Testing Reliability of Animal Models in Research and Training Programs in Forensic Entomology, Part II.

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Final Report on Findings

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Appendix I -- Figures

Figure 1. Rarefaction curves for carrion arthropods collected from aerial net sweeps and pitfall traps on four carcass subjects (small pigs, medium pigs, large pigs, humans) over a 32-day period.

Figure 2A-C. Between-subject quantitative similarity (Morisita's index) for carrion arthropods collected from aerial net sweeps and pitfall traps on human and pig subjects over a 32-day period. AveMorSim = Average Morisita Similarity taken over all 32 days of the succession. Best fit lines and regression equations indicated to show trend only.

Figure 3A-C. Between-subject quantitative similarity (Morisita index) for carrion arthropods collected from aerial net sweeps and pitfall traps on pig carcasses of three weight classes over 32-day period. AveMorSim = Average Morisita Similarity taken over all 32 days of the succession. Best fit lines and regression equations indicated to show trend only.

Figure 4. Mean inter-subject dissimilarity scores (Clarke's R) for carrion arthropods collected from aerial net sweeps and pitfall traps on human and pig carcasses over a 32-day period. *Indicates between-group dissimilarities are satistically significant at the 95% confidence level.

Appendix II -- Photographs of Experimental Units

Photographs are labeled from upper left hand corner and continue clockwise.

Set 1 -- Day 4 -- July 4, 1998
- a. Pig E
- b. Pig D
- c. Human S
- d. Pig F

Set 2 -- Day 14 -- July 14, 1998
- a. Pig H
- b. Human S
- c. Human R
- d. Pig E

Set 3 -- Day 32 -- August 1, 1998
- a. Human S
- b. Human R
- c. Pig F
- d. Pig D

Appendix III -- Forensic entomology student/death investigator helpers.

Set 1 -- Students actively engaged in learning forensic entomology while conducting research at the Body Farm.
- a. Students and Dr. Haskell at photo layout shoot for Discovery Magazine article, "A Maggot for the Prosecution.", published in the November 1998 issue.
- b. Dr. Haskell and student processing maggots in laboratory.
- c. Students processing live flies in the rearing room of the lab.
- d. Students processing the experimental units at the research site.

Introduction

A national focus on scientific evidence, both in the popular and scientific press, has resulted from the well-covered Simpson trial in California. With a number of challenges to scientific evidence in this famous California case, the reliability of entomological evidence has similarly been challenged in separate cases, including the U.S. Federal District Court (Middle District of Tennessee), First Judicial Circuit Court (Escambia County, Fla.), and the York Regional Court (Newmarket, Ontario, Canada). Common areas of objection to entomology-based studies is the untested assertion that historical and repeated use of the Anthropological Research Facility (ARF) in Knoxville, Tennessee, is "saturated" with decomposer organisms, thus rendering ARF an atypical site for field research in forensic science. It has been widely recognized that the ARF offers a uniqueness in the use of freshly dead human remains for field studies in decomposition found at no other research facility in the world. The continued use of the facility has been possible only through specific state laws which prescribe that field research on decomposition of human remains be conducted at the ARF (following Tennessee statutes). In accordance with these dictates, NIJ funded an analysis of a 1989 field study at the ARF of human and pig decomposition (NIJ Grant 94-IJ-CX-0039). Following this analysis, a criticism was raised that human and pig subjects were incomparable due to differences in size.

The above criticisms were addressed in this second NIJ-funded study in two ways: first, a replicated weight series of pig subjects that bracketed the weight of two adult human subjects was included as part of the experimental design; and second, a separate analysis of the saturation hypothesis was conducted by analyzing carrion-arthropod populations sampled from replicate pigs at ARF and at varying distances from ARF. These studies also permitted comparison to the earlier 1989 results because carrion-arthropod data on human and porcine subjects were kept separate. It should be noted that only the first study is reported within this document; analysis of the second is being finalized at this time and will be reported upon in a master's thesis defense at the end of October, 2001.

Within the past several years, data generated from the above studies have been persuasive enough to successfully prosecute cases in more than 25 trials across the country (Florida, Illinois, Indiana, Oklahoma, Idaho, Washington, Texas, Pennsylvania, Kentucky, West Virginia, California, and Nevada). In a number of these cases, final sentencing included the death penalty. Our research results have

been provided to other entomological experts who have testified in a number of these trials. Because of such collaboration, responses from forensic entomology experts have been one of greater confidence due to greater reliability of insect data.

It is clear from the large numbers of insect specimens collected from the aforementioned NIJ studies that a small subset of carrion-arthropod species function as forensically-important organisms (i.e., principally blow flies and their relatives, plus some beetle species). Practically speaking, this finding corroborates the majority of homicide cases whose entomology-based estimates of the postmortem interval (PMI) have used blow flies. Preliminary results from the current analysis indicate parallel patterns of blow fly colonization in human and porcine subjects, at least during the initial days of succession until flies begin exiting the remains. In these early days, the common blow flies *Cochliomyia macellaria, Phormia regina,* and *Phaenicia coeruleiviridis,* show little or no preference for human or pig tissues.

Objectives

The objectives of this NIJ funded study were to: 1) test a size range of pigs (50-200 lbs) against replicate human bodies for differences in arthropod succession and decomposition; 2) determine what collection techniques recovered the largest majority of forensically important insects; 3) monitor the insect fauna present in eastern Tennessee during the summer for their potential use in future casework; 4) determine if carrion-arthropod populations are indeed `saturated' at ARF by virtue of its repeated and historic use as an outdoor forensic sciences laboratory. As in the first NIJ-funded study, a chief focus of the study was to determine if pig carcasses can function as human surrogates in training and research programs in forensic entomology.

In this second NIJ-funded study, replicate human (2) and pig subjects (6) were placed side-by-side on the same day and subjected to identical collection methods and exposure conditions over a 32-day period during summer. Six pig carcasses, lumped into three weight classes (small, medium, large), and two human cadavers allowed a larger field trial of possible pairwise comparisons to be made. Several sampling methods for gathering arthropod specimens were used, however, the results of only two methods (aerial net sweeps, pitfall traps) are reported as they constituted the only `quantitative' samples that we deemed amenable for statistical analysis.

Field Methods

The Anthropological Research Facility (ARF) is located on the grounds of the University of Tennessee, Knoxville. Dr. William Bass provided logistical, laboratory and housing support for the research team. Dr. Bass also provided access to the facility while we conducted the field work. Additional research assistance was provided by forensic experts, crime scene investigators, medical examiners and forensic students from many local, state and federal agencies and academic institutions with expertise in the forensic sciences: University of Tennessee, University of Missouri, University of Florida, University of Indianapolis, Purdue University, Michigan State University, California State University, Stanislaus.

1. Experimental Unit Placement and Sampling Times

Each human corpse was received in a cooled state for at least 48 hours from the Anatomy Department of West Virginia University, Morgantown, West Virginia. Two human specimens, one male and one female, were delivered in the evening to the ARF in unautopsied and unembalmed conditions. Upon notification of their availability and delivery, six pigs (two each of 50, 100, and 200 lbs) were anaesthetized, euthanized and delivered to ARF at approximately the same time as the human subjects. Thus, times of death were all within a 24-hour period for all eight subjects. Night placement exposed the eight subjects equally to insects the next morning. (The forensically important blow flies are inactive at night in unlighted areas.)

To test the adequacy of pig carcasses as surrogate human corpses and to quantify the extent to which pigs of different sizes differ in their respective arthropod faunas, experimental subjects were spaced 10-meter apart at random locations. Each subject was sampled daily between 1500 and 1600 hrs when insect activity reached its peak and continued for 32 days. Samples from pitfall traps constituted the largest portion of nocturnal insects. A photographic and video diary was created for each subject on each day of sampling to provide a visual record of changes insect infestation and progression of decomposition.

2. Arthropod Sampling

Sampling methods followed those of the previous Tennessee study and methods used by forensic entomologists at death scene investigations. These included: aerial net sweeps, pitfall traps, hand collection, and collection of live immatures for rearing studies. An unbaited control site for monitoring of background insect fauna was established approximately 75 yards from ARF. Sampling methods at the control site included use of pitfall traps and a malaise trap.

2a. Aerial Net Sampling

Aerial net sweeps sampled the flying arthropod fauna over each corpse of the study. Ten full sweeps of the net was performed in rapid succession over each subject and constituted one sample. Collected specimens were placed into labeled vials (date, location, subject #, sample #) containing 70-80% ethyl alcohol.

2b. Hand Collections

Hand collections were taken of crawling and immature arthropods from both the remains and areas adjacent to remains using fingers and forceps. Adult specimens were placed in vials containing 70-80% ethyl alcohol; whereas, immatures were placed in vials containing KAA (kerosene, glacial acetic acid, and ethyl alcohol) to kill and fix larval tissues.

2c. Live Collections of Larvae and Stage Rearing Procedures

Rearing of immatures was necessary because larval keys are not sufficient for identifying certain forensically-important flies (e.g., the flesh flies: family Sarcophagidae). Thus, identification of these groups is best accomplished at the adult stage using adult keys.

Live collections of fly eggs, larvae and pupae were hand collected (25+ specimens) and placed into rearing pouches containing beef liver. These pouches were then placed into rearing containers ('maggot motels'). Larval rearing pouches were constructed of aluminum foil placed inside rearing containers made from 16-oz Styrofoam cups with plastic lids. Cups had approximately 1 inch of vermiculite

in the bottom. Rearing pouches held 2 oz of beef liver used as food for about 25 eggs or larvae. Wet toweling was placed over the liver to prevent desiccation of both the liver and the feeding larvae. The top edges of the aluminum pouches were lightly crimped to also minimize desiccation while still enabling mature larvae to migrate out to pupate in the vermiculite.

Rearing containers were maintained at 24°C (+-4°C) and were observed daily for changes in growth rate and life cycle stages. Once adults had all emerged and died (death occurred for specimens if deprived of food or water for 48 hrs) reared adults were placed in ethyl alcohol and the dates of initial collection and final emergence recorded. As larval development progressed, we also found it informative to remove 3rd instar specimens from the rearing cups for preservation purposes. This procedure provided an additional check on the identity of each species. From the pair of dates on the labels it was immediately known which specimens were reared to which stage of development.

2d. Pitfall Traps

Pitfall traps were used to obtain representative ground-dwelling arthropod samples and to pinpoint migratory periods of fly larvae. One pair of pitfall traps was buried 12-18 inches from the thoracic side of each subject. The sloping topography of the site required that subjects be placed perpendicular to the slope with one pitfall buried uphill and the other downhill from each subject. Each trap was constructed of a 4 in diameter plastic funnel and a 16-oz glass jar fitted inside a 4-in diameter PVC pipe buried at ground level. The neck of the funnel was cut off to increase the opening into the receiving jar. Jars were charged with 75% ethanol instead of ethylene glycol because traps were emptied daily.

3. Soil Samples

Obtaining soil samples under and around the subjects would have been desirable, however, this procedure disrupts the insect fauna that use the soil for cover and protection. Soil removal could result in destruction of subterranean tunnels and runways and in disruption of feeding activities under or around the subjects. Consequently, judicious and limited soil samples were taken by carefully sifting areas of soil where it was thought specimens would be found.

4. Climatological Data

The linkage between insect development and environmental conditions provides the rationale for recording climate, both on small local scales and large scale. With environmental data recorded alongside biological data on arthropod development and succession, it was possible to conduct quantitative comparisons of local and distant weather data. Such comparisons will not be explored in this report.

4a. Climate Data

Overall weather conditions were monitored on each sampling day. Data were recorded on cloud cover, estimated wind speed and direction, rainfall within the past 24 hours, and ambient air temperature.

Temperatures collected alongside each subject included: 1) body surface temperature, 2) internal body temperature front (mouth), 3) internal body temperature rear (anus), and 4) maggot mass temperature. Two additional temperature records were taken using on-site data loggers with one sensor set 24 inches off the ground and the other set inside the subject. Readings were taken at 30 min intervals.

Statistical Analysis

Variation among subjects and sampling dates were assessed using six statistics:

(a) two measures of community similarity; (b) a hypergeometric model of species richness (rarefaction) that standardizes arthropod catches by equalizing sample sizes; (c) a random model of species colonization (Null Model 1; Gotelli and Graves 1996) whose reshuffling algorithm places species randomly and equiprobably on different carcass subjects and uses species-based (Jaccard) and abundance-based (Morisita) similarity indices to compute between-subject differences in species composition; and (d) mean dissimilarity in arthropod composition between human and pig subjects (Clarke's R) with the probability of observing an equal or larger Clarke's R under randomization.

(a) S_1 and S_2, degree of taxonomic similarity in arthropod species composition between two carcass subjects for shared counts of species and individuals, respectively, divided by the total number of species and individuals, respectively. For each pair of subjects, S was expressed as a percentage and calculated twice: once using shared taxa of the subject pairs (S_1), and a second time using individuals belonging to shared taxa (S_2). S_1 and S_2 range from 0% (no similarity) to 100% (complete similarity) and was calculated from the pooled data of 32 days.

(b) $Es_{(n)}$, expected species richness, calculated from a hypergeometric model (Hurlbert 1971, Simberloff 1972) is based on sampling without replacement from some parent distribution (i.e., observed community) that assumes individuals were sampled equiprobably and independently of one another.

(c) A *Null Model of Simple Colonization* (Rice and Belland 1982, Gotelli and Graves 1996) was applied to t taxa on c carcasses, simulates random colonization of carcasses by a pool of P equiprobable taxa. The percentage of shared species and individuals, defined by Jaccard's qualitiative similarity (J) and Morisita's quantitative similarity (M), was used to quantify similarity of each carcass pair, compared against what the expected percentage of shared species and individuals of that carcass pair would be under the random colonization model. In each bootstrap simulation, we drew randomly the observed number of species found on each carcass, and then computed J and M between all possible pairs of carcasses (i.e., pseudo-J's). The simulations were repeated 1000 times to generate 95% confidence intervals for each Jaccard and Morisita index. Pairwise Jaccard and Morisita similarities of natural carrion-arthropod communities were then compared to similarities of random communities and examined for statistical significance. This procedure was repeated for each of the 32 days of the study.

(d) C, Clarke's (1993) index compares between subject to within-subject dissimilarities to test if arthropod species composition differs between human and pig subjects. If the smallest difference between subjects is larger than every difference within subjects, then $C = 1$, but if differences between subjects are similar to those among subjects, C will approach 0. Bootstrap simulation was used to evaluate whether dissimilarities between subjects are larger than expected by random chance. The P value for the hypothesis test is $(x + 1)/(r + 1)$, where x is the number of more extreme values than the observed value found in r simulations

(i.e., 1000 in our tests). This procedure was repeated for each of the 32 days of the study.

Results and Discussion

Distribution of Taxa and Individuals

Over the 32 days of the study, aerial net sweeps and pitfall traps caught 28,679 organisms belonging to 61 taxa. Similarity statistics revealed that 49 of the 61 taxa were common to both humans and pigs (S_1 = 80%) and that these 49 taxa contributed 99.67% of the sampled individuals (S_2). These results indicate that all but the rarest taxa colonized both human and pig subjects. Thus, both subjects not only attracted a large majority of the same arthropod species in common but also the most common and moderately common species.

Of the 12 taxa recovered from humans or pigs, 5 and 7 taxa were unique to the human and pig, respectively. In decreasing order of total abundance, the 5 taxa from the humans were gastropod snails (4 individuals), calliphorid pupae #1 (3), calliphorid pupae #2 (3), a stratiomyid larva (1), and taxon #212 (1). The 7 taxa unique to pigs were Lepidopteran larvae (70 individuals), clerid beetles (4), tethinid flies (4), carabid larvae (3), a hemerobiid neuropteran (1), a stratiomyid egg (1), and taxon #218 (1). These taxa made up only 0.33% of the total catch. Although these 12 taxa constituted a diverse group of arthropods, with one exception (i.e., the 70 Lepidopteran larvae), they were very rare at the study site, making up only 0.33% (or 96/28679) of the total catch. Thus, based on these distributions, we concluded that most members of the carrion-arthropod community showed little or no preference for human or pig corpses.

Rarefaction and Null Model Results

Because species richness is influenced by sample size, even if identical sampling methods are practiced, it is inadvisable to compare simple species counts for two or more communities (Gotelli and Graves 1996). In this study, 32-day counts of arthropods from two humans were compared against those in three weight classes of pigs. More than twice as many individual arthropods were collected from humans (9710 individuals) than on small pigs (4496), so it is not

surprising that more arthropod taxa accumulated in the human (54 taxa) than the small pigs (49 taxa). Rarefaction calculates the expected number of species ($Es_{(n)}$) based on random subsamples of individuals. When a large sample is "rarefied" to equal the sample size of a small sample, direct comparison is possible because the species richness of both samples is now based on an identical number of individuals.

Rarefaction curves (and their 95% confidence limits) for carrion-arthropod communities in human and pig carcasses show that humans (H) and small pigs (SP) attracted similar numbers of taxa (49 and 48) so as to be statistically indistinguishable (Figure 1). Rarefaction curves for large pigs (LP) and medium pigs (MP) fell below the H-SP cluster revealing a significantly lower accumulation of species (40-42 taxa) at a common sample size of 4496 individuals. Thus, the higher number of arthropod species attracted to human cadavers was not simply an artifact of its larger catch of individual arthropods taken from aerial net sweeps and pitfall traps. That the total catch from small pigs would, after rarefaction-adjustment, show a higher `density' of arthropod taxa than either large- or medium-sized pigs was unexpected. On the other hand, it is scientifically comforting that 50-lb pigs, which have been used by forensic entomologists for many years, are indistinguishable from 150-lb humans after rarefaction adjustment.

Because human and pig subjects differed significantly in species richness, as revealed by rarefaction, we decided to match species richness of each subject in the observed communities to those generated by the null model. Consequently, for each simulation, four random samples that represented the arthropod complex for each subject (human, small pigs, medium pigs, large pigs) were drawn from the available species pool for that day, using a pseudorandom number generator. Each sample matched in species richness one of the four observed subjects. Jaccard (J) and Morisita (M) similarity values were calculated for all pairwise combinations of the four simulated communities. Simulations were repeated 1000 times. Results of the iterations were used to calculate means and 95% confidence intervals (CI) for Jaccard and Morisita similarities among the carrion-arthropod faunas drawn randomly from the species pool. This modification of Johnson's (unpublished) simple colonization model is equivalent to the approach used by Rice and Belland (1982) to study the similarity of moss floras in five regions of Bonne Bay, Newfoundland. In general, Jaccard results generated smaller confidence intervals (based on richness-based differences) that were easier to interpret statistically than abundance-based results of the Morisita index which was more sensitive than

Jaccard to changes in species richness and abundance. Consequently, we limited tests of statistical significance to Jaccard results and graphical displays of pairwise similarity to Morisita results.

Although there is considerable day-to-day heterogeneity among the Morisita similarities and an even mix of upward and downward trends in the time series for the six plots (Figure 2 and 3), average similarities were similar for the six pairwise plots. In pairwise combinations that included human subjects, 32-day means in Morisita similarity were slightly lower (Fig. 2A-C) than combinations that included pig-only subjects (Fig. 3A-C). These results indicate that carrion-arthropod faunas were more alike when the same species and similar weight classes were compared (i.e., medium and large pigs; Fig. 3C), than subjects belonging to different species and to different weight classes (i.e., humans and small pigs; Fig. 2A). The difference between the largest and smallest of these similarities, however, did not exceed 17% for any subject pair.

In only a very small number of cases did Jaccard similarities in the observed communities differ significantly from similarities of their corresponding random communities. Otherwise, similarities of the observed communities fell within the CI's of their counterpart random communities. On only 3 endpoint days (26, 27, 30) and in only 4 subject pairs within those days did similarities of observed communities fall outside the CI's of their counterpart random communities. More importantly, however, in only one of these cases (humans-small pigs on day 30) did the observed community have significantly lower similarities than comparable pairs of the random communities. This result bolsters the previous finding that carrion-arthropod communities are alike enough taxonomically and ecologically to assort themselves consistent with a random colonization model on a day-to-day basis up to day 30.

Between-Subject Dissimilarities

Unlike the simpler paired tests revealed in the previous section, Clarke's analysis allows species composition to be compared among groups of different subjects and computes dissimilarity between types of pairs, namely, within-group and between-group dissimilarity. If the smallest difference between groups is larger than every difference within groups, then R = 1 and the two groups are likely to be significantly different in their species composition. However, if differences

between groups are similar to those among groups, R will be close to (or less than) 0 and the two groups are unlikely to be statistically different.

Like the Morisita similarities in Figs 2-3, Clarke R values showed considerable day-to-day variability but significant between-subject (human-pig) differences in arthropod dissimilarity occurred on only 5 of the 32 days (Fig. 4). Significant departures in carrion-arthropod composition in human and pig subjects again occurred near the endpoint of the succession, starting with day 19 and ending with day 31. Because of the interacting effects of carcass weight and arthropod species richness, treating the six pigs as a single group, compared to the two-replicate human group, created high within-group variation that had the potential of exceeding between-group dissimilarity. This unbalanced design of replicates led to several negative R-values in the 32-day plot (Fig. 4). However, because each simulation randomly reassigns group labels and calculations are performed for all permutations of labels, leading to a P value, balanced groups are not required (Philippi et al. 1998).

Conclusions

In this study, three independent analyses bolstered results of an earlier NIJ study and confirmed the conclusion that carrion-arthropods form indistinct communities on human and porcine subjects on select sets of days in the succession. Community-level tests revealed little or no preferences by the carrion-arthropod community, as a whole, for porcine or human tissues during most days of the succession. Simple counts of joint taxa revealed that 80% of the taxa caught in quantitative samples (aerial net sweeps, pitfall traps) were common to both humans and pigs and that these taxa contributed 99.67% of the total catch indicating that all but the rarest species colonized both human and pig subjects. This result held even when comparisons involved pigs of different weight classes (small, medium, large) combined with human subjects. Indeed, rarefaction analysis revealed two clusters of subjects that placed humans and small pigs in one cluster and medium and large pigs in the other, based on differences in species richness. Two ecostatistical tests that employed a null colonization model (Gottelli and Graves 1996) and an inter-subject dissimilarity test (Clarke's R) each confirmed the null hypotheses of random colonization and inter-subject nonsignificance in arthropod species composition for all early and middle days of the succession. Significant departures in arthropod composition in pig and human subjects was

observed in the endpoint fauna, when only calcified remnants (bones, sinews) of the subjects remained, beginning with day 19 (for Clarke's R test) and day 30 (colonization model). Taken together, the ecostatistical methods employed in this study tested for between-subject differences in species-based and abundance-based similarity, species density, and species composition of the carrion-arthropod community.

Rarefaction results confirmed the field intuitions of forensic entomologists that 50 lb pigs are reliable models of human corpses, insofar as having comparable densities of arthropod species is concerned. Consequently, the use of 50-lb pigs over the past 15 years by different research groups working in different habitats and latitudes appear to have provided opportunities for reliable cross-site comparisons as well as pig-human comparisons at least in those habitats where pig carcasses have been used.

Experiments have been conducted and analysis is proceeding to test the saturation hypothesis of ARF in order to determine if ARF records, in general, can be extrapolated to other areas of the country.

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Rice, J. and R.J. Belland. 1982. A simulation study of moss floras using Jaccard's coefficient of similarity. Journal of Biogeography 9: 411-419.

Simberloff, D. 1972. Properties of the rarefaction diversity measurement. American Naturalist 106: 414-418.

Products and Outcomes of NIJ Awards in Forensic Entomology

Over the past 11 years more than 150 scientific workshops, seminars and other presentations were given where details of these two NIJ studies were discussed. The majority of these presentations were training sessions for death scene investigators, criminal trial attorneys and criminal justice personnel.

No. 94-IJ-CX-0039 (1989) Body Farm Research Study:

Schoenly, K.G and N.H. Haskell. 2000. Testing the reliability of animal models in research and training programs in forensic entomology. Final Report. *National Institute of Justice Journal.* January 2000; U.S. Department of Justice, Office of Justice Programs; National Institute of Justice, Washington, D.C.

The dissecting microscope purchased with this grant continues to be used on a continuous basis in both death investigations and research. All specimens from the 1998 Body Farm study were identified using this piece of equipment. Also, over the past 6 years, the microscope has been used to identify thousands of insect specimens from more than 200 death investigations across the country. This tool will continue to see use in forensic entomology research and death investigations for decades to come.

Abstracts:

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No. 97-IJ-CX-0046 (1998) Body Farm Research Study

Jessica Sachs. 1998 Discovery Magazine. "A Maggot for the Prosecution". November 1998.

Shahid, A.S., R.D. Hall, N.H. Haskell, and R. Merritt. 2000. "*Chrysomya rufifacies* (Macquart) (Diptera: Calliphoridae) Established in the Vicinity of Knoxville, Tennessee, USA." J. Forensic Sci 2000: 45;(4):896-897.

Note: The discovery of *C. rufifacies* and the above publication as a result of this study alerted forensic entomologists of the possibility of this southern species having an extended range of distribution not known before. Later in 1998 and in subsequent years, this species has been found colonizing human and pig remains throughout the midwest. By knowing its presence in Tennessee during the summer of 1998 from a number of varied carcasses, correct conclusions were then made when the species was found in forensic cases.

Baden, M. and Marion Roach. 2001. *Dead reckoning.* Simon & Schuster. New York. 288 pp.

Discusses research conducted and importance of the facility by authors at ARF.

Masters thesis for Adam Shahid, Department of Entomology, University of Missouri. "Comparison of the Anthropological Research Facility to other Remote Decomposition Sites." Graduation: December 2001.

A number of additional papers, presentations and studies are planned using the data recovered from the 1998 Body Farm Study results. Three papers are planned for publication dealing directly with first, a paper reporting what is primarily in this final report for the NIJ. Two additional papers are proposed that will report the statistical findings of the study from an ecological perspective. A fourth paper (likely the first to be published in the sequence to set the stage for the human/pig analysis) will be published that tests the "saturation" hypothesis at the ARF. This will be the publication from the M.S. thesis listed above from the University of Missouri. There could be many more papers resulting from the collected data ranging from the sequence of insect species over time (Phoridae, Piophilidae, and Sepsidae), climatological/insect studies, species richness and presence, and a host of others.

A current study just completed on quantification of anthropological PMI assessments may require additional data for verification. The two ARF studies in 1989 and 1998 provide detailed photographic information in conjunction with climate data. These two studies can provide very time specific information from multiple corpses, which may enhance the ability to conduct both qualitative and quantitative data analysis.

One of the most rewarding, but unplanned, outcomes of the 1998 research was the extensive training of helpful staff and assistants who gained from spending several consecutive days on the project and provided badly-needed manpower. The assistants were from a broad spectrum of law enforcement (Federal, State and Local) and academia and included death scene investigators, forensic pathologists, entomologists, and students in forensic entomology, forensic pathology, forensic anthropology, English literature, criminal justice, and others (See Appendix III). The following list gives the affiliations of those workers who assisted with the 50-day project. As is apparent, personnel came from literally all across the U.S. with one individual originating from Australia .

James Voss, San Bernadino Police Department, California
Bruce Barnett, Randy Arieux, Brevard County Sheriff's Department, Florida
Monty Nelson, King County Medical Examiner's Office, Washington
Andy Parker, Tallahassee Police Department, Florida
Michael LaForte, Jacksonville Sheriff's Office, Florida
Jason Byrd, Entomologist at the University of Florida
Jessica Sachs, Freelance Science Writer, Georgia
Max Aquilera, Discover Magazine Photographer, Brooklyn, New York
Brad Gibson, University of North Carolina at Wilmington, North Carolina
Amy Smith, United States Army, Maryland
Cameron Mackay, Queensland Police Service, Brisbane, Australia
Laura Gioeni, Charles Griffin, FBI, South Carolina
Mary Collins, FBI, Illinois
David Tate, School of Health Sciences at Purdue University
Tracy Smith, Fort Frye High School, Ohio
David Williams, Forensic Odontologist, Maryland
Joyce Williams, Emergency Room Nurse, Maryland
John Wallace, Lancaster, Pennsylvania
Sara Schultenover, G.W. University, Franklin, Tennessee
Rich Merrit, Dept of Entomology, E. Lansing, Michigan
Tom Rogers, Jackson, Michigan.
Mark Sheperdigian, Waterford, Michigan
Gene White, Troy, Michigan
Pat Hottel, Schaumburg, Illinois
Eric Smith, Lynchburg, Virginia
Michael Chapman, Irvine, California
Jerry Sitgfried, Reading, Pennsylvania
Jim Sargent, Brookfield, Wisconsin

Stephanie French, Pete Obenauer, Veronica Gibson, University of Tennessee
Kathy Heinsohn, Leesburg, Virginia
Robert Quick, Bob Hasty, Norfolk Police Dept., Norfolk, Virginia
Stace Alcala, Jennifer Gabra, Heather Thew, Tammy Greene, Kristen Baumann, Kelly Guthridge, Lilith Judd, University of Indianapolis, Indiana
Stoney Bachman, Norway, South Carolina
Mark Banks, Indianapolis Fire Department, Indianapolis, Indiana
Chris Osborne, Oakland County Sheriff Department, Michigan
Jan Johnson, FDLE Crime Lab, Pensacola, Florida
Michael Berkland, Medical Examiner for Okaloosa and Walton Counties, Florida
Christine Haskell, Purdue University, W. Lafayette, Indiana
Jeremy Holbrook, Western State College of Colorado, Colorado

17 States plus Australia -- 50 Students trained during the research.

APPENDIX I

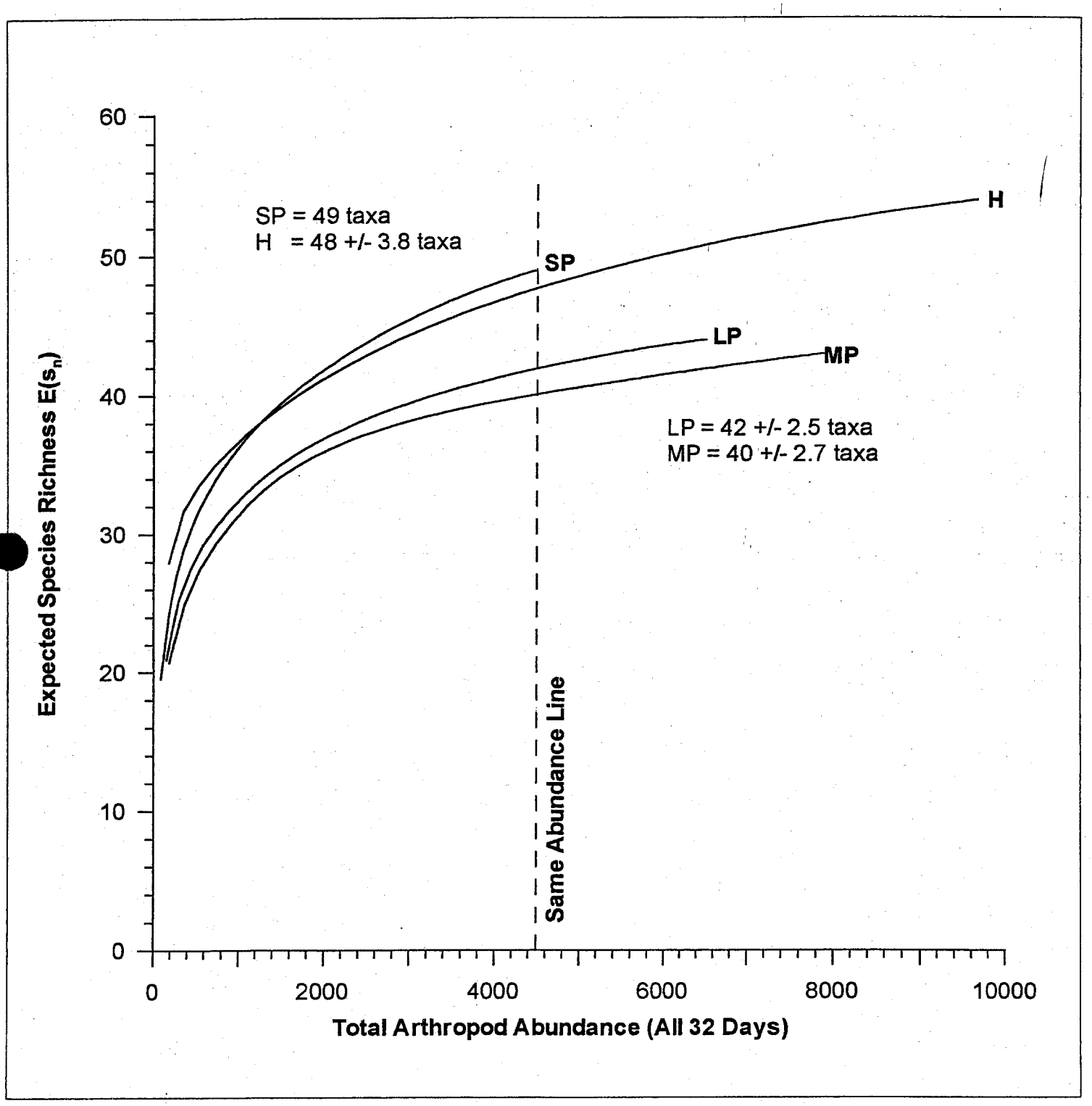
Appendix I -- Figures

Figure 1. Rarefaction curves for carrion arthropods collected from aerial net sweeps and pitfall traps on four carcass subjects (small pigs, medium pigs, large pigs, humans) over a 32-day period.

Figure 2A-C. Between-subject quantitative similarity (Morisita's index) for carrion arthropods collected from aerial net sweeps and pitfall traps on human and pig subjects over a 32-day period. AveMorSim = Average Morisita Similarity taken over all 32 days of the succession. Best fit lines and regression equations indicated to show trend only.

Figure 3A-C. Between-subject quantitative similarity (Morisita index) for carrion arthropods collected from aerial net sweeps and pitfall traps on pig carcasses of three weight classes over 32-day period. AveMorSim = Average Morisita Similarity taken over all 32 days of the succession. Best fit lines and regression equations indicated to show trend only.

Figure 4. Mean inter-subject dissimilarity scores (Clarke's R) for carrion arthropods collected from aerial net sweeps and pitfall traps on human and pig carcasses over a 32-day period. *Indicates between-group dissimilarities are satistically significant at the 95% confidence level.



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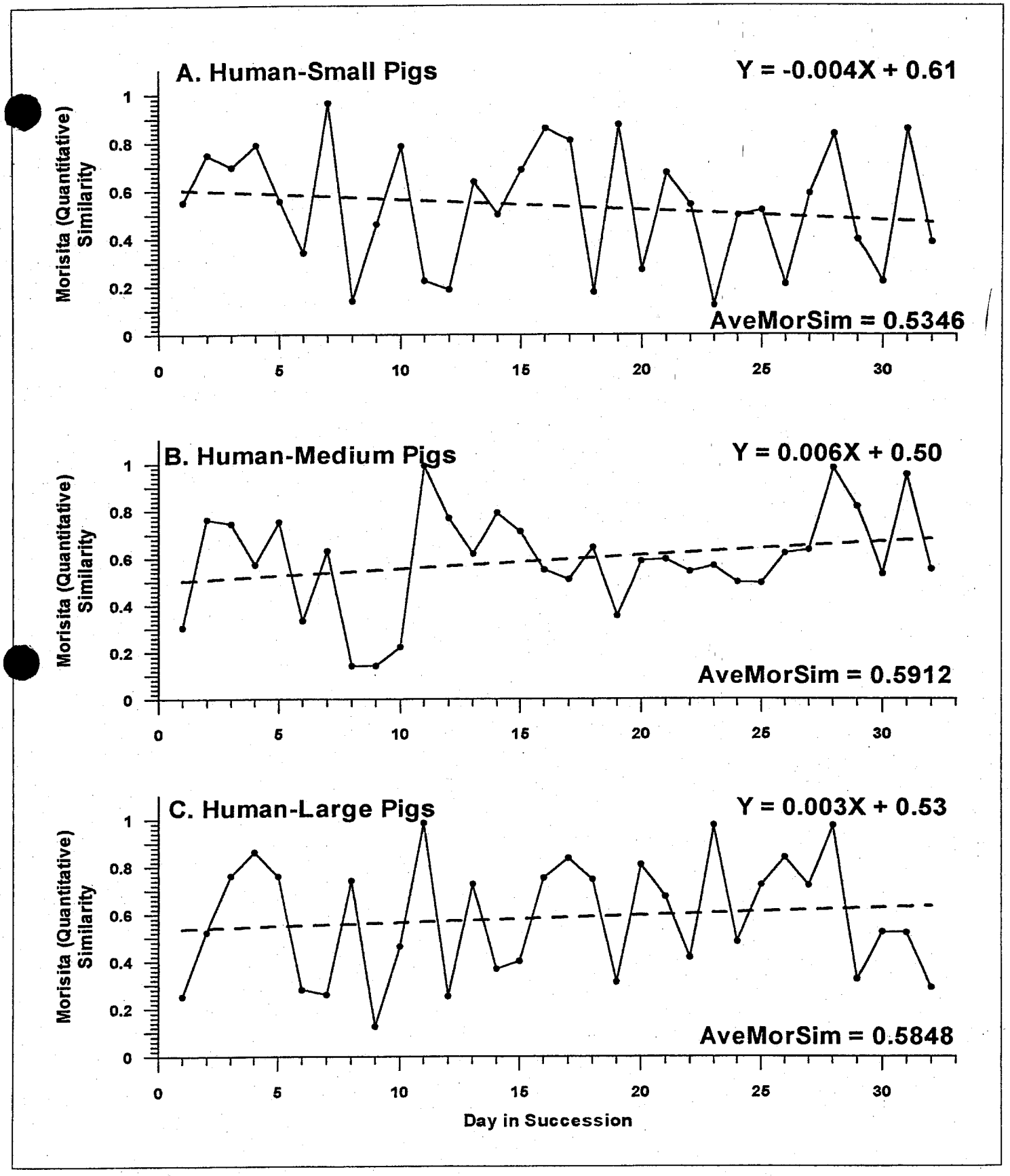


Fig. 2A-C. Between-subject quantitative similarity (Morisita's index) for carrion arthropods collected from aerial net sweeps and pitfall traps on human and pig subjects over a 32-day period. AveMorSim = Average Morisita Similarity taken over all 32 days of the succession. Best fit lines and regression equations indicated to show trend only.

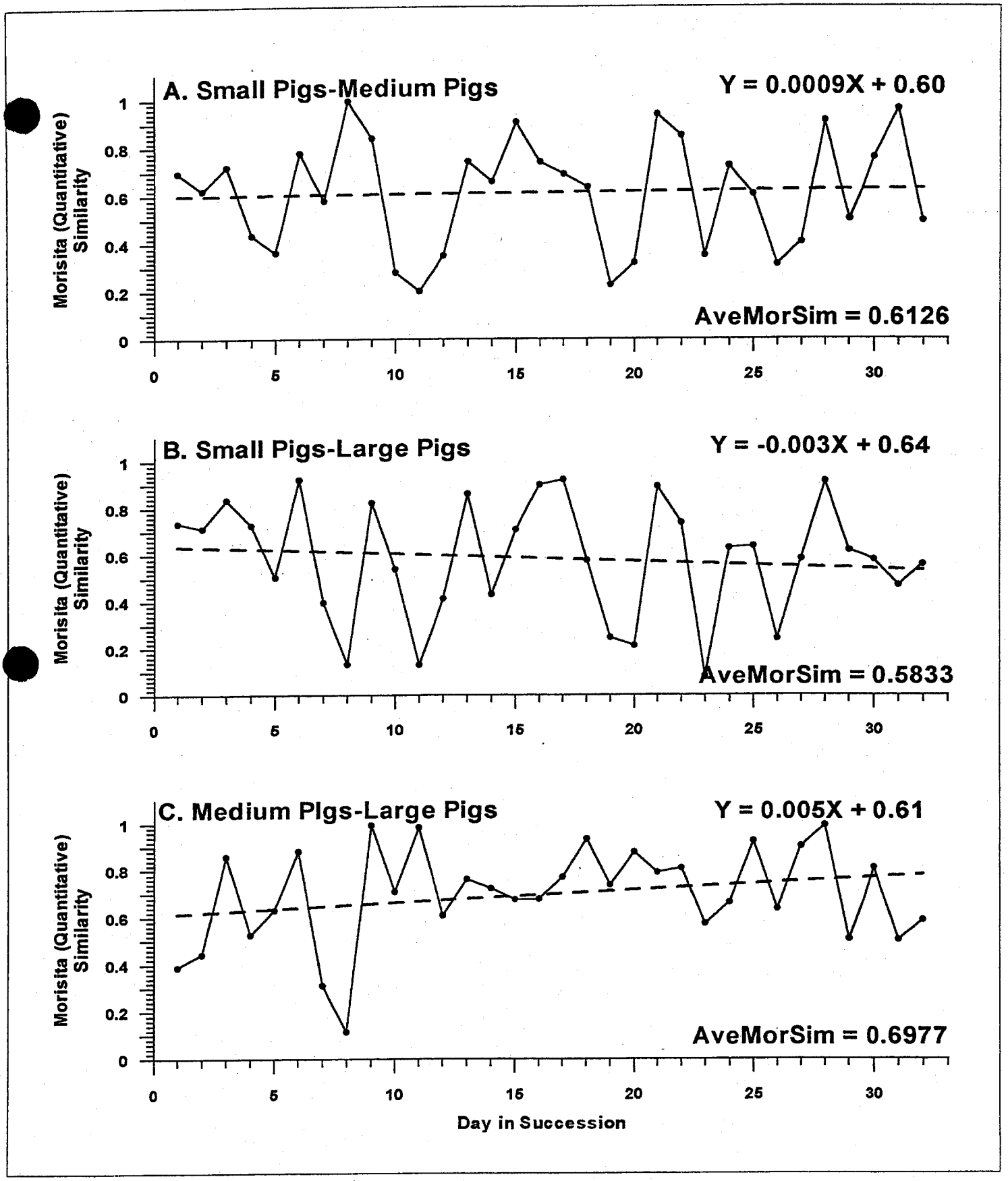


Fig. 3A-C. Between-subject quantitative similarity (Morisita index) for carrion arthropods collected from aerial net sweeps and pitfall traps on pig carcasses of three weight classes over a 32-day period. AveMorSim = Average Morisita Similarity taken over all 32 days of the succession. Best fit lines and regression equations indicated to show trend only.

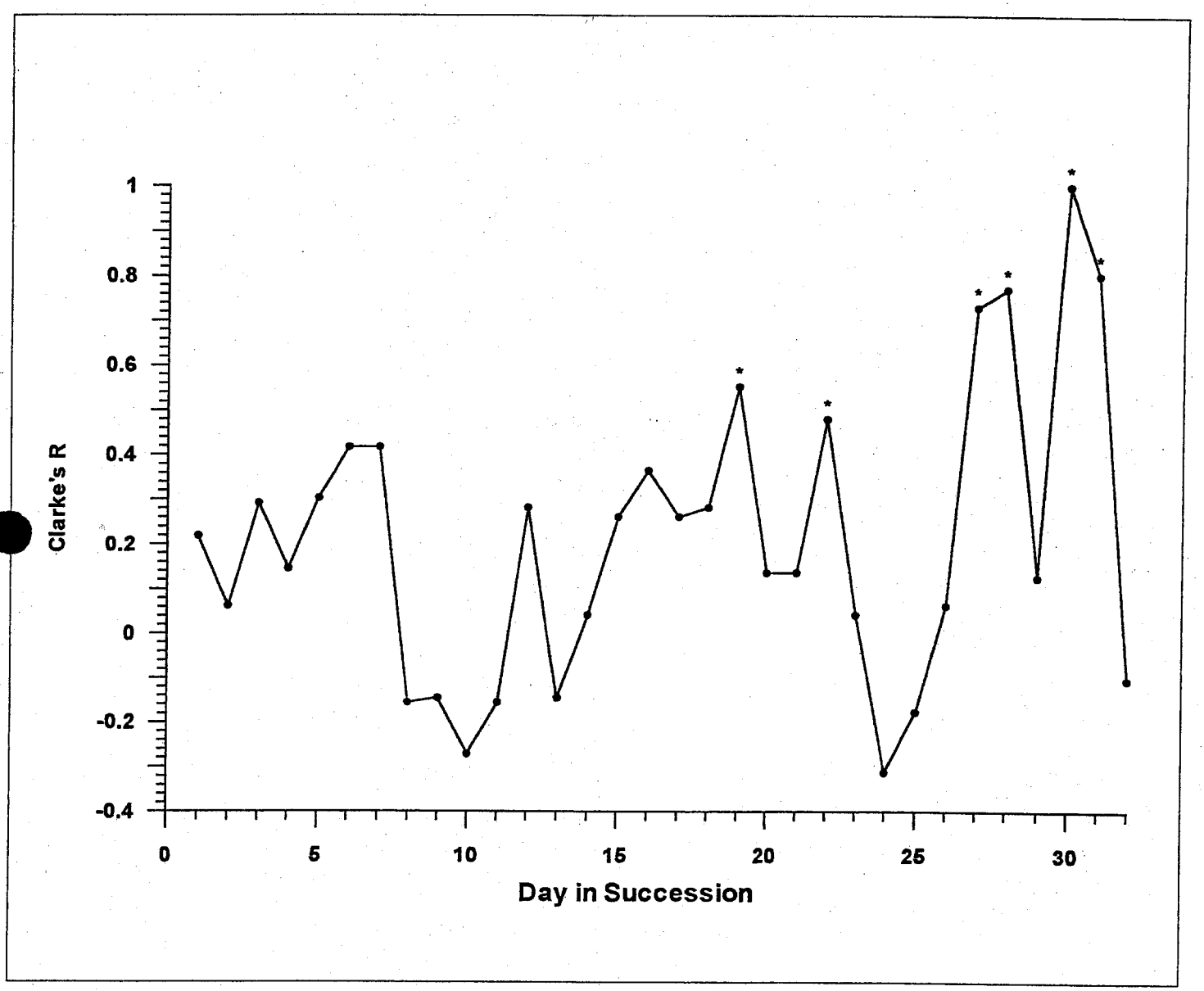


Fig. 4. Mean inter-subject dissimilarity scores (Clarke's R) for carrion arthropods collected from aerial net sweeps and pitfall traps on human and pig carcasses over a 32-day period. *Indicates between-group dissimilarities are statistically significant at the 95% confidence level.

APPENDIX II

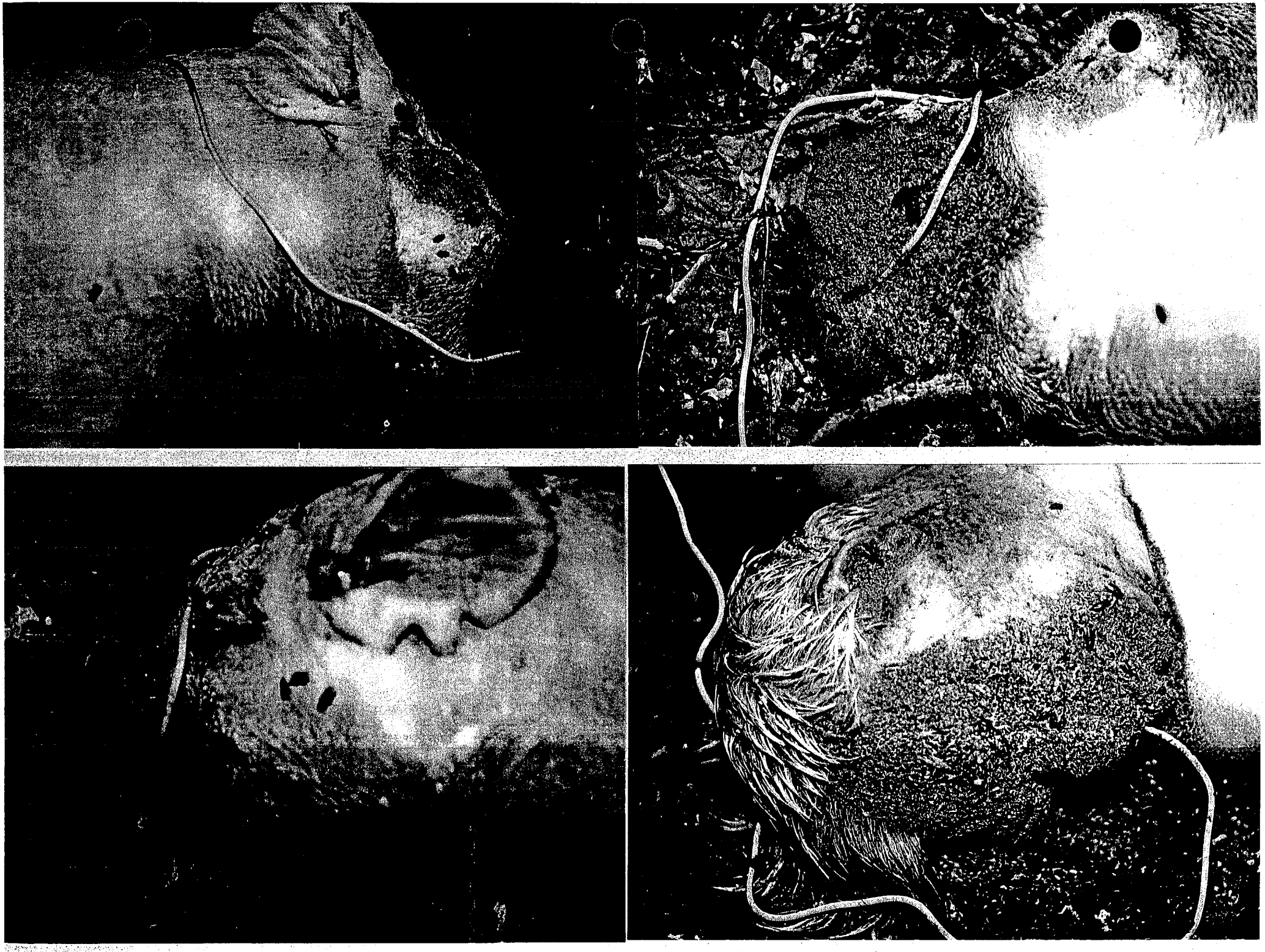
Appendix II -- Photographs of Experimental Units

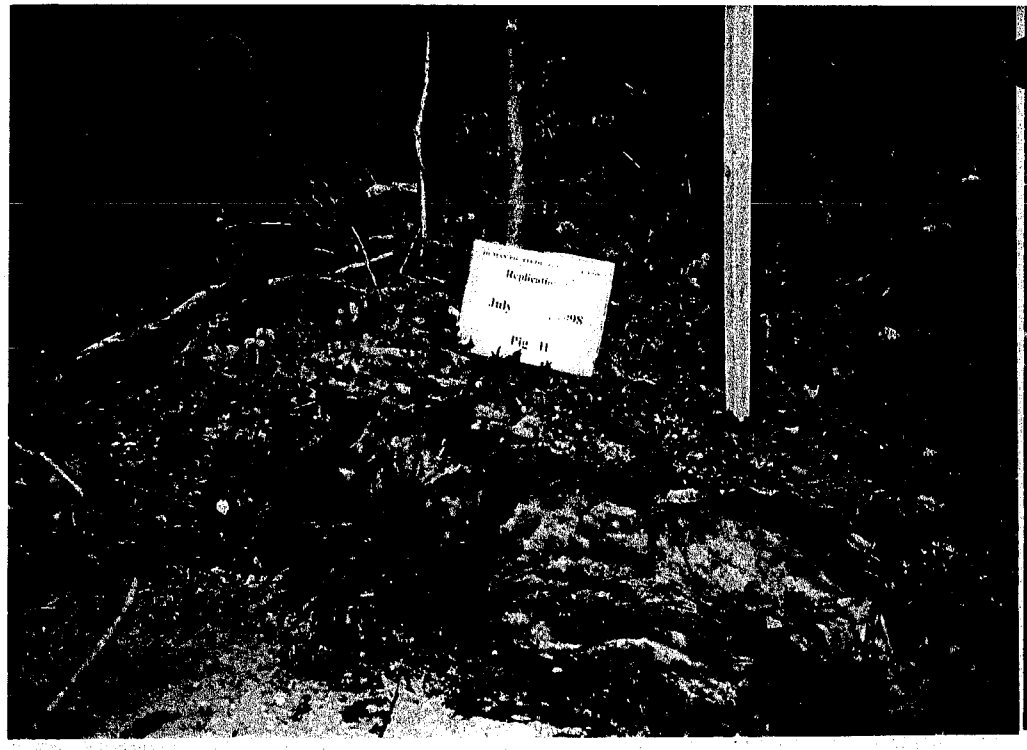
Photographs are labeled from upper left hand corner and continue clockwise.

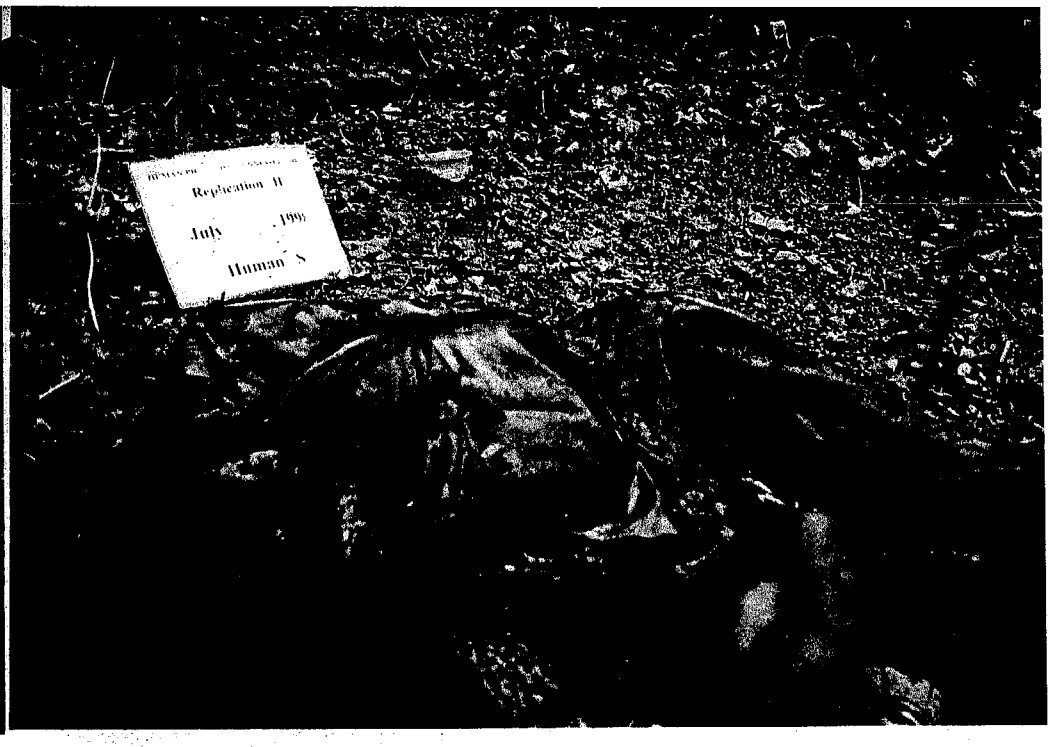
Set 1 -- Day 4 -- July 4, 1998
- a. Pig E
- b. Pig D
- c. Human S
- d. Pig F

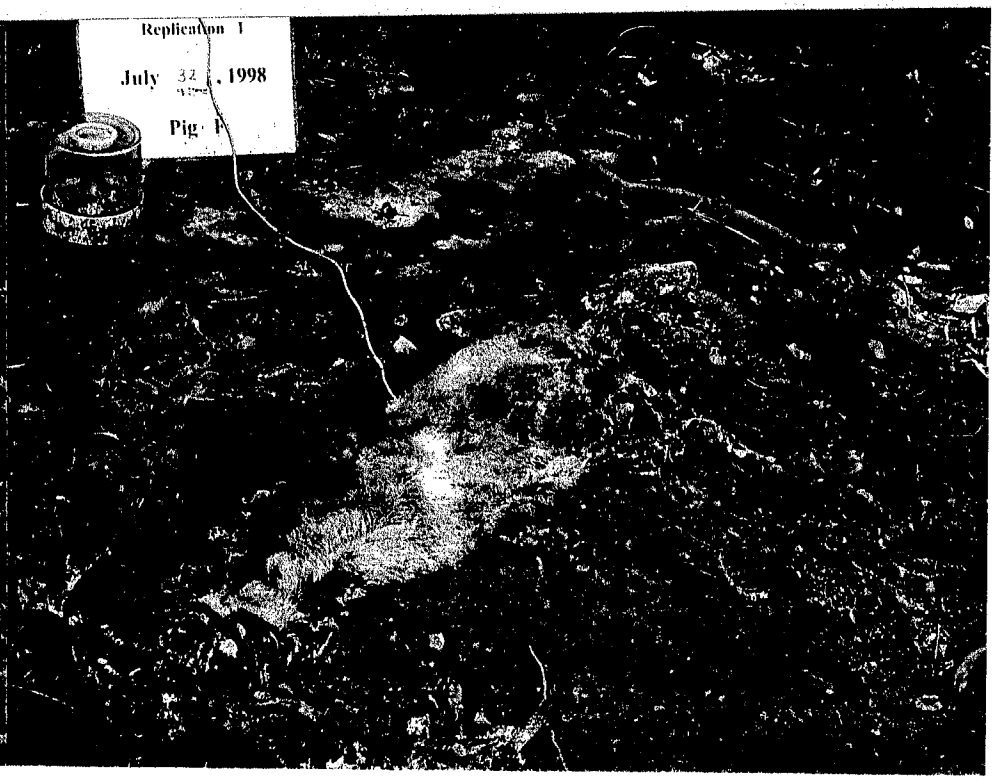
Set 2 -- Day 14 -- July 14, 1998
- a. Pig H
- b. Human S
- c. Human R
- d. Pig E

Set 3 -- Day 32 -- August 1, 1998
- a. Human S
- b. Human R
- c. Pig F
- d. Pig D









APPENDIX III

Photographs are labeled from upper left hand corner and continue clockwise.

Appendix III -- Forensic entomology student/death investigator helpers.

Set 1 -- Students actively engaged in learning forensic entomology while conducting research at the Body Farm.

a. Students and Dr. Haskell at photo layout shoot for Discovery Magazine article, "A Maggot for the Prosecution.", published in the November 1998 issue.
b. Dr. Haskell and student processing maggots in laboratory.
c. Students processing live flies in the rearing room of the lab.
d. Students processing the experimental units at the research site.