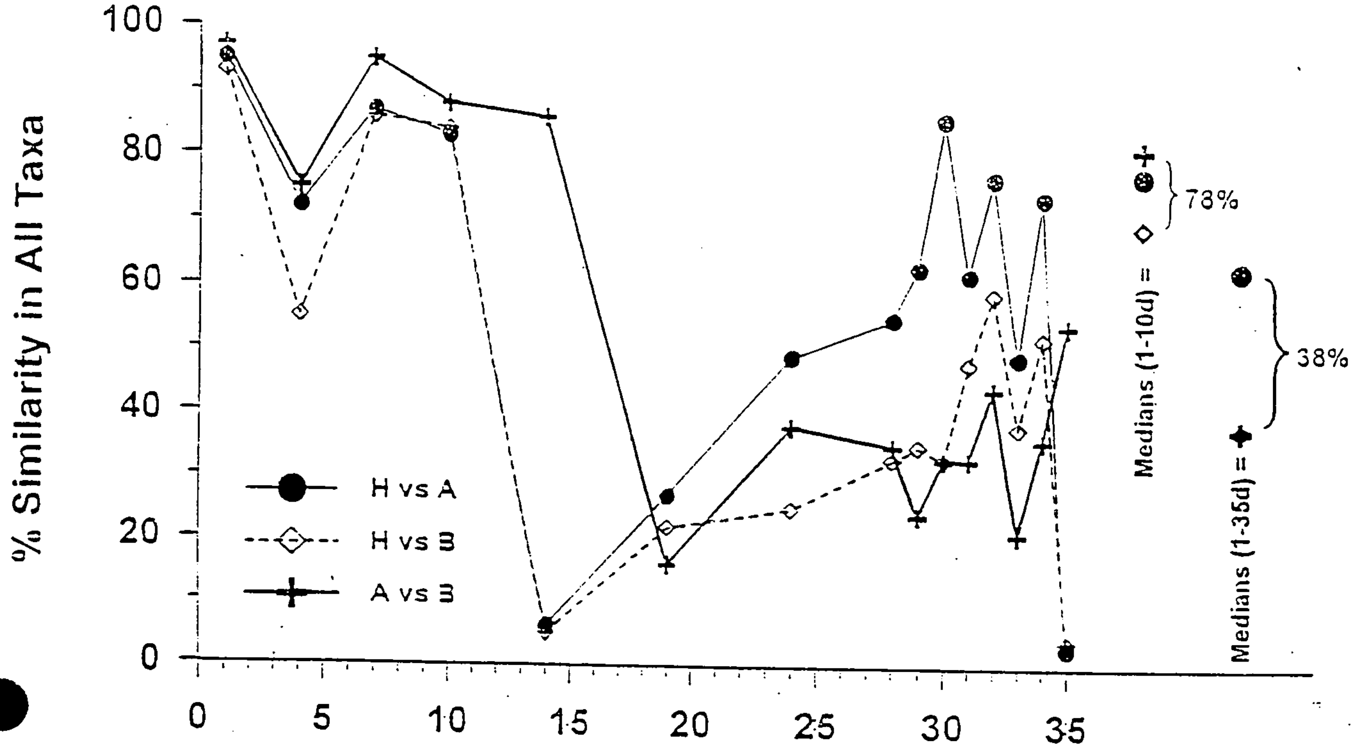
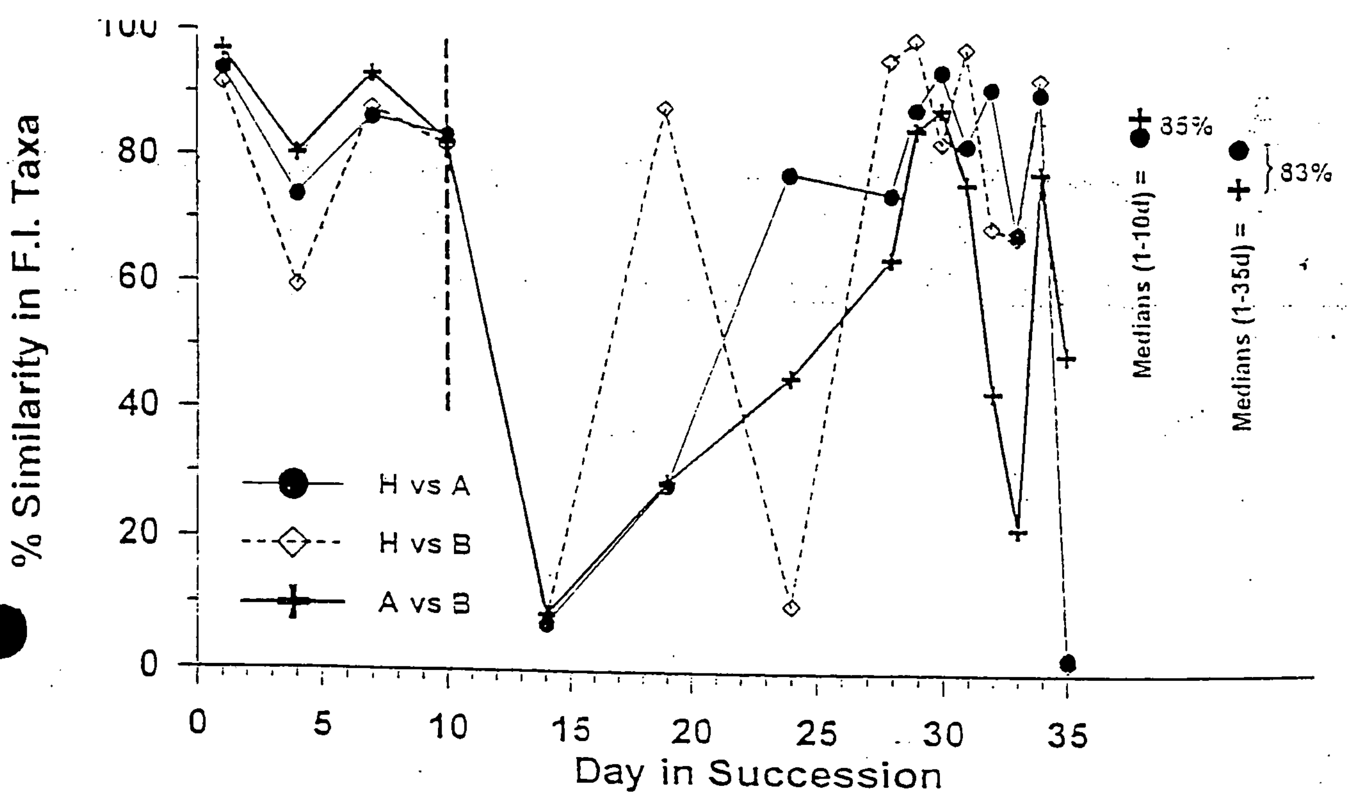


Figure 2. Pairwise Comparison of Taxonomic Composition: Forensically Important Taxa



evidence are truly the most visible and occur in the highest numbers. Therefore, observation and collection of these insect fauna should be obvious even to investigators with little entomological training. To the forensically trained entomologist, most, if not all, critical taxa will be recognized and collected in adequate numbers for an analysis of the insect data with a reasonable degree of scientific certainty.

C. 3. Successional Trends of Forensically Important Taxa Mirrored Whole Communities but were More Alike in All Pairwise Tests.

The successional trends of the forensically important taxa followed the total, all taxa similarities, but showed greater similarity than the total taxa did. Figures 1 and 2 provide the all taxa and the Forensically important taxa where the data from day 1 to day 10 had a 78% similarity as compared to the forensically important taxa at 85%. When the total duration of the study was considered (all days), the similarity dropped to 38% while the forensically important all day data similarity medians were at 83%. This supports reliability of observing and recovering the forensically important taxa and individuals even when out at several weeks postmortem. Also, it is hoped that once pigs of greater mass are studied with human remains of comparable size, these similarities will continue through the full range of decomposition and not just for the first two weeks of the process. It must be kept in mind that it is the forensically important taxa that are the key in any decomposition study. The mere presence of an insect on a remains may be of no significance at all. Any insect has to be somewhere, and why not resting on a corpse in the woods?

C. 4. Only 1 of 35 Forensically Important Insect Species was Unique to the Human Subject (that is, sampled only from the human subject). None of the 35 Forensically Important Insect Species was Unique to Pigs A and B (sampled only from either Pig A or Pig B).

There was one forensically important taxa not found on all units, and it was unique to the human. A total of 6, 3rd instar larvae of the Diptera family Sarcophagidae were recovered from the human in this study of which this taxa was not found to have colonized either Pig A of Pig B. These 6 individuals from one taxa represented a very small percentage (0.004%) of a total number, 14,389 individuals, collected from the three units over the study from the days analyzed. It is also possible that sampling techniques missed low numbers of that taxa that could have been on the two pig units. While it is true that not every specimen has been examined in this study, the most commonly used forensic insect indicator species (the life stages of the blow flies) were common to both the pigs and the human. However, even if there was uniqueness of this one taxa, these data are negligible and would have little bearing in a forensic case when considered against other taxa of much higher frequency.

C. 5. Different Collection Methods Captured 35-100% of the Sampled Forensically Important Taxa and 30-100% of the Forensically Important Individuals.

It is shown in Figure 4 that the different collection techniques captured the majority of forensically important taxa. This ranged from 35-100% of the forensically important taxa and from 30-100% of the forensically important individuals. In Figure 4, there are clusters of forensically important taxa and individuals captured by the collection methods at the highest rank of the distribution (left end). These methods account for capture of the most abundant individuals and taxa found in the study. Here again, these data are demonstrating that the collection techniques used in forensic cases and potential sampling will provide the adequate entomological evidence needed to reach a reasonable and confident conclusion in forensic entomological analysis of a death investigation.

C.6. Hand Collection was the Single Best Method for Sampling Forensically Important Taxa Followed by the Aerial Net Method.

When a comparison was conducted of the collection techniques used in this study, it was found that the hand collection technique, actually picking the individuals from and around the remains was the best overall method for sampling. The data are shown as pie charts in Figure 5 as the percentage of taxa and individuals from each of the methods used in collection. The methods included, hand collecting of crawling insects, aerial sweeping over the remains, sticky trap sampling, and pitfall traps to capture ground crawling insects. Hand sampling captured 84.6 % of the forensically important taxa and nearly 100% of the individuals (99.9%) from the human. Aerial net sampling of flying adult insects over the remains was next at 61.1% of the taxa and 82.7% of the individuals. For the two pig units it was similar except the sticky trap collected a slightly higher percentage (79.8 vs. 76.3%) of the forensically important individuals for Pig A than did the aerial net sampling.

The importance of these data is seen in the recommended sampling techniques for death scene investigations where the two primary and standard methods of collecting insects from dead bodies is the aerial netting of flying adults and the specific hand collection of the larvae, ground crawling beetles and others. It is comforting to see that the methods used in hundreds of cases around the world are the same methods which provide the greatest percentage of recovered forensically important insects.

C.7. The Background Fauna Included Small Numbers of Forensically Important Taxa and Individuals.

A control site, located at a distance from the study site (ca. 75 m) was important to include in the experimental design. This provided a monitoring of the normal or naturally occurring insect fauna not necessarily associated with carrion insect fauna. Figure 6 provides rank abundance of these taxa and individuals away from the carrion and did identify those taxa and individuals

Figure 3. Rank Abundance of Taxa which were Collected from the Human Experimental Unit, Pig A, and Pig B

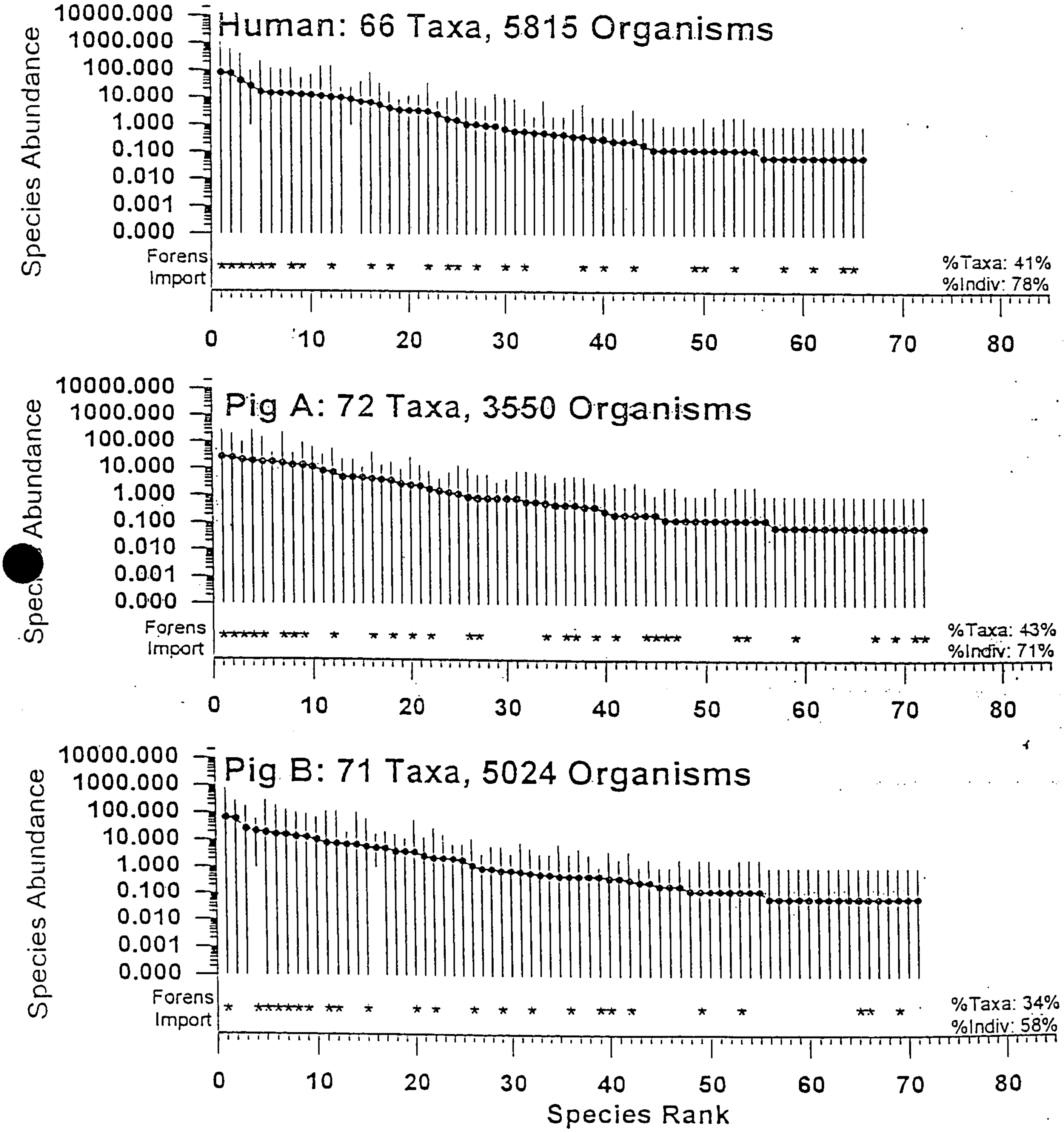


Figure 4. Rank Abundance of Taxa by Collection Method which were Collected from the Human Experimental Unit, Pig A, and Pig B

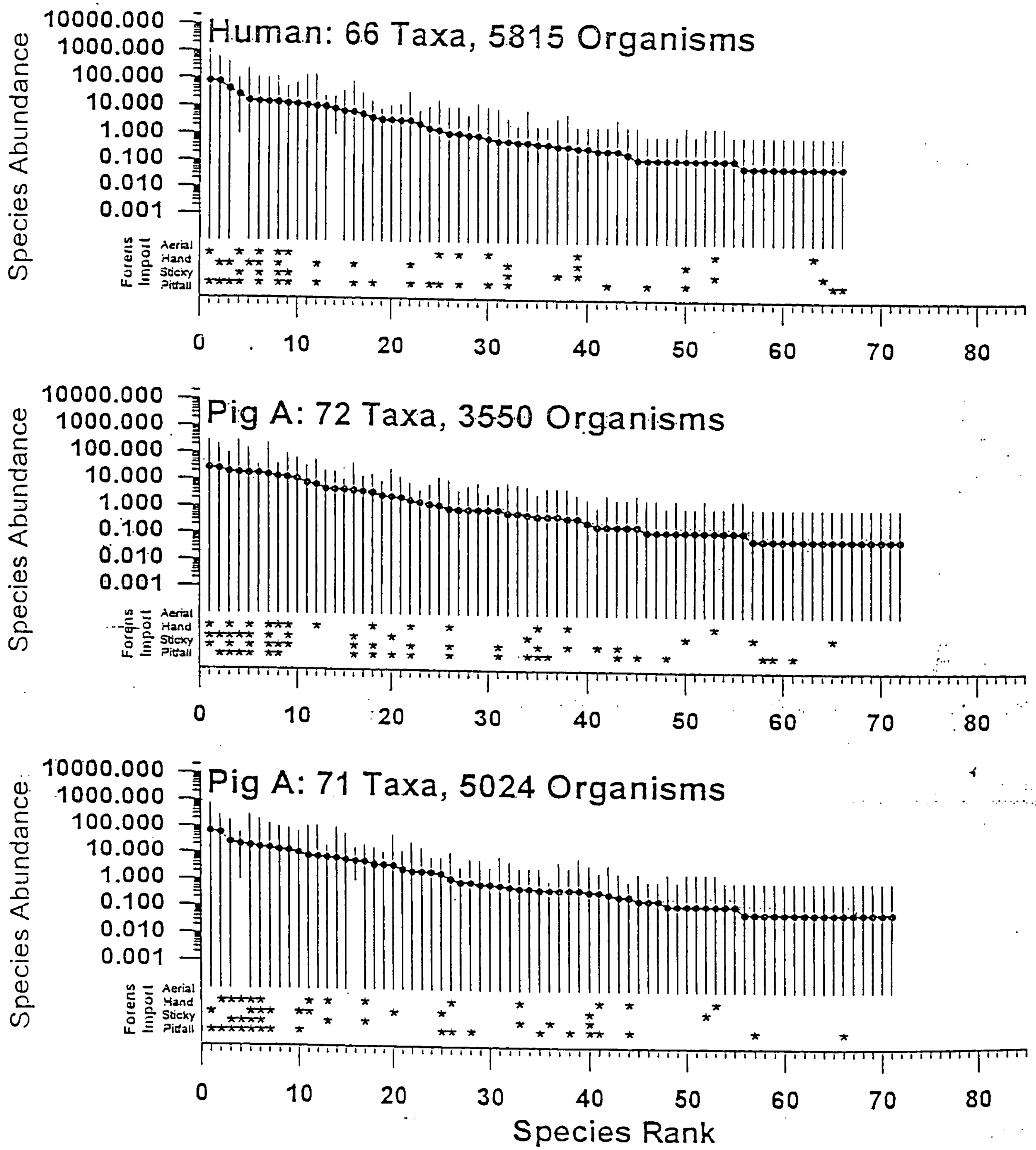


Figure 5. The Four Collection Techniques (aerial, hand, sticky trap, pitfall trap) Used for Insect Sampling with the Percentage of Forensically Important Taxa and Individuals Recovered

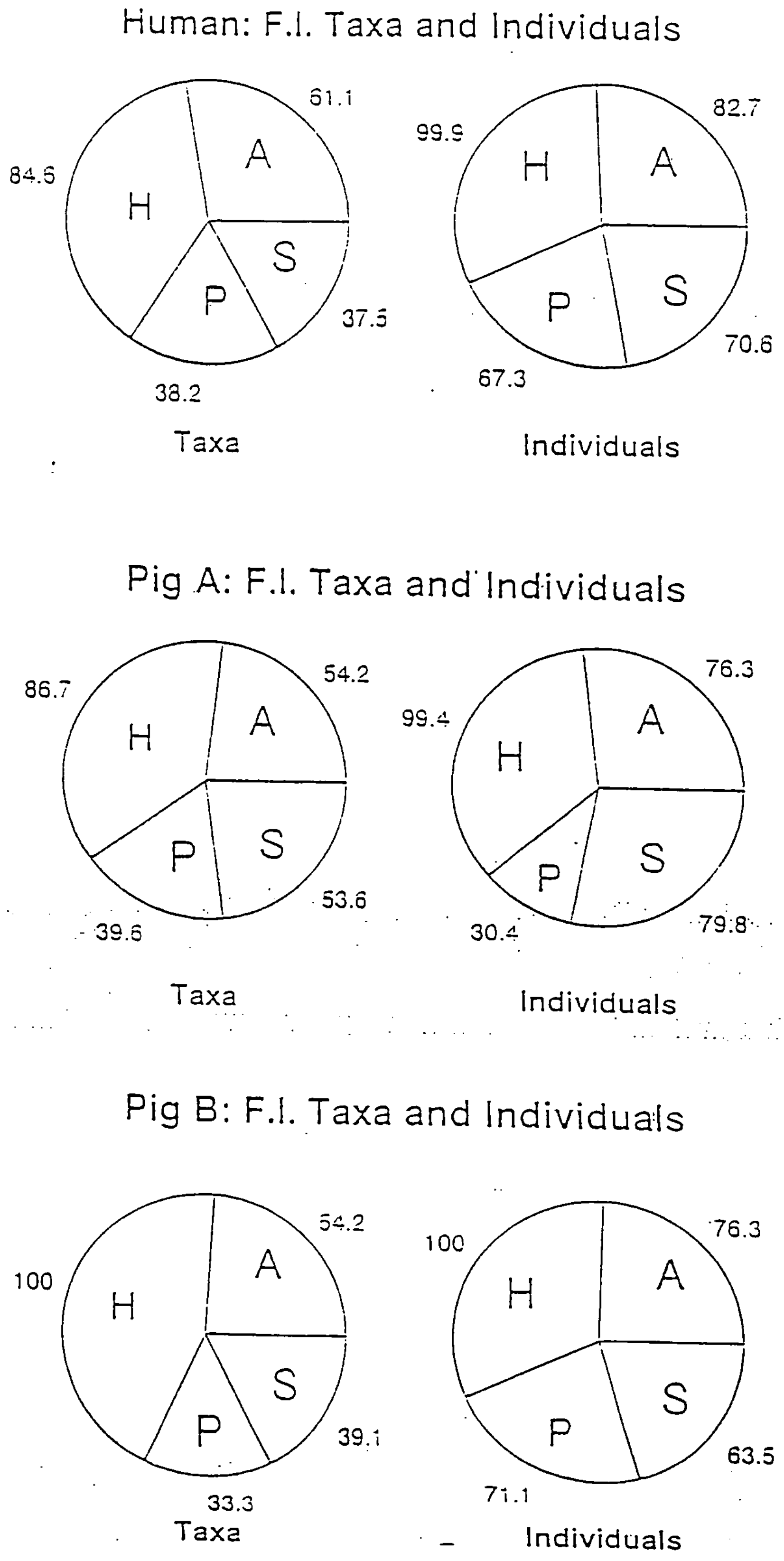
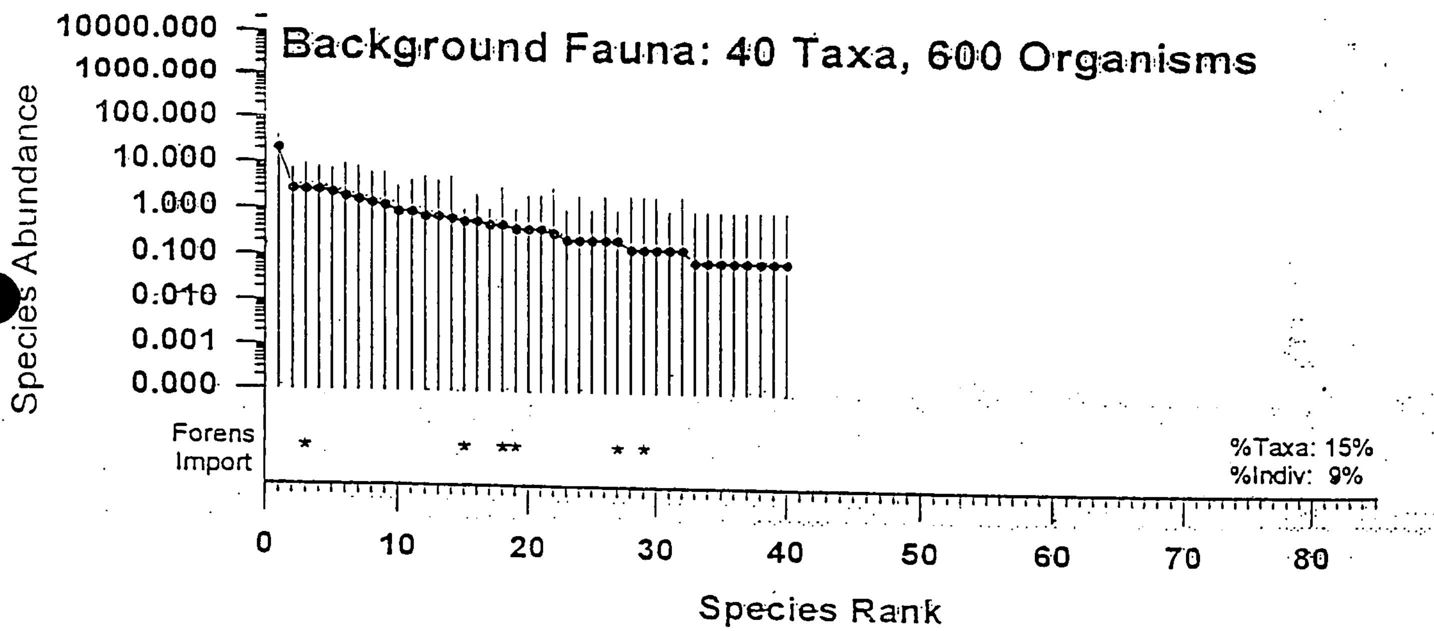


Figure 6. Rank Abundance of Background Insect Fauna Collected from Control Site



considered forensically important. There were a total of 40 insect taxa with 600 individuals of which only 15% were considered forensically important taxa and only 9% forensically important individuals. It is not surprising that there were some forensic insects present, because these forensic insects are known to range widely in search of food resources. What is surprising, in lieu of the suggestion of an overloading of the research site itself with carrion arthropods is that if that were the case (the overloading), greater species abundance of the carrion taxas and individuals would have been present. This is truly not the case. Only 600 individuals were captured when compared with nearly 15,000 individuals from the three units studied. Further studies on this question are being undertaken at this time, the results of which will hopefully answer the question fully. From the above data, it does not appear that there is a general overloading or unusually high abundance of the carrion insects in the geographic location of the study site.

C. 8. As Decomposition Progressed, the Carrion Fauna began to Resemble the Background Fauna.

When comparing the background fauna (the control site) with the Human, Pig A and Pig B, there was very little similarity during the first 10 days of the study (see Figure 7). As the study approached the end of the study duration, days 25 to 35, the comparisons became more similar. This result is what is expected when decomposition advances. As the postmortem interval moves further and further out in time, the indigenous or normal insect fauna will again reestablish from the specific and specialized fauna found to colonize the dead animal at that very specific geographic location. At some point in time, depending on environmental, and geographic influences, the normal soil and botanical insect fauna for that area will finally come back. In some cases, this time could be several years. This could be an area of additional study in the area of soil insects and their disruption over months or years due to changes in soil pH or shifts in plant species.

C. 9. As Decomposition Progressed, Different Subjects (Human, Pig A, Pig B) Gave Similar Turnover Rates.

The changes in the arthropod fauna among the three different experimental units were similar as decomposition progressed. Figure 8 provides percent rate of taxa turnover. It is seen that as the days progress the percent rate turnover in taxa were similar among the three unit types (between 22% and 26%, with the human in the middle of Pig A and Pig B). This suggests that as decomposition progresses, the changes taking place in the insect fauna are following in similar fashion. Even though the overall similarities in the later days were not as similar (section C.1.), there was a close similarity in the changes of the insect fauna as the decomposition progressed. This would provide another indication of the likelihood that it is a function of mass of the experimental units and not an inherent difference in the attractibility between the pigs and the human.

Figure 7. Pairwise Comparison of the Control Site Fauna to the Human, Pig A and Pig B

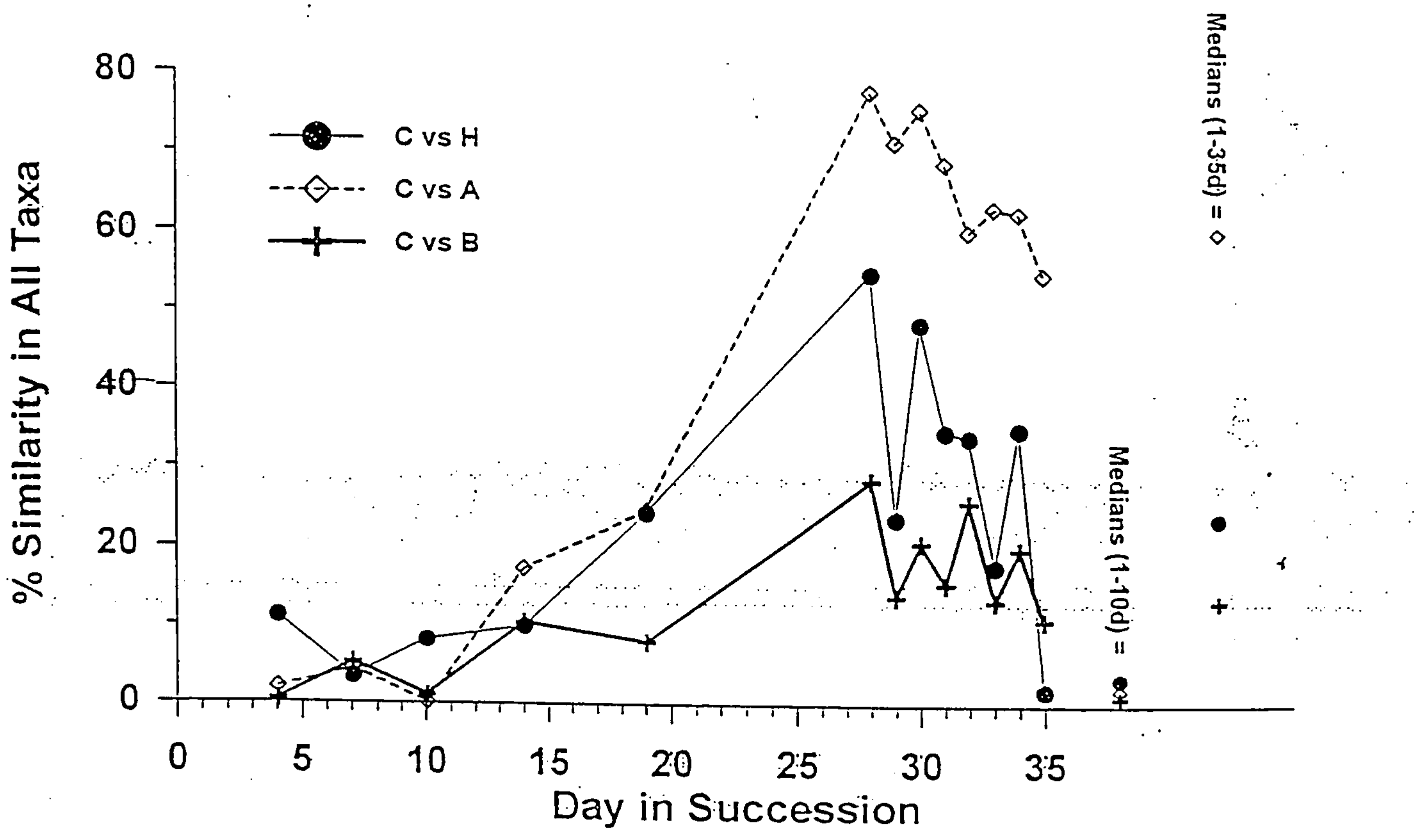
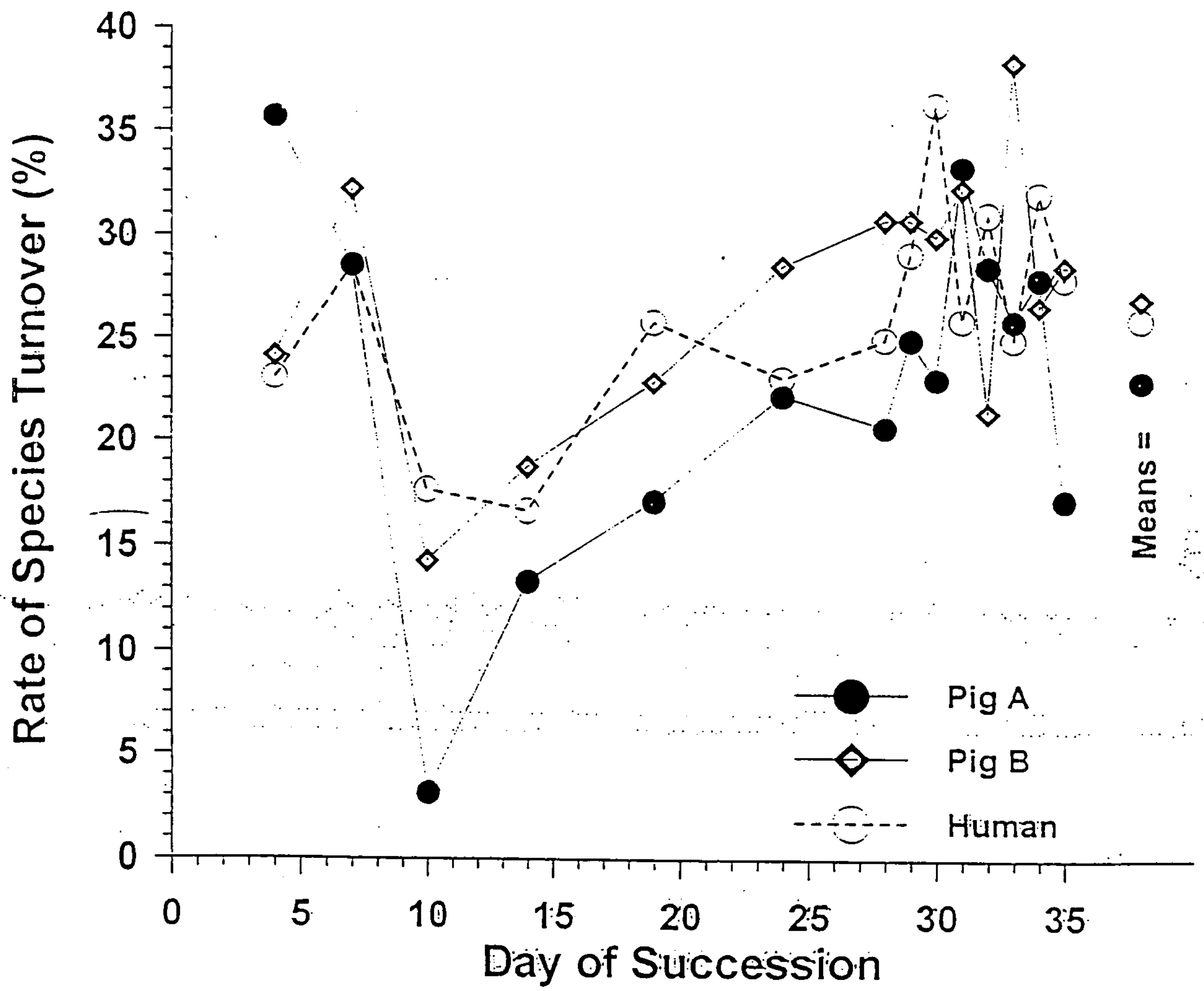


Figure 8. Rate of Turnover of Insect Taxa between the Human, Pig A, and Pig B



C. 10. Calliphorid Presence is Variable Among Species over Time.

Calliphoridae is the primary insect group used in death case investigations. All life stages of the calliphorids have been found associated with human death investigations throughout North America. Valuable postmortem interval estimates have been produced using eggs, 1st, 2nd, and 3rd instar larvae, as well as the migrating larvae and puparia in these documented cases(Lord, 1990).

Likewise, during this study, all stages of the blow fly life cycle were recovered. The species of blow flies included five species of the group which were common to Eastern Tennessee during mid-summer. These species were collected by aerial net over the human and included: *Phormia regina* as the most common with 109 adults recovered, *Phaenicia coeruleiviridis* was the second most prevalent with 57, *Cochliomyia macellaria* yeilded 8 adults and both *Lucilia illustris* and *Phaenicia sericata,* provided only 2 adults each to the total of 178.

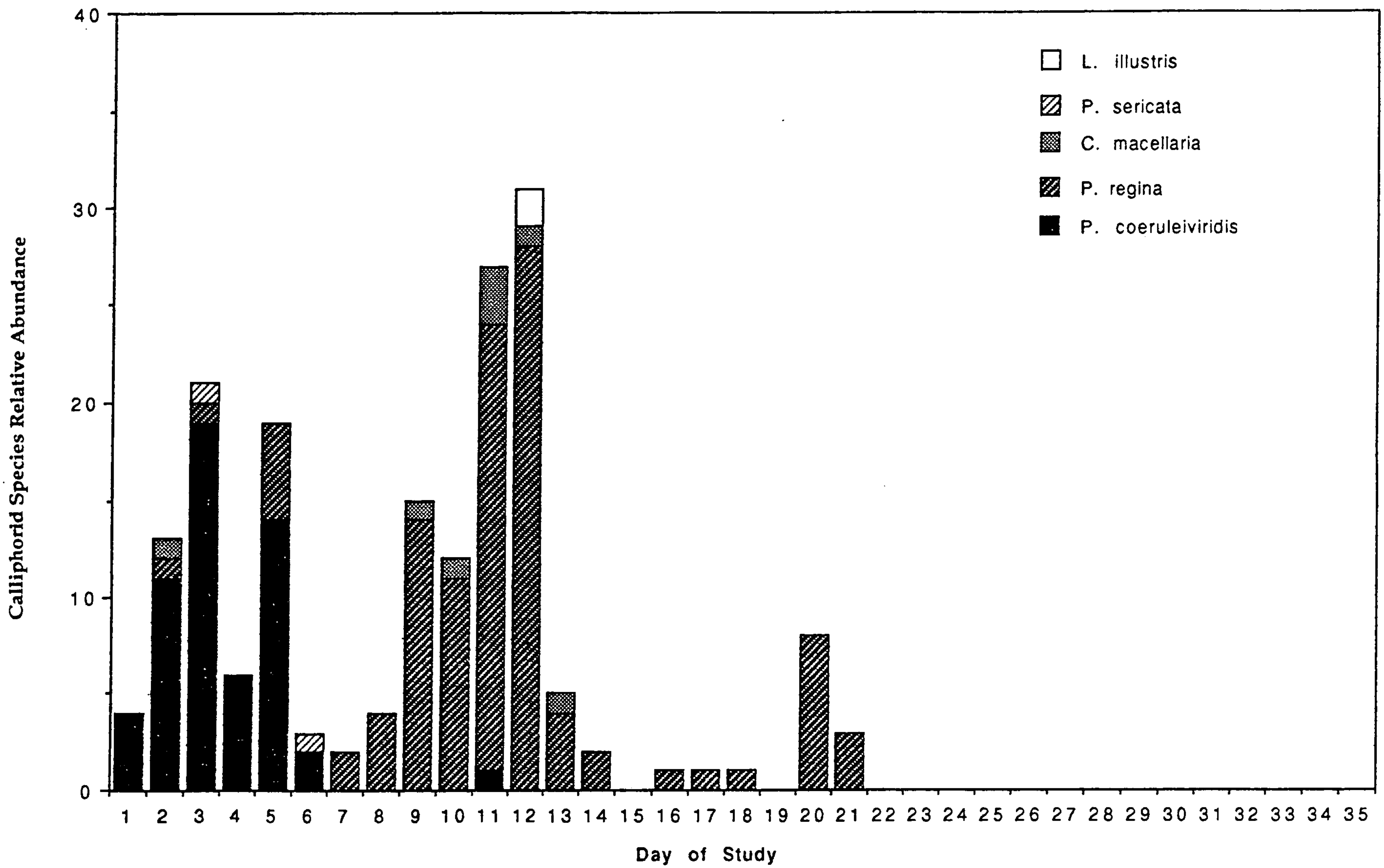
Figure 9 plots the relative abundance of adult blow fly species collected over the period of the 35 days. As is seen, there is a daily succession within the blow fly group itself, with the Luciliini Tribe (Green Bottle Flies) being found early during colonization, represented by the species *P. coeruleiviridis*. This speices was in high numbers through day five and then gave way to the most abundant species, *P. regina* by day 7 through 12. After day 13 only *P. regina* was recovered from the remains and these were most likely adults emerging from the first generation hatch.

There were never any adult calliphorids recovered from the body after day 21. This fact reinforces the idea that there can only be one true generation of Calliphoridae on a remains during warmer weather. There can be successive daily clutches for the first few days, but no second generation produced from the progeny of the first colonizers.

By day 2 other species (*P. regina* and *C. macellaria*) made their appearance. This is consistent with other citations in the literature (Hall and Doisey 1993, Hall and Haskell 1995, Haskell, et. al. 1997) which indicate that these species will delay in their infestation of a remains. This is valuable knowledge when, for instance, *P. regina* is found on a remains and it can be suggested that the person was dead an additional 12 to 24 hours before this species of fly would be found to deposit eggs. Likewise, if only *P. sericata* or *P. coeruleiviridis* were found, the colonization time would be almost immediate if death occurred during daylight hours.

Attempts to rear *P. coeruleiviridis* from early stages through 3rd instar larvae failed in every case. This species is incapable of being reared to adult in the lab in the normal small "maggot motel" type container. *Phaenicia coeruleiviridis* can be recognized by its never-ending migration with the larvae turning a somewhat salmon color. Eventually the larvae simple shrivel and die. These shriveled migrating maggots were collected from the rearing cups by the hundreds during live collections from the first two days of the study. Live collections from later in the second day and the third day, yielded other species that were coming through to adults (primarily *P. regina).* On a few occasions (ca. 4), adult blow flies loose in the lab (they had escaped during rearing) attempted to oviposit through

Figure 9. Calliphorid Species Relative Abundance per Day on the Human



the screening on the top of the rearing cups. This will be avoided by using solid covers on the cups during the next study.

During the migration phase of the life cycle, when feeding is completed and the larvae leave the food source, directional migration was observed. On several occasions maggots were seen migrating east when migration was initiated during the morning, and during the afternoon, those which were migrating were moving in a westerly or southwesterly direction. This knowledge can be helpful when attempting to locate puparia from migrating maggots at a scene of extended postmortem interval (PMI). During one time period, the larvae were observed migrating up adjacent trees by the thousands, shortly after a heavy down pour of rain (1.5"in 45 mins.).

Newly eclosed (hatched) blow flies can be collected in the pitfall traps in close proximity or at distances from the carcasses. While not entirely practical for scene work (although it might be possible to place pitfalls at a scene and check at regular interval to watch for new adults) the pitfall traps will provide useful while doing studies. They will also be very useful in identifying initiation of maggot migration, the time when migration is most frequent, and secessional periods of maggot migration.

C. 11. Sex Ratios of Calliphorids Present May Provide an Indication as to 1st Generation Eclosion.

The sex ratios of the different blow fly species were assessed for those adult flies collected with the aerial net and in the pitfall traps. It was seen that there was a very high ratio of females to males at the carrion and was consistent with previous data from other studies in Indiana, Tennesse, Illinois, Pennsylvania and Texas. Later in the study, at 16 to 21 days, the proportion of *P.regina* females to males reduced to a lower proportion. This was due to the emergence of the newly hatched generation of flies produced from the carrion which are a approximately a 1:1 ratio of females to males. This could be helpful when at a scene, especially an enclosed scene, where there are thousands of adult blow flies present and it is difficult to determine if there has been a first hatch or not. By using ratios of females to males, this question may be answered.

C. 12. The Diptera Families of Sepsidae and Piophilidae were Found in High Numbers of Adults and as Multiple Species, which May Provide Important Successional Information.

It was unexpected to see the high numbers of adult flies from the Diptera Families Sepsidae and Piophilidae for a considerable duration during mid- and late decomposition. Both families produced high numbers of adults for several days. There were multiple species present (species specific identification were not attempted during this data analysis) and there seemed to be a change of the species complex over the period. The new study being conducted during the summer of 1998 will include species identification of specimens from these two groups. Once this is accomplished, there may be a refinement possible in the successional data provided by species assemblages from these groups to enhance other successional data available.

C. 13. Vespidae Wasps Disturbed Ovipositing Female Blow Flies and On Occasion Captured Them on the Wing for Food.

The presence of individuals from the Hymenoptera order was expected at the carrion to feed on fluids and young stages of the blow flies. The observation of Vespids, *Dolichovespula maculata* (the Baldfaced Hornet) coming into the carrion and actually causing female blow flies to suspend oviposition and fly off was unexpected. The source of these adult hornets was from a nest hanging from a tree at about 25 ft distance and approximately 20 ft in the air. On three observations, adult hornets actually swooped down and snatched adult flying blow flies from the air as they flew closely to the carcasses searching for a place to oviposit. The vespid species, *Vespula* sp. (Yelklowjackets) were observed feeding on purging fluid from the remains. On rare occasions, individuals of *Vespula* sp. were seen carrying off eggs or early larvae (likely 1st instars). The yellowjackets did not appear to disturb the adult female blow flies to the extent that the hornets did.

Summary of Main Conclusions Drawn

The above results have shown that the 50 lb pig will adequately provide insect faunistic data for the initial portion of decomposition of a human remains for approximately 10-12 days during mid summer in the eastern central U.S. It is suspected that greater mass of the surrogate animal would be necessary to parallel the human to duration of the decomposition. Therefore, testing of larger animal with human remains will be needed to answer this question fully.

For current forensic application, it is shown that the common insect collection procedures and techniques used in death scene investigations continue to hold as the best methods for recovering the greatest number of forensically important species. This is a critical aspect to know so as to keep on the cutting edge of the science.

Valuable data on what calliphorid species are present in eastern Tennessee during mid summer has been generated in this study. Five common species have been recovered over the 35 day study during this warm weather periods and include: *Phaenicia coeruleiviridis, Phaenicia sericata, Phormia regina, Lucilia illustris,* and *Cochliomyia macellaria* most of which agree with studies by Reed 1958, and Rodrigus and Bass 1983. In addition, successional patterns were seen with *P. regina* and *C. macellaria* delaying in there colonization by as much as 24 hours when temperatures were into the upper 80s or lower 90s. Also, there is only one generation of blowflies on any human corpse during warmer weather, although there can be successive daily eggs being laid over a period of 4 to six days following death.

Other insects which may provide additional data for estimation of the postmortem interval include species of the Diptera groups Sepsidae and

Piophilidae. It was seen from the data that these two groups yielded several species and were present for a considerable duration.

Data derived from this study has already been used in case studies in Tennessee and has shown to be extremely important in several high profile court cases across Tennessee in both district and federal courts.

It is important that further study of larger pigs compared to humans be undertaken to supplement these data gathered during the 1989 human/pig study in Tennessee.

D. Acknowledgments

These researchers would like to thank the NIJ for major support of this project, along with the Indiana Coroner's Association, Knox County Tennessee Medical Examiner's Office, and Dr. William Bass and his staff of University of Tennessee, Department of Anthropology.

E. References Cited

Early, M. and Goff, M. L. 1986. Arthropod succession patterns in exposed carrion on the island of O'ahu, Hawaiian Islands, USA. Journal of Medical Entomology 23: 520-531.(Tullis and Goff 1987)

Hall, R.D. and K.E.Doisey. 1993. Length of time after death: effect on attraction and oviposition or larviposition of midsummer blow flies (Diptera: Calliphoridae) and flesh flies (Diptera: Sarcophagidae) of medicolegal importance in Missouri. Ann. Ent. Soc. 86:589-593.

Hall, R.D. and N.H. Haskell. 1995. Forensic entomology - applications in medicolegal investigations. in Forensic Sciences. Ed. C. Wecht, Mathew Bender, New York, NY.

Haskell, N.H. 1989. Calliphoridae of pig carrion in northwest Indiana: a seasonal comparative study. Master's Thesis, Purdue University, May 1989, West Lafayette, Indiana.

Haskell,N.H., R.D. Hall, V.J.Cervenka, and M.C. Clark. 1997. On the body; insects' life stages presence, their postmortem artifacts. in *Forensic Taphonomy, The Postmortem Fate of Human Remains.* eds W.D. Haglund and M.H. Sorg. CRC Press, Boca Raton, FL pp 415-448.

James, F. C. and Rathbun, S. 1981. Rarefaction, relative abundance, and diversity of avian communities. The Auk 98: 785-800.

Lord, W.D. 1990. Case histories of the use of insects in investigations. In *Entomology and Death: A Procedural Guide.* Eds. E.P. Catts and N. H. Haskell, pp. 9-37. Joyce's Print Shop, Clemson, S.C.

Lord, W.D. and J.F. Burger. 1984. Arthropods associated with herring gull (*Larus argentatus*) and great black-backed gulls (*Larus marinus)* carrion on islands in the gulf of Maine.

Payne, J.A. 1965. A summer carrion study of the baby pig Sus scrofa Linnaeus. Ecology, 46:592-602.

Payne, J.A. and E.W. King. 1970. Coleoptera associated with pig carrion. Nature 219:1180-1181.

Payne, J.A. and E.W. King. 1972. Insect succession and decomposition of pig carcasses in water. J. Geo. Ent. Soc. 7:153-162.

Reed, H.B. 1958. A study of dog carcass communities in Tennessee, with speciesl reference to the insects. The Midland Naturalist, 59 (1):213-245.

Rodrigus, William C. and William M. Bass. 1983. Insect activity and its relationship to decay rates of human cadavers in east Tennessee. J. For. Sci. 28(2):423-432.

Schoenly, K., K. Griest and S. Rhine. 1991. An experimental field protocol for investigating the postmortem interval using multidisciplinary indicators. Journal of Forensic Sciences 36: 1395-1415.

Smith, K.E.V. 1986. *A manual of forensic entomology.* Cornell Univsersity Press, Ithica, New York.