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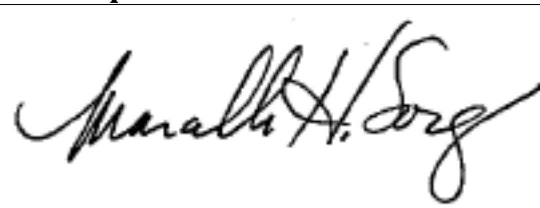
Signature of PI/PD	 **Marcella H. Sorg** **PI/PD**

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Abstract

The goal of this project was to develop regionally specific standards for taphonomic (postmortem) data collection and interpretation in northern New England, to be used in the recovery and interpretation of human skeletal remains. The objectives included analysis of a 30-year outdoor case series and controlled observational studies of nine pig (*Sus scrofa)* cadavers to illuminate key components of the model.

Cases in the series had a known postmortem interval under two years. We analyzed case files for taphonomic patterns and calculated the accumulated degree days (ADD) based on the nearest weather station. Most were found in the woods and 69% were scavenged. Scavenging, including defleshing and bone modification, potentially precludes or obscures decomposition, resulting in scattered, incomplete, and damaged remains, which may be unsuited for testing using, e.g, the models of Megyesi et al. (2005) or Vass (2010) to estimate the postmortem interval (PMI).

Based on findings from the case series analysis, we proposed components of the northern New England model including high scavenging prevalence, seasonal cold temperatures and snow with restricted insect access, and mostly forested environments. We used geographic information systems and weather station data to analyze environmental characteristics and calculate accumulated degree-days for specific PMIs.

We refined the model using nine pig cadavers as a preliminary validation of the presence of key components of the model using controlled observation. Pigs served as case study examples of patterns seen in the forensic case series, with the added advantage that we could observe some taphonomic sequences throughout the entire postmortem process using infrared cameras, temperature/humidity data loggers and periodic examination. Whereas this approach, combined with the limited number of pig cadavers, does not allow statistical conclusions, it does allow formation of a preliminary model of decomposition processes in this region. From the model presented here hypotheses can be generated and tested in the future.

Major variables included scavenging/no scavenging, death in warm or cold weather, and placement in forest or field. Decomposition, scavenging, and changes in weather were monitored. Microenvironmental context was assessed in terms of botanical, entomological, and geological characteristics.

The high level of scavenging was validated among the unprotected pig cadavers, all of which were scavenged, and new features of scavenging were identified. For example: (a) defleshing did not include bone modification in any of the scavenged animals; (b) deep snow did not prevent scavenging; and (c) multiple species were involved at different decomposition phases. We present a draft protocol to identify defleshing without bone modification. We also provide a video detailing the scavenger guild behaviors during winter scavenging. We have produced a visual decomposition atlas based on the pigs that were protected from scavenging, including both accumulated temperature and temporal benchmarks.

Our research suggests important ways in which forensic cases in northern New England are characteristically different from other regions in access to heat,

moisture and scavenging. The proposed *Northern New England Taphonomic Complex* includes the following key traits: (a) 5-6 months average temperatures below 4°C (40°F) with a corresponding absence of necrophagous insect activity; (b) 75-80% of the land forested; (c) low human population density; (c) precipitation above 127 cm (50 inches) a year; and (d) a high level of scavenger involvement. We propose associated protocols for scene processing.

Results of the research are being utilized in the Maine and New Hampshire criminal justice community. This regional taphonomy information system approach can be adopted in other regions, with the potential of data comparison across regions. A symposium organized for the 2013 American Academy of Forensic Sciences explored patterns found in multiple regions and began the work of comparing patterns.

Executive Summary

Research Problem

From both a theoretical and practical point of view, forensic anthropologists need to improve their knowledge of regional and microenvironmental taphonomic variation, particularly related to the estimation of postmortem intervals. During the past twenty-five years there has been an increase in our attention to forensic taphonomy, but the focus has been largely on taphonomic "universals" for decomposition processes. Recently published models for the estimation of postmortem interval (PMI) using Accumulated Degree Days (ADD) generally present a single, sequential decomposition process that includes insect involvement, no scavenger modification, and little attention to seasonal variation except ADD and (in one study) humidity. Because we have not had adequate datasets from our local regions, we have tended to 'look where the light was best,' and utilize published guidelines developed in other regions. It is critical that we develop regionally and ecologically specific models, validate them, and incorporate them into an interdisciplinary forensic team approach to death investigation. Such taphonomic models should incorporate attention both to the condition of the remains and to the environmental and ecological context.

Purpose

The purpose of this project has been to improve the quality of forensic anthropology as it contributes to death investigation and law enforcement particularly focusing on the protocols for detection and recovery of remains from outdoor settings. The overall project goal was to develop regionally specific standards for taphonomic (postmortem) data collection and interpretation to be used by forensic anthropologists in the recovery, examination, and interpretation of human skeletal remains. In order to accomplish this goal the three-year proposal included the following five objectives: (1) analyze taphonomic data for a 30-year series of outdoor scene cases along with a related cadaver dog searches; (2) develop an environmentally and regionally specific taphonomic model of postmortem change; (3) propose provisional guidelines for search and recovery of remains based on those findings; (4) test key aspects of the model in an actualistic setting using pig cadavers; and (5) disseminate the results of the research to the criminal justice and forensic science communities. This effort was done collaboratively with the Maine Department of Public Safety (Maine State Police Evidence Response Team) and the Maine Office of Chief Medical Examiner, and with guidance from an experienced, senior interdisciplinary team of forensic scientists and investigators. The project focused on data needed for locating human remains and estimating time since death in northern New England.

For the last 25 years forensic scientists, particularly forensic anthropologists, have considered how to improve death investigations by considering the environmental context (Haglund and Sorg 1997; 2002). We have become aware that, although ambient temperature is a key driver of postmortem processes, the variables that dictate the condition of the body are complex. The "Body Farm" in eastern Tennessee was one of the first facilities to consider these details systematically using donated human cadavers (Bass 2002).

Forensic taphonomy has become a central feature of forensic research and analysis by forensic anthropologists and scientists in related forensic disciplines, such as entomology, soil science and botany. With this expanding research has come the challenge of developing valid and reliable methods, with increasing emphasis on documenting the details of the environmental context (Dirkmaat et al. 2008; Sorg et al. 2012). Particularly important are those factors that either concentrate or limit the body's access to heat, moisture, and scavenging (Sorg and Haglund 2002).

Forensic anthropologists have appreciated the effects of contextual differences on decomposition processes, publishing a number of local case series analyses focused on the condition of the remains, including for example cases from the Arizona-Sonoran Desert (Galloway 1997), from multiple settings in Edmonton, Alberta (Komar 1998), forested settings in northern New England (Sorg et al. 1998), as well as experimental human cadaver studies in eastern Tennessee (Bass 1997; Wilson-Taylor 2013). However, these studies have focused on the condition of the body and decomposition processes connected to a particular geographic location without much attention given to variation in the ecological, environmental, and microenvironmental contexts. As forensic anthropologists have become more involved in the recovery of remains (Dirkmaat 2008) it has become more possible to illuminate contextual variables, a critical piece of the taphonomic puzzle.

Research Design

The project utilized forensic case data from Maine and New Hampshire in addition to experimental decomposition studies of nine pig cadavers placed at two outdoor research sites in Maine. The first step was to analyze existing data from forensic anthropology outdoor cases, using only those cases with known postmortem intervals. The second was to develop the regional model. The third step was to perform controlled field observations on major components of the model using pig (*Sus scrofa)* cadavers, providing an actualistic validity test.

The project information system is an ARC-GIS dataset constructed to archive and link climatologic, biogeographic and case-specific data. An interdisciplinary team of advisors worked with project staff in order to review project data and develop standards for outdoor scene data collection. Project leadership analyzed the taphonomic variables associated with the case data and the experimental pig cadaver studies, including both the environmental context and the condition of the remains.

Outdoor forensic cases from Maine and New Hampshire with a known PMI were included in the case series. Since the maximum postmortem interval in the controlled field observation was two years, we focused only on cases up to 24 months PMI. We limited the field observations to terrestrial surface depositions. Images and reports from these cases were scanned into a digital data reference set. Using point data coordinates or a centroid township GPS location, cases were processed into the Taphonomy GIS to enable mapping, production of an environmental profile, and calculation of ADD. The case series dataset was then sorted to locate subsets of more homogeneous cases with which to explore certain issues. We also selected a subset of 20 unscavenged cases with a PMI less than one year for which to assess "Total Body Score" (Megyesi et al. 2005) and their predicted ADD value, which was compared the predicted range to the actual ADD.

In building the forensic case series, we found that cases older than ten years tended not to have a point GPS location, so the system has not been used as much as anticipated with the case series analysis. We are still working out the best format to store historic case data, given the frequent missing values. Availability of scene data, body condition descriptions, and photographs tended not to be systematic across all cases. We are working with the Maine State Police Evidence Response Team and the Offices of Chief Medical Examiner in Maine and New Hampshire to construct more homogeneous scene processing protocols, so the data on new cases going forward are more complete.

The case series paper files and photographs were reviewed and data associated with major taphonomic condition and context variables were analyzed We documented that the vast majority of forensic anthropology cases in Maine involve scavenging, which significantly impacts defleshing, disarticulation, and precludes or obscures decomposition. Scavenging produces scattering and loss of bone elements. Defleshing by scavengers can be mistaken for defleshing from decomposition and insect activity. Due to the key role scavengers play, we received permission for a change of scope to incorporate a greater focus on scavenging, and do the related changes to the research design, but with a decision to retain the investigation of decomposition protected from scavenging.

Throughout the project we utilized a wide range of interdisciplinary experts to advise and guide us. We selected specialties for inclusion throughout the project as needed. Primary specialties included botany, entomology, geology, wildlife biology, cadaver K-9 specialist, and medical examiner. Also included to a lesser extent were pedology, organic chemistry, state police, and archaeology. Most of the individual consultations with experts and all three of the annual interdisciplinary workshops were videotaped for continuing reference.

To contextualize the environment in northern New England, we built a Regional Taphonomy Geographic Information System using Arc-GIS for Maine, New Hampshire and Vermont. By inputting a GPS location from cases in the series, new cases, or experimental sites, the Regional Taphonomy GIS can produce for that site an environmental profile documenting topography, elevation, annual precipitation, annual temperatures, soil properties, land use, land vegetation cover, and leaf on/leaf off aerial views of any site in the three states. We have built a computerized tool to link to weather station datasets (or experiment site data logger datasets), which calculates accumulated degree days for a given date range.

Building on the findings of the case series analysis, we put together a regional taphonomy model that reflected major variables observed in the case series. The actualistic experiments were structured as controlled observations of the major variables we had observed in the case series. Thus, a cohort of six of the nine pig cadavers were placed in scavenger-accessible locations, and three were placed in cages without scavenger access. A cohort of five of the nine died during cold (< 4°C average daily temperature) temperature seasons, and four died during warm temperature seasons. All sites had a digital weather station tracking hourly temperature and humidity, as well as two heat and motion sensitive cameras for capturing still images and video at each site. Because remains in most outdoor cases in our series were found in or near woods, seven of nine pig cadavers were placed in wooded settings, and two in a field area near the edge of the woods. We limited our scavenger-access contexts to modal forensic environments: in or near woods, within 15-30 m of an access road. The pigs that were accessible to scavengers were clothed to provide human scent.

Although the design does not focus on building sample sizes, it allowed us to replicate and observe in a controlled fashion the taphonomic effects that were salient in the case series, including scavenging, cold temperature and snow cover, sequencing of cold to warm seasons, as well as canopy effects on temperature and humidity. Because the late-fall cohort was put in place after frost, for example, the field observations document a common taphonomic sequence seen in our region: early decomposition in the absence of necrophagous insects, including the effects of freezing, thawing, and snow cover. All sites and controls were assessed in terms of their vegetation, soils, and geology.

The project proposal was for three years. We received permission for a fourth (no cost extension) year to provide time to complete the analysis of the images and extend the observations on the pig cadavers.

Results

This project successfully demonstrates the steps and tools that are helpful for the ongoing development of the proposed regional forensic taphonomy model for northern New England, which can be used as an example by other regions. Northern New England's climate (cold temperatures, moderate humidity and precipitation, characteristic freeze/thaw patterns in fall and spring, heavy snow cover for several consecutive months each year), biogeography (heavy, pervasive forests of evergreen, deciduous, or mixed tree taxa, high scavenger density, large and variable scavenger guild, moderate topographic contrasts, and low human population density constitute a characteristic environmental profile that strongly affects postmortem (taphonomic) processes.

One of the critical issues in northern New England regional taphonomy is whether these variables might cause problems with PMI estimation methods developed in other regions (e.g., Megyesi et al. 2005). In order to apply this method to our case series, we filtered our case series to select only non-scavenged, terrestrial cases with a known PMI (n=20 cases from Maine and New Hampshire combined). We used the known PMI, selected the nearest weather station, and calculated the actual ADD for each case. Photographs and case report descriptions were used to score the TBS for each case, and the TBS was inserted into Megyesi et al.'s regression model. The model worked reasonably well to predict an ADD range that encompassed the actual ADD in 12 of 20 cases. In seven cases the estimated an ADD range was higher than the actual ADD, at one standard error; but in range at 95%, i.e., only by doubling the standard error. More research will be needed to explore whether the regional taphonomy systematically shifts the TBS to higher scores, compared to Indiana cases. All of the cases in which scores were too high died in warm months and were discovered prior to winter. Occult scavenger defleshing, i.e., lacking bone modification or scattering, cannot be ruled out at this time, which would have made the TBS artificially high.

Our controlled pig cadaver observations can help interpret what we are seeing in the case series. During winter, a "scavenger guild" of mammalian and avian species may completely deflesh a body, even under deep snow cover. Furthermore, when temperatures are cold, these scavengers can consume flesh in a leisurely fashion, without having to compete with insects. The mammals more often feed at night, and the birds in the daylight. Some cadavers, however, may not be modified at all during the winter, even when scavengers have access to the body over many months.

Insect infestation can delay or limit mammalian scavenging. In warmer seasons, there is competition until the skeletonization has occurred. Once a body is fully engaged with insect larvae, most scavengers avoid it until the soft tissue is gone. There are exceptions to this, with animals that can tolerate decomposition bacteria such as the turkey vulture, or animals that like to consume insect larvae, such as bear or raven. Four pig cadavers (warm weather spring or early fall deposition) underwent a fairly homogenous sequence of insect infestation, followed by vulture involvement, and then coyote scattering and modification of the already-defleshed bones. It is important to note that coyotes did not deflesh any of the pigs, despite their abundance in the area.

Scavenger defleshing can potentially interrupt or even preclude decomposition and insect infestation. For this reason, scavenging potentially interferes with models of PMI estimation based on skeletonization by decomposition and insect feeding. It becomes very important to discriminate scavenger-mediated defleshing from decomposition or insect-mediated soft tissue removal in forensic cases. If temperatures are known to have been below 4°C, there is no confusion. But in warmer temperatures some occult scavenger defleshing and insect-involved decomposition may occur in parallel, generally including insect infestation and avian feeding. We present a preliminary set of guidelines for discriminating defleshing by scavengers from skeletonization by insects and decomposition; the guidelines will need further study.

We have documented three patterns of scavenging in our research. The first succession cold weather scavengers, defleshing without insect involvement, and with minimal scatter, included the marten, raccoon, bobcat, fisher, ermine, raven, crow, blue jay, chickadee. The first succession warm weather scavengers, defleshing with insect involvement, and with minimal scatter, included the turkey vulture and the raven. The second succession bone modifying scavengers, which also scattered remains, were active in both cold and warm weather after skeletonization; these include the coyote and porcupine predominantly.

Among the caged (non-scavenged) pigs, we were able to demonstrate both seasonal (cold versus warm weather) and microenvironmental (forest canopy versus open field) differences. As expected, the overwintered cadavers in cages remained intact under the snow from November through early April, at which point they very rapidly became infested with insects and decomposed. The microenvironment under canopy was associated with a reduced ADD, but the pig's skeletonization was more rapid, compared it the temporally matched open field pig, probably due to higher accumulated humidity. In the open field, decomposition for the overwintered pig was delayed at all 100-ADD benchmarks compared to the pig under canopy, reaching skeletonization at 1440 ADD. Sunlight apparently contributed to mummification of some of the skin over the torso, which persisted and delayed full skeletonization, although the bones underneath were fully defleshed. In contrast, the overwintered cadaver under forest canopy became fully skeletal with no mummification 34 days earlier, at 645 ADD.

The decomposition island that develops under and immediately surrounding the decomposing corpse can be a helpful sign of the primary body location, even when scavengers remove the remains. The decomposition island is also a helpful indicator that tends to rule out scavenger defleshing. Persistence of the island, however, depends on the type of vegetation underneath. The conifer needle forest floor does not have latent seeds. The stained area regains its original color after about a year, and the island can no longer be recognized. The island in a field or meadow, however, shows a clearly delineated difference, which persists longer, even after the bones are gone, due to the differential plant species and darker color of their leaves.

Conclusions

We propose the term *Northern New England Taphonomic Complex* as a shorthand umbrella that covers all of the following key traits: (a) five to six months of average temperatures below 4°C with a corresponding absence of necrophagous insect activity; (b) forests covering more than 75-80% of the land, low population density in most of the area covered; (c) precipitation above 127 cm a year on average; and (d) a high level of scavenger exposure around 70-75% of cases. These factors influence the body's access to heat, moisture, and scavenging, and should be considered in interpreting body condition and context in outdoor forensic cases. The independent variables in the complex constitute macroenvironmental, regional characteristics that one can expect to find; these are associated with a cluster of dependent variables, i.e., taphonomic features more frequently seen in individual cases from that region.

Our research demonstrates important ways in which forensic cases in northern New England are characteristically different from other regions. One of the most important differences is the very high prevalence of scavenging found in our case series, affecting about 75-80% of forensic cases exposed outdoors. This high level was also replicated in our pig cadaver observations; all six of the un-caged pigs were scavenged. Observations from the case series and the experiments allow us to paint a more fine-grained picture of forensic scavenging, particularly issues surrounding defleshing by mammalian and avian species.

We address this problem by suggesting a draft protocol to identify defleshing by animals, even in the absence of bone modification. This will require some additional data collection at the scene: (a) documenting in detail the extent of disturbance of anatomical order; (b) locating scattered remains up to .4 km (a quarter mile) or more; (c) documenting the extent and pattern of scatter; (d) locating and investigating the decomposition island(s) and insect remains if present (including those within the soil); and investigating the ADD/PMI issues. Without attention to such detail, we believe these cases that are scavenged can be erroneously misinterpreted as having decomposed, including cases used for models in the literature. This potentially reduces the precision of models to estimating PMI that are based on decomposition processes.

The unscavenged caged pigs provide insight into the effects of overwintering, which we feel needs more research. For example, the species of insects, including more species normally seen in later postmortem times, may have been attracted as the snow melts. This indicates some decomposition may have occurred during the winter when temperatures were generally below freezing, but the body was insulated with heavy snow cover.

We documented many events of the project on video, including interviews with subject matter experts, the interdisciplinary workshops, and the process of doing the pig placements and observations. To the extent that the northern New England taphonomy information system approach would work for other regions, this videographic archive could be utilized to build training pieces, or produce a longer piece on regional taphonomy.

Utilizing pig cadaver subjects and processing is very expensive, with the result that sample sizes are really quite small. The forensic case series studies really are necessary, so we have to solve the missing data problem by systematizing our taphonomic protocols.

This project develops a dynamic system to observe, document, and test regionally specific models of taphonomic change relevant for improving forensic death investigation. The Northern New England Regional Taphonomy Project utilizes a combination of publicly available datasets, geographic information systems, forensic case information, and experimental research, which was archived and analyzed via commonly available software applications (Table 4). This regional taphonomy information system approach can be adopted in other regions, with the potential of data comparison across regions.

Implications for Policy and Practice

Our research has already changed the way we process outdoor scenes in Maine and potentially in New Hampshire. The Maine State Police Evidence Response Team and Warden Service search team works with the anthropologist and the medical examiner to document scatter patterns, search for decomposition islands, and pay closer attention to microenvironemental factors that limit heat or scavenging. This is now happening even if the anthropologist is unable to participate in a body recovery. The anthropologist is consulted more often by the medical examiner about PMI estimations, even in non-skeletal cases. We are using the guidelines for discriminating scavenger defleshing from skeletonization due to decomposition and insect activity.

We have presented a draft protocol for outdoor scene processing to the State Police Evidence Response Team in Maine during a recent training. We have also presented this material in training the death investigators in New Hampshire. And we have been invited to deliver a lecture on "Regional Taphonomy" to the medical examiners (national) at the Colby Forensic Sciences Summer Course. A number of anthropologists have seen the short winter scavenging video at the NIJ Conference and the AAFS Meeting, and we have had several requests to use this video for their classroom teaching. In February 2013 we convened a symposium at AAFS focused on regional taphonomy issues, including the steps to build a collaborative, interdisciplinary regional taphonomy network. The network will be the subject of future proposals.

The impact of developing a functioning regional/national taphonomy network is has already been the subject of a multiple discussions with others who are interested in doing their own regional taphonomic approaches, searching for areas of overlap, and networking to improve collaboration and practice. By putting in place structures to collect, archive, and utilize regional data, forensic scientists build a foundation for ongoing research, both experimental and applied. The effort to construct such a system should be seen as an ongoing endeavor of quality improvement.

We are preparing an invited prospectus for an edited volume that would be built from this symposium, with contributions from additional investigators that were unable to present at this AAFS venue. We have proposed forming a virtual network of regional taphonomy centers, which would be linked digitally, sharing information and expertise, as well as building a database of cases and experimental data, and develop research designs to test shared phenomena with combined datasets.

From both a theoretical and practical point of view, forensic anthropologists need to improve their knowledge of regional and microenvironmental taphonomic variation, particularly related to the estimation of postmortem intervals. During the past twenty-five years there has been an increase in our attention to forensic taphonomy, but the focus has been largely on taphonomic "universals." Because we have not had adequate local datasets, we have tended to look where the light was best, and borrow guidelines developed in other regions. This project represents a course correction, providing a description and initial analysis of the Northern New England Taphonomic Complex, which is being incorporated into policy and practice in the region.

Chapter 1 Introduction

Problem Statement

From both a theoretical and practical point of view, forensic anthropologists need to improve their knowledge of regional and microenvironmental taphonomic variation, particularly related to the estimation of postmortem intervals. During the past twenty-five years there has been an increase in our attention to forensic taphonomy, but the focus has been largely on taphonomic "universals" for decomposition processes. Recently published models for the estimation of PMI using Accumulated Degree Days (ADD) generally present a single, sequential decomposition process that includes insect involvement, no scavenger modification, and little attention to seasonal variation except ADD and (in one study) humidity. These models were developed using regional datasets, which may not be applicable to other geographic locations, or to different microenvironments within that region. Because we have not had adequate datasets from multiple regions, we have tended to 'look where the light was best,' and utilize published guidelines developed in other regions. It is critical that we develop regionally and ecologically specific models, validate them, and incorporate them into an interdisciplinary forensic team approach to death investigation. Such taphonomic models should incorporate attention both to the condition of the remains and to the environmental and ecological context.

This project addresses the need for taphonomic models by focusing on outdoor terrestrial forensic contexts in northern New England (Maine, New Hampshire and Vermont), within the temperate broadleaf and mixed forest biome, and including the two Level II Ecosystems: the Atlantic Highlands and the Mixed Wood Plains (ftp://ftp.epa.gov/wed/ecoregions/cec_na/NA_LEVEL_II.pdf). The climate for this region is characterized as temperate/humid continental climate under the Koppen-Geiger System (Peel et al. 2007), which includes short, warm summers and long, snowy winters.

Literature Review

Forensic Taphonomy's Focus on Context

The earliest incorporation of interdisciplinary taphonomy concepts to forensic death investigation began in the late 1980s when Sorg (1986) and Haglund (Haglund 1991; Haglund et al. 1988; Haglund et al. 1989) applied research on scavenger modification of remains and decomposition into their own forensic casework. A 1993 symposium at the American Academy of Forensic Sciences resulted in two edited volumes (Haglund and Sorg 1997; Haglund and Sorg 2002a), and emphasized the importance of microenvironmental context in the fate and interpretation of the condition of the remain. Forensic taphonomy has become a central feature of forensic research and analysis by forensic anthropologists and scientists in related forensic disciplines, such as entomology, soil science and botany. With this expanding research has come the challenge of developing valid and reliable methods, with increasing emphasis on documenting the details of the environmental context (Dirkmaat et al. 2008; Sorg et al. 2012). Particularly important are those factors that either concentrate or limit the body's access to heat, moisture, and scavenging (Sorg and Haglund 2002).

Forensic anthropologists have appreciated the effects of contextual differences on decomposition processes, publishing a number of local case series analyses focused on the condition of the remains, including for example from the Arizona-Sonoran Desert (Galloway 1997), from multiple settings in Edmonton, Alberta (Komar 1998), forested settings in northern New England (Sorg et al. 1998), as well as experimental human cadaver studies in eastern Tennessee (Bass 1997; Wilson-Taylor 2013). These studies have focused on the condition of the body and decomposition processes connected to a particular geographic location, but without much attention given to variation in the ecological, environmental, and micrenvironmental contexts. As forensic anthropologists have become more involved in the recovery of remains (Dirkmaat 2008) it has become more possible to illuminate contextual variables, a critical piece of the taphonomic puzzle. Controlled observation methodologies continue to contribute knowledge to the growing body of taphonomic research (Marden et al. 2012).

Cold Temperatures

Bunch (2009), Micozzi (1986, 1997), Parsons (2009), and Stokes et al. (2009) have used non-human mammal surrogates to investigate the effects of cold and/or freezing temperatures on decomposition under experimental conditions. Micozzi (1997) in particular discusses the potential confounding importance of freeze/thaw sequences, notes the differential decomposition near the soil interface, and reports greater deterioration of the outer surfaces in frozen-thawed animals. In forensic settings, the freeze-thaw sequences and microenvironmental context differences can introduce substantial deviation and variation from experimental conditions, as shown by Komar (1998) in her case series study in Alberta.

Moisture, Soil Composition, Soil Acidity, Econiche

A number of more recent experimental studies have used pig cadavers *(Sus scrofa)* to explore variation in regional, seasonal, and microenvironmental characteristics and their various effects on decomposition rates. In an Australian study of 20 newborn pigs Archer (2004) looks at seasonal variation in a damp forest. Decomposition speed, as indicated by loss of body mass and decay stage, was generally greater in warmer and wetter seasons. Decomposition differed from year to year due to weather changes. Higher moisture has been demonstrated to speed loss of mass and decomposition, unless clay content of soil is high (Archer 2004; Carter et al. 2010; Jaggers 2009), or unless adipocere forms (Duraes 2010). Acid soils contexts and the associated microbial action can speed decomposition as well (Haslam 2009). In northern England, pigs were buried in three habitats (pasture, moorland, deciduous woodland) and recovered 6, 12, and 24 months later (Wilson 2007). This study showed seasonal and microenvironment differences, even within the same habitat and within the same pig. The authors point to the importance of variation in soil type and structure.

Insect Activity

Carrion-eating insects are important taphonomic agents (Anderson and Cervenka 2002; Goff 2009; Haskell et al. 1997), consuming soft tissue and skeletonizing a body. Although taphonomically important necrophagous insect taxa have a widespread distribution, they may behave differently depending on the season or local environment (Anderson and VanLaerhoven 1996; Hobischak et al. 2006; Sharanowski et al. 2008). Experimental insect studies using pig cadavers have been published for many areas, documenting regionally specific data for South China (Wang et al. 2008), West Virginia (Joy et al. 2006), British Columbia (Anderson and VanLaerhoven 1996), Alberta (Hobischak et al. 2006), Saskatchewan (Sharanowski et al. 2008), New Brunswick (Michaud and Moreau 2011), Germany (Schroeder et al. 2003), and the Hawaiian intertidal zone (Davis and Goff 2000).

Sun and shade can variably affect decomposition rates and insect succession. In an experimental study of 18 pig cadavers in a Saskatchewan prairie ecozone, pigs were placed on the surface in either sun or shade, in one of three seasons (Sharanowski et al. 2008). Only in spring did sun-exposed pigs decompose faster. Those pigs in sun had more associated insect species. This may be due to factors other than temperature, according to a West Virginia study (Joy et al. 2006), which demonstrated that the faster insect development under sun occurs regardless of any temperature advantage.

Recent experimental studies in England demonstrate the critical importance of insects across terrestrial decomposition environments (Bachmann and Simmons 2010; Simmons et al. 2010a; Simmons et al. 2010b). In colder climates insects may dominate as well, but only during the warmer months, about half of the year (Sorg and Wren 2011).

Cadaver Decomposition Island

The presence of a decomposing body in terrestrial settings will stain and chemically alter the soil under and (in the case of buried remains) around it; the modified soil is termed “gravesoil” (Carter et al. 2007). The chemical changes include an increase of pH, nitrogen, and phosphorus (Benninger et al. 2008), as well as ammonia, calcium, carbon, magnesium, and potassium (Tibbett and Carter 2008). The best indicator of decomposition is currently thought to be nitrogen, measured as ninhydrin-reactive nitrogen, NRN (Carter 2008; Van Belle 2009). NRN detection in laboratory testing can be useful in identifying areas where a body may have decomposed.

The interface between the decomposing body and the underlying soil, called the "cadaver decomposition island," (CDI) can be an important chemical and visual indicator of the previous presence of a decomposing body (Tibbett and Carter 2008). Tibbett and Carter cite Bornemissza's 1957 (Australian study using guinea pigs) description of the "black putrefaction and butyric fermentation" stages, which create the greatest soil changes:

> Fluid seepage contributes to development of a crust of hair, plant matter, and the uppermost soil layer beneath the body. During fermentation, the decomposition fluids released from the body, along with the waste products excreted by the insects feeding on the body, combine to kill the plants beneath the body and the soil fauna, altering the microenvironment. (p. 113)

In a British Columbia pig decomposition study, Anderson and VanLaerhoven (1996) document that the vegetation under and extending out from the body up to 30 cm was killed, as well as most of the arthropod species living in the associated soil. The most affected layer of soil directly under the body is termed the "carrion zone." In one of the earliest pig decomposition studies, done in South Carolina in summer, Payne (1965) notes that during the dry decomposition stages, the surrounding insect fauna began to mix with the carrion fauna under the body.

Mammalian and Avian Scavenging

Understanding typical scavenger "signatures" and sequences may help in assessing relative postmortem interval (Haglund 1997), as well as locating missing skeletal elements that have been scattered (Haglund 1997b). One recent case study involved indoor scavenging by two large pet dogs in a heated home after the owner died, likely about a month earlier during winter (Steadman and Worne 2007). No soft tissue and very few parts of the skeleton remained (calvaria, two long bone shafts, and some bone shaft splinters). There was no evidence of decomposition or insect infestation. Carson and colleagues present a case series of black bear scavenged cases from New Mexico (Carson 2000), which are compared to earlier published studies of canid and polar bear-scavenged cases (Haglund 1997a; Merbs 1997). They conclude that bears may be more likely to modify the axillary skeleton. In another study of zoo animals, carnivore canines and carnassial teeth were measured and documented in order to identify the probable species responsible for a bite marks (Murmann et al. 2006). A similar study from the ecology literature includes a calculation of bite force across species (Christiansen and Wroe 2007).

Several experimental scavenging studies using pig cadavers have focused on scatter patterns. Kjorlien and colleagues studied scatter patterns for 24 clothed and unclothed pig cadavers in Alberta, 12 in woodland settings and 12 in open grassland (Kjorlien et al. 2009). They report that unclothed and grassland pigs were scavenged earlier. Scattering trajectories followed game trails and tended to go away from human activity.

In a similar Australian study, O'Brien and colleagues placed pig cadavers with controls in four environmental contexts and observed scavenging using 24-hour trail cameras (O'Brien et al. 2010). They documented variation among sites, seasons, and hour of the day involving only small and medium sized carnivores. Avian scavengers were more common during the day and mammals at night. The intensity of scavenging for these taxa was higher for the bloat stage and later stages, compared to the fresh stage.

Now-classic studies of canid scavenging patterns still inform forensic case analyses (Haglund et al., 1989; Haglund, 1991, 1997; Willey and Snyder, 1989. Willey and Snyder studied wolves provisioned with road-kill deer, and they offer caveats about the limits of experimental forensic studies of decomposition in which scavenger access is controlled. They note that scavenging can disrupt decomposition processes and insect involvement with bodies, interfering with estimates of time since death. Scavenging can speed insect succession, while reducing the number of insects. With scavenger movement of body parts there is more exposure to sunlight and drying, which inhibits insect activity. And with scavenger meat consumption, insect eggs and larvae are likewise removed.

It is important to note that scavenging, e.g., by canids, can occur at any stage of decomposition, and can include both consumption of flesh and modification of bone. Similar to sequences reported in non-human studies (Blumenschine 1986; Willey and Snyder 1989), canids begin with the face (Haglund's phase 0) and then ventral cavities (Haglund's phase 1). Although there have been and continue to be studies of the bone modification that results from scavenging (Pickering et al. 2012; Sorg and Bonnichsen 1989), there has been scant attention to identifying defleshing without bone modification, and specifically the problem of discriminating decomposition from defleshing in the forensic context.

Estimating the Postmortem Interval

Two important forensic projects have attempted to correlate the condition of the remains in terms of soft tissue lost to decomposition and ADD (Megyesi et al. 2005; Vass et al. 1992, 2002; Vass 2010). In 1992, Vass and colleagues monitored seven bodies at a decomposition study facility in eastern Tennessee over four seasons as they decomposed and became skeletal, testing for volatile fatty acids (VFAs) released into the soil. He converted the postmortem interval to ADD based on the maximum and minimum daily temperature at the site, tracking the association of ADD with decomposition changes. The bodies became skeletonized by 1285 ADD $\pm$ 110. The ADD total needed for skeletonization in this study has been used as a baseline for more recent studies. In an Indiana study, 68 forensic cases with known postmortem intervals were given a "Total Body Score" (TBS), which was associated with their postmortem interval, then calibrated against the Vass study's total of 1285 ADD, producing a linear regression (Megyesi et al. 2005). The TBS assesses the decomposition phase for different body regions and assigns an ordinal score; the scores for different regions are summed. The resulting regression model produces an estimated ADD, which can be converted to PMI using local temperature data. It is important to note that none of these bodies were known to be significantly scavenged, but lost their soft tissue through decomposition (Nawrocki personal communication).

In a similar 2010 study, Vass scored the body with a single estimate of "percent decomposed," calibrated to scales suggested for warmer and cooler temperature regimes. Bodies at the eastern Tennessee research facility were used to develop and test the formulas, including both buried and surface remains. In order to apply these formulas, it is necessary to have the humidity reading. The formula provides an ADD, which must be converted to PMI using local site temperatures or weather station data. As with the Megyesi study, the formulas are for bodies in which flesh is removed by insects and decomposition processes, but not by mammalian and avian scavenging.

Michaud and Moreau (2011) have also developed a regression formula relating decomposition stages and ADD in New Brunswick, which should be tested with our Northern New England data in the future. As with Megyesi et al. (2005) and Vass (2010) this model assumes no scavenging is involved. Michaud and Moreau have developed their model using pig surrogates placed on boards covered with soil. They placed the pigs only during the May to September time frame.

Rationale for Research

Because heat is needed for chemical and bacterial decomposition, and because moisture also affects its speed and quality, we can expect there to be regional differences in taphonomic patterns due primarily to ecology, climate and weather. These regional differences need to be documented and better understood in order to improve the taphonomic foundations of forensic death investigations.

Although heat (quantified in as ADD) holds promise as a master variable that drives the decomposition processes in experimental settings (Megyesi et al. 2005; Simmons 2008; Vass 2010), it is important to develop local datasets and models that can be tested using real cases, and identify local taphonomic variables that may interrupt or influence these basic processes.

Attention needs to be focused on a conformation of methods and nomenclature to describe variation along a set of common taphonomic parameters, so that we can stitch together a more complete, multivariate taphonomic data field based on ecological variables. This includes the following examples: common ways to express access to heat, such as accumulated degree days (ADD); humidity, such as accumulated relative humidity days (AHD); and decomposition progress, such as total body score (TBS). It also includes standardizing methods for scene investigation and data collection, particularly (a) logging heat at the scene, (b) calibration with weather station data, (c) collecting data about solar access (e.g., percent of tree canopy and evergreen versus deciduous vegetation shading the body), (d) noting scavenger access (e.g., identifying the local scavenger guild and signatures of their presence), (e) describing seasonal and sub-seasonal patterns, (f) noting variation in the timing of metamorphosis of local sarcosaprophagous insects, and (g) noting variation in local plant distribution and biology.

The best approach to understanding regional patterns is through a combined case series and controlled observation experimental research design. The use of pig cadavers provides an opportunity to do controlled observation of the temperature, humidity and associated condition of remains through time. Key regional taphonomic factors, such as temperature, tree canopy and scavenging can be varied. Utilizing a detailed forensic case series analysis, patterns seen in forensic cases with a known postmortem interval can be structurally replicated. Whereas this approach, combined with a very limited number of pig cadavers, does not allow statistical conclusions, it does allow formation of a preliminary model of decomposition processes in this region. Building on the model presented in this study, hypotheses can be generated and tested in the future. It is important to use standard concepts and terminology, and describe the local ecology, focusing on key regional information: in Northern New England, that includes data about climate and weather, forest canopy, ground vegetation, and evidence for the involvement of avian and mammalian scavengers: an eco-environmental profile.

The ultimate purpose of this project is to develop Northern New England regional forensic standards for taphonomic data collection and interpretation. These approaches should be applicable by forensic anthropologists, as well as law enforcement evidence response personnel and medical examiner personnel in the recovery, examination, and interpretation of human skeletal remains. Such regional models are necessary in order to correctly interpret taphonomic (postmortem) change, estimate time since death, interpret cadaver dog searches, and discriminate taphonomic change from trauma.

Chapter 2 Methods

Project Goals and Objectives

The overall goal of this project was to develop regional standards for taphonomic data collection and interpretation to be used by forensic anthropologists in the recovery, examination, and interpretation of human skeletal remains in outdoor scenes, particularly focusing on postmortem interval. Located in northern New England, the project utilized forensic case data from Maine and New Hampshire in addition to experimental decomposition studies of pig cadavers placed at two outdoor research sites in Maine. The first objective was to analyze existing data from forensic anthropology outdoor cases, including associated cadaver dog case data, using only those cases with known postmortem intervals under two years, in order to develop one or more taphonomic models of decomposition that would be climatologically and contextually appropriate for the region. The second objective was to explore those models using pig (*Sus scrofa)* cadavers, providing an actualistic validity test using controlled observation methods.

Three other objectives were established to reach the project goal. First, the project would create an ARC-GIS dataset to archive and link climatologic, biogeographic and case-specific data. Second, an interdisciplinary team of advisors would work with project staff in order to analyze project data and develop standards for outdoor scene data collection. Third, the project leadership would analyze the taphonomic variables associated with the case data and the experimental pig cadaver studies, including both the environmental context and the condition of the remains.

Methodological Approach

This project used a two-stage approach, case series analysis and controlled naturalistic observation, to develop a preliminary regional taphonomy model. In the case series we looked for the presence/absence of common taphonomic features. Because these were forensic cases investigated over a 30-year timeframe, these data had not been systematically collected across cases, although some patterns were revealed, such as scavenging. But the case series data did not lend itself to quantitative analysis of other variables. We used the controlled observation of the pig cadavers as a way to validate what we could document as present in the case series. In this sense, each pig is also a case study, mirroring modal environmental characteristics of the cases. Observing the pig cadavers through time also allows us to document temporal taphonomic sequences via cameras, temperature/humidity data loggers, and direct inspection at intervals. We utilized known environmental data of the region to contextualize these observations.

This method, and the preliminary model derived from the observations, permits us to incorporate environmental data for the region, and link it to the presence of several taphonomic features we have observed in individual forensic cases and pig cases. But, with the exception of bone modification and scatter from scavenging, it does not allow us to say what the prevalence of these features is likely to be in forensic cases for the region. The observations, taken together, form a reasonable model, which is grounded by documentation in case files and field notes and known environmental data, and which can now be tested.

Adjustments to the Initial Plan

Expanded Visual Data

A decision was made early on to utilize videographic and photographic documentation to a greater degree than originally planned. Both still and video cameras were used to monitor the pig cadavers. In addition, field research activities and workshops were largely documented on video/audio tape. The additional video documentation provides a richer project data archive, and has enabled production of a short documentary on scavenging in winter as well as the indexing of thousands of images for retrieval of visual data related to key variables.

Limiting the Scope to Terrestrial Contexts

Although the proposal had included aquatic taphonomic contexts, two barriers caused us to focus only on terrestrial scenes. First, our budget and experimental design included only nine pig cadavers, and we decided we could not cover both aquatic and terrestrial contexts adequately. Second, Dr. John Dearborn, longtime consultant on Maine forensic aquatic cases, passed away early in the project time span. We did not have a replacement.

Expanding the Emphasis on Scavenging

We documented that the vast majority of forensic anthropology cases in Maine involve scavenging, which significantly impacts defleshing, disarticulation, and decomposition. It produces scattering and loss of bone elements. Defleshing by scavengers can be mistaken for defleshing from decomposition and insect activity. Due to this key role scavengers play, we received permission for a change of scope to incorporate a greater focus on scavenging, and do the related changes to the research design.

Reduction of Entomology Role

We had planned a key role for entomology throughout the pig cadaver experiments. However, he withdrew after approximately six months due to his schedule and the difficulty shipping specimens across state lines. We utilized the early project data, and continued to collect general data related to insect infestation, but were not able to do species identifications after that.

Changing the Location of Experiments

We had proposed placing the pig cadavers at the Maine Criminal Justice Academy. Unfortunately, it turned out that the land at the Academy is private, leased by the state. This meant a fairly long and complex process would have been needed to expand the explicit uses of the land in the Academy's lease for our experimental research purposes, and this process would have had an uncertain outcome. Two wildlife consultants offered private land that was immediately available, and we accepted both of their offers. Having two locations gave us more flexibility in environmental variables. Both locations offered security commensurate with the Academy land. We did use the Academy's facilities for one of our interdisciplinary workshops.

Reducing the Primacy of the Case Series Data.

Long postmortem interval bias. Cases in the series were biased in terms of postmortem interval, including more cases with longer intervals, and fewer cases that matched the timeframe of the actualistic research portion of the project, which was only two years.

Non-systematic taphonomic data documentation. As we began scrutiny of the forensic cases that were candidates for the study dataset, it became clear that the case data from these original scenes were limited as a foundation for a fine-grained regional taphonomy model. First, many of the cases lacked GPS point data, particularly the earlier cases; and point data was important in order to fully utilize the Geographic Information System we developed. Second, we had to add subcategories in order to segregate cases that had experienced scavenging (the majority) from those that had not, and restrict inclusion to those with postmortem intervals under 24 months in order to compare with the experimental pig cadavers' postmortem intervals. The result was to reduce the analytical sample sizes considerably. We attempted to expand the sample by exploring outdoor scene medical examiner cases that were not referred to the forensic anthropologist, but found the taphonomic data were not sufficient. As a result, we used the case series combined with environmental data about the region to outline major components that should be included in a taphonomic model (such as the presence of scavenging and forested environments), and utilized the pig cadaver data to develop more detail around these components.

No Cost Extension

The project proposal was for three years. We received permission for a fourth (no cost extension) year to provide time to complete the analysis of the images and extend the observations on the pig cadavers.

Interdisciplinary Team and Collaborating Organizations

We utilized a wide range of experts throughout the project (Table 1) to advise and guide us. We selected a group of specialties for inclusion throughout the project; these included botany, entomology, geology, wildlife biology, cadaver K-9 specialist, and medical examiner. Also included in significant roles were pedology, organic chemistry, state police, and archaeology. Most of the consultations with individual experts and all three of the annual interdisciplinary workshops were videotaped.

In June 2009, August 2010, and June 2011 we organized interdisciplinary taphonomy workshops, which included visits to the research sites, for the purpose of expert input and guidance. (See Chapter 6 for a list of presentations.)

The project benefitted from the collaboration with a number of institutions and organizations, detailed in Table 2, below. Both the Maine Criminal Justice Academy and the University of Maine hosted workshop activities. The Maine State Police Evidence Response Team and Office of Chief Medical Examiner collaborated with us by utilizing results of the project for new cases, and by considering changes to their protocols for outdoor scenes based on our findings.

During the 2009 workshop the primary interdisciplinary team members were introduced to the project, the proposed pig experiment locations, and each other. Each discipline representative provided presentations about the potential contribution of their discipline to the project. We discussed and received recommendations for sample collection, and began to consider the importance of scavenger issues for the research design.

During the 2010 workshop, we discussed in depth the major issues that had emerged with scavenging, and the advisability of changing the initially proposed location for the pig cadaver experiment. Local experts in wildlife behavior gave presentations. We visited a longtime coyote bait site, as well as a taxidermy bone disposal area in order to consider scavenging effects and how to address these in the research design.

We incorporated and piloted our proposed data collection protocols into three simulated and real scene investigations. We organized a non-criminal outdoor scene investigation of remains found in a medical examiner case in May 2010, which included pilot participation of botany, archaeology, medical examiner and pedology functions to attempt to locate scattered remains. In July 2010, we incorporated proposed protocols into a simulated scavenger scatter scene, with pilot participation of botany, archaeology, pedology, and mapping. For this all-day exercise, we collected and mapped remains from a coyote bait site that had been in use for 20 years. Volunteers and equipment from the Maine State Wardens Service and Maine State Police Evidence Response Team, as well as students and faculty from the University of Maine participated. In April and May 2011 we incorporated modified protocols into another two major outdoor scene investigations. In each of these, we qualitatively explored the feasibility for expanding environmental data collection in routine forensic scene investigations. Practical issues such as the amount of expertise and equipment needed at the scene, the time needed, and the benefits were considered.

At the 2011 workshop, we discussed preliminary results from the first three seasons of the pig cadaver experiments, as well as our experience in applying proposed protocols. We visited the two field sites. Team members and students who had been working more closely with the project gave presentations about their research; presentations were videotaped at the workshop site and at the field sites.

Table 1. Interdisciplinary team members and consultants

University of Maine

- Ann Dieffenbacher-Krall, botanist, University of Maine, Climate Change Institute
- Alice R. Kelley, geologist, University of Maine, Climate Change Institute
- Andrea Nurse, botanist, University of Maine, Climate Change Institute
- Christa Schwintzer, botanist, University of Maine, School of Biology and Ecology
- Ivan Fernandez, soil scientist, University of Maine, Department of Plant, Soil and Environmental Sciences and Climate Change Institute
- Harold Borns, geologist, University of Maine, Climate Change Institute
- John Dearborn, marine biologist, University of Maine, School of Marine Sciences (participated during the first two years, now deceased)
- William Parker, geographic information systems technician, University of Maine, Margaret Chase Smith Policy Center
- Brian Robinson, archaeologist, University of Maine, Dept. of Anthropology

State of Maine Government

- Edward David, medical examiner and certified cadaver K9 trainer, Maine State Office of Chief Medical Examiner
- Herbert Leighton, detective Maine State Police Criminal Investigation and team leader, Maine State Police Evidence Response Team
- Scott R. Bryant, detective Maine State Police Criminal Investigation and trainer and senior team member Maine State Police Evidence Response Team
- Deborah Palman, wildlife biologist and certified cadaver K9 trainer, Maine Warden Service (retired)
- Gerald Lavigne, wildlife management consultant, Maine Warden Service (retired)

Other Consultants

- Robert Howe, Maine guide and owner of Pine Ridge Lodge, Bingham, Maine
- Andrew Collar, project videographer, Digital Spirit, Inc., Waterville, Maine
- William D. Haglund, anthropologist, Seattle, WA
- Gail Anderson, entomologist, Simon Fraser University, School of Criminology
- Kim Fallon, death investigator, New Hampshire Office of Chief Medical Examiner
- John Burger, entomologist, University of New Hampshire, Dept. of Zoology

Table 2. Collaborating institutions and organizations

- Maine State Department of Public Safety, particularly the Maine State Police Evidence Response Team, of which the PI/PD is a cooperating member, and the State Police Crime Laboratory
    - PI/PD works with these organizations on all forensic anthropology cases for the state. The project GIS system has been used to produce site maps, environmental profiles and estimates of postmortem interval for new and cold cases. The protocol developed by the project has been presented to the Evidence Response Team and they are utilizing it currently.
- Maine State Office of Chief Medical Examiner
    - PI/PD is the state's forensic anthropologist, consulting on all outdoor scene cases involving skeletal and many involving decomposed remains. The project GIS system has been used to produce site maps, environmental profiles and estimates of postmortem interval for both new and cold cases.
- New Hampshire Office of Chief Medical Examiner
    - PI/PD is the state's forensic anthropologist, mainly for all cases involving skeletal remains. The project GIS system is now available to produce site maps, environmental profiles and estimates of postmortem interval for both new and cold cases. The office has expressed interest in incorporating project information and suggested protocols into their investigator training.
- Maine Criminal Justice Academy
    - They have collaborated by providing classroom space for the 2009 workshop.
- Maine Warden Service
    - The mapping team participated in the bone yard mapping exercise where mapping, photographing, documenting, and taking soil samples. Two recently retired Warden Specialists participated on the interdisciplinary team.
- American Greenlands Restoration Incorporated
    - This company owns the land for the un-caged pig cohort. The owner, John Sferazo, has given permission to use this gated wildlife preserve for the experimental pig cadaver activities.
- Pine Grove Lodge, Pleasant Ridge Plt, Maine
    - This is the headquarters for the un-caged pig cohort. The owner, Robert Howe, manages the land on which the pigs are placed.
- Dunlatr Farm, Orneville, Maine
    - This is the headquarters for the caged pig cohort. The owner, Gerald Lavigne, owns the land on which the pigs are placed.

Building the Regional Taphonomy Information System

Linking Environmental, Case Series and Experimental Data

Our first goal was to analyze existing forensic case data by creating a Regional Taphonomy GIS to which we linked scene environmental data, nearest weather station temperature and humidity data, climate data, case series data, and data from the pig experiments (Table 3 and Appendices D, and F).

During Project Year 1, we built a Regional Taphonomy Geographic Information System using Arc-GIS for Maine and New Hampshire environmental data; Vermont was added in the third year. By inputting a GPS location, the Regional Taphonomy GIS can produce for that site an environmental profile documenting topography, elevation, annual precipitation, annual temperatures, soil properties, land use, land vegetation cover, and leaf on/leaf off aerial views of any site in the three states. We have built a tool to link to weather station data (or experiment site data logger data) and calculate accumulated degree days. (For examples of these tools, see ACCESS files associated with this report. The Arc-GIS layers are, for the most part, publicly available datasets, and are not provided with this report.)

The system can be adjusted to link to optional case series and experimental research site layers: case information about body condition and scene details, as well as photographic images for cases in the series or specific pig sites.

In order to build the GIS system we included four overall types of data: (1) topographic, soils, and land cover map spatial data from the U.S. Geological Survey; (2) temperature and rainfall spatial data from the U.S. Weather Service, which we linked to weather station locations in our GIS; (3) leaf on and leaf off aerial orthophotographs from the Maine, New Hampshire, and Vermont Geographic Information System offices, as well as aerial orthophotos for Maine from the National Resources Conservation Service; and (4) forensic anthropology case data for northern New England, and (5) data from our research site locations. Connected with the environmental layers of the GIS, we have three externally linked databases.

- Pig Cadaver Sites Temperature and Humidity Database for total of nine pigs
- Weather Station Database for Maine, New Hampshire and Vermont for stations that included at least 30 years relatively uninterrupted data
- Forensic Case Series Database for Maine and New Hampshire

We also created several digital taphonomy tools using the Regional Taphonomy GIS, the externally linked databases, and ACCESS 2007. These tools are used to calculate Accumulated Degree Days (ADD) and Accumulated Humidity Days from data loggers at the pig cadaver sites or at a scene, and produce environmental profiles:

- ADD and AHD Calculator Tool uses temperature and humidity data from data loggers on scene or from the nearest weather station for a specific PMI date range
    - *ADD and AHD for Specific PMI*: ADD is calculated by averaging the daily high and low temperatures that are above freezing for each day in the Postmortem Interval (PMI), and then adding the daily averages together (excluding the Found day). AHD is similarly calculated by

averaging the daily high and low relative humidity and adding the daily averages together.

    - *Weather Station Data*: Tools can be customized to use public weather station data from any state or region where they are available. It can also use data from data logger placed at the scene. All temperatures are in Celsius.
- Environmental Profile Tool uses GIS location and GIS environmental data layers to generate a map and a list of environmental characteristics for a specific site.

Table 3. Components of the northern New England regional forensic taphonomy system

Dimensions of Regional Approach	Data Sources	Computer Applications & Tools
• Biogeography & topography • Climate and weather • Human density and built environment • Identified key regional variables affecting access to heat, moisture, insects, and scavenging	• GIS layers include topography, vegetation, temperature and rainfall, soil type and chemistry, orthophotos leaf on/off • Forensic case reports of body condition and scene context; photographs from scene and morgue • Temperature and humidity data since 1980 for all weather stations in region • Temperature and humidity data from data loggers at experimental sites • Images from trail cameras and investigator cameras at experimental research sites • Environmental context data at experimental research sites (plants, canopy, fauna, insects geology) • Body condition data for pig cadavers at regular site visits	Computer applications • Arc-GIS, v.9 • MS Excel 2007 • MS ACCESS 2007 • Adobe Design Bridge image tagging Project generated tools • ADD and AHD Calculator for data logger data • ADD and AHD Calculator for weather station data • Map generator linking sites and nearest weather stations • Environmental profile generator for sites

ADD and Accumulated Humidity Calculator for Data Logger Input

The first ACCESS tool, the pig site ADD and accumulated humidity calculator, uses downloaded temperature and humidity data obtained from data loggers at each pig site to calculate ADDs and AHDs for each pig at different points in time (Appendix D). This tool would also be appropriate for calculating ADD and AHD from data loggers placed at a forensic scene.

Temperature data for the each of the pig cadaver experimental sites are recorded by an Omega OM-CP-RHTEMP1000 temperature and relative humidity (RH) data logger at each site. They began data recording on their date of placement. During site visits, the data from each pig site are extracted by connecting the data recorder to a laptop computer through the Omega software. These data are then converted in Excel through functions and formulas into a format used in the Access Database temperature tables, which are then used by the ADD calculator tool.

The tool opens to a form that displays date input boxes and command buttons that help the user navigate the information downloaded from the recorders. The form automatically calculates the ADD for a given postmortem Interval (PMI) or date range for each site.

Map and Environmental Profile Generator

Additionally, with the click of a button, the tool displays a map of the location of the pig cadavers on an aerial photo and GIS environmental profile of the location with information such as elevation, soil characteristics, and forest cover (Appendix D).

ADD and Accumulated Humidity Calculator for Weather Station Data Input

Similarly, there is a tool that can calculate an ADD and accumulated humidity for a forensic site using GPS coordinates and data from the nearest weather station data (Appendix D). The NOAA weather station data for Maine and New Hampshire for the past twenty years have been incorporated into the system. The weather stations records are from the National Oceanic and Atmospheric Association (NOAA) database. The process starts by going to the NOAA website and ordering the data for all the weather stations in each state. The station location along with ID and name are provided with the temperature data so the stations can be accurately added to the map for that state.

The data are downloaded in comma delimited text format and then converted into Excel to the format used in the Access database. The tool currently allows a user to open a form to calculate ADD for a given PMI period going back to 1/1/1980. The database needs to be updated regularly with the most current available temperature data.

Pig Cadaver Actualistic Taphonomic Experiments

Development of Sample Stratification

Background data from the forensic case series informed our pig experiment sample design (Table 4). We initially found that most (about 75-80%) of outdoor Maine and New Hampshire (terrestrial) forensic anthropology cases were modified (defleshed, chewed, and/or scattered) by scavengers. We decided early in the project to focus close attention on scavenging as an important regional taphonomic characteristic, and set up our experimental design to explore the taphonomic implications, especially for PMI estimation. It was for this reason that six of nine pig cadavers were placed in scavenger-accessible locations.

Remains in most outdoor cases in our series were found in or near woods, which is logical for our region due to the high percent of forest cover. Most land in Maine (about 90%) and New Hampshire (84%) is forested. Most forested forensic settings were mixed deciduous hardwood and evergreen, with a minority evergreen-only. We put seven of nine pig cadavers in woods, and two in a *field* area near the edge of the woods.

Remains were also found relatively close (15-30 m) to access roads. These are frequently unpaved woods roads, yet traversable by motor vehicle. Thus, we limited our experimental contexts to this sort of modal forensic environment: in or near woods, within 15-30 m of an access road.

Very few northern New England forensic cases are buried; if they were initially buried, they were very likely going to be unearthed by mammalian scavengers before discovery. Thus, we decided to place all of the pig cadavers on the surface.

The cases in the case series exhibited great seasonal variation in the condition of the remains and known taphonomic histories. Case discoveries almost never occurred in winter, but spring cases included those that had overwintered. From mid-October to mid-April the average temperature is likely to be below 4°C., which inhibits necrophagous insects. This contributes to the higher rate of scavenging. With warmer temperatures mammalian and insect scavengers are in competition. For this reason, we divided the sample deaths into three seasons.

Our wildlife and hunting experts emphasized the importance of scent and familiarity as influences on coyote and bear scavenging. Larger scavengers are at the top of the regional food chain, and they generally have a choice about what food to seek. Expert experiences with bear and coyote baiting suggested, for example, that the odor of a pig (or human) cadaver or human clothing would be strange and might be something to be initially avoided. Cadaver K-9s are readily taught to discriminate between human and non-human decomposition scent. So decomposing humans would smell different to scavenger from the (decomposing) animals normally found in their environment. Adding human clothing to the pig cadavers would, by extension, be another way we could improve the validity of using the pig as a human forensic model. For this reason all of the scavenger-accessible pigs were clothed.

In summary, the pigs were placed in modal terrestrial forensic contexts and comparable environmental contexts (Table 4, 5): in the woods, approximately 15-30 m from the unpaved access roads. We placed nine pig cadavers, six accessible to scavengers and three protected from scavengers by cages. We varied the temperature that results from tree canopy (seven with canopy presence and two with no canopy), and whether the canopy is evergreen (four) or mixed evergreen-deciduous (three). Lastly we varied the season. Five were placed in late fall after the arrival of cold temperatures, and four were placed in warm weather, two in late spring, and two in late summer.

This design replicates the variation in the case series and emphasizes the key components of the model: scavenging/non-scavenging; woods/field; warm/cold temperature at death. Because the late-fall (cold) cohort was put in place after frost, it also models early decomposition in the absence of necrophagous insects, including the effects of freezing, thawing, and snow cover. Control sites within about 30 m were identified with similar environmental characteristics.

It is important to note that the design does not attempt to provide a statistical sample, but rather controlled observations replicating the model's primary phenomena or environmental characteristics, seen in the case series. For example, most of the cases in the series are located in the woods and have been scavenged; this is reflected in our experimental sample with seven pigs in woods and two in the field, and six pigs unprotected from scavenging and three protected.

Research Sites

Locality I was used for the caged pigs. It is a primarily wooded area with some *field* areas of several acres at the back of a private farm in Orneville, Maine. The caged pig sites were located approximately 60 m apart. Locality II was used for the un-caged pigs. It is a private, gated wildlife preserve in Concord Township, Maine, approximately 2000 acres in size, and away from human habitation. The un-caged pig sites were located approximately .4 to 1.6 km (25 to 1.0 mile) apart.

Just prior to placement, an assessment was done of the site and the control site. Tree canopy coverage was recorded for all of the sites using a standard convex spherical densiometer (a small mirror with grid lines: count number of cells reflecting open sky versus canopy to get percent cover). A very basic geological assessment was done for all sites.

Table 4. Pig placements based on analysis of forensic case series variation

	Un-forested *Field* with No Canopy N=2	Forested with 70-80% Canopy N=7	
		Evergreen Canopy N=4	Mixed Deciduous-Evergreen Canopy N=3
Caged to Prevent Scavenging N=3	1 pig Nov 2010	1 pig Nov 2010	1 pig May 2011
Un-caged to Allow Scavenging N=6	1 pig Sept 2011	2 pigs Oct 2010 1 pig Sept 2011	1 pig Oct 2010 1 pig May 2011

Table 5. Example of GIS environmental profiles: comparison of representative pig experimental sites at Locality 1, with cages to prevent scavenging and Locality 2, un-caged, with scavenger access

Location	Locality 1 Site N	Locality 1 Site M	Locality 2 Field	Locality 2 Woods
Elevation	480	480	310	310
Forest Cover	Evergreen forest	Mixed forest	Open Space	Mixed forest
Soil pH	5.5	5.5	4.8	4.8
Soil Clay	7.5%	7.5%	7%	7%
Soil Sand	70.4%	70.4%	70.8%	70.8%
Soil Silt	22.1%	22.1%	22.2%	22.2%
Soil Hydrology Group	B	B	C	C

The following description of one site's plants and soils provides an example of the botanical assessment: **Site 3, Lot O**; 45^0 00.141'N; 69^0 52.388'W, Elevation: 512 ft asl. Site 3 is a well-drained, 6m x 6m plot with zero slope. On the south, the site sits at the foot of a steep, 2.4 m (8-foot) bank of gravel and cobbled till. Tree cover is exclusively white pine (*Pinus strobus*-12 stems with DBH ranging from 5 to 16 cm). Canopy height is approximately 11 m and average percent cover measured by the densitometer is 23% with no leaf (needle) fall inside the releve. Canopy of beech and poplar (*Populus grandidentata* and *Populus tremuloides*) line the NE border with 50% leaf fall. A single stem of white pine makes up the sub-canopy layer. The shrub layer contains less than 5% white pine plus a single stem of balsam fir. Herbaceous vegetation consists of less than 1% coverage of balsam fir, *Potentilla* species, red oak, and red maple plus single stems of strawberry (*Fragaria* species) and ash (*Fraxinus americana*). Litter depth of less than ½ inch consists of white pine needles and the leaves of red maple, red oak, and both species of poplar. The A horizon consists of less than 1/2 inch of loose organic material over sand and gravel till.

The following is an example of a geological assessment, including features particularly relevant for taphonomy: soil porosity, topography and slope.

O Site Properties and qualities
* Slope: 0 to 8 percent
* Depth to restrictive feature: More than 200 cm
* Drainage class: Somewhat excessively drained
* Capacity of the most limiting layer to transmit water
* Depth to water table: More than 200 cm
* Frequency of flooding: None
* Frequency of ponding: None
* Available water capacity: Very low (about 1 cm)

Typical profile
* 0 to 3 cm: Loamy sand
* 3 to 60 cm: Loamy sand
* 60 to150 cm: Coarse sand

Landform: Glaciofluvial materials

Pig Cadavers

Nine pigs were purchased wholesale from a local abattoir. They were humanely killed with a gunshot to the head on the same morning they were placed at each site. Weights ranged from 62 to 104 kg. Prior to slaughter they were certified by a licensed veterinarian to be disease-free.

Weather Stations and Cameras

Weather stations track hourly temperature and humidity, and trail cameras document visual changes in the body and scavenger modification. All pig cadaver sites were equipped weather station devices (Omega OM-CP-RHTEMP1000) (Figure 1) to monitor hourly changes in temperature and humidity. They each had trail cameras equipped with heat and motion sensors (Moultrie GameSpy Infrared Digital Trail Camera). At each site, one camera was set to record stills and the other short videos. Cameras had auxiliary solar panels (Figure 2) to keep batteries charged, although those under heavier canopy require battery changes (Figure 3).

Figure 1. Temperature and humidity data logger and white plastic, ventilatd housing and solar shield

Figure 2. Solar panel to power one of the cameras

Figure 3. Changing the batteries in one of the trail cameras

Site Visits

During regular site visits, data were downloaded from the weather stations and cameras, equipment batteries are changed, changes in body condition and environments are noted, and specimens are collected. Visits to the pig sites occurred approximately once a week during active decomposition, and about once a month otherwise, unless the snow was too deep. Disturbance and/or scattering of the remains at the un-caged sites were described at each visit. Bone modification and decomposition progress was photographed. During the first several warm months of 2011, insect specimens were taken and sent for analysis to the entomologist. Following that period, associated insects were noted and photographed. During the visits, still photographs were done using portable waterproof Olympus Stylus Tough 8010 14 MP digital cameras.

Professional videography (Figure 4) was done approximately once every quarter: during annual workshops, on the occasion of any visit by members of the interdisciplinary team, or on the occasion of new pig placements. In September 2011 we mapped and collected all of the remains from the N site un-caged pig, and closed out that site. We also mapped, but did not collect, the remains from the O site un-caged pig using a total station.

Figure 4. Videographic documentation of the condition of the remains

Data Processing

Images from all of the cameras, an estimated 40,000 images, were tagged in Adobe Design Bridge to index taphonomic characteristics seen in the images. Image tags allow speedy sorting of thousands of images in order to locate weather events, certain dates or seasons, certain types of scavengers, particular scavenger behaviors, decomposition phases of the body, and defleshing of the body. For example, these images were mined to produce a Decomposition Atlas for each scavenger-protected pig (see Appendix A, B, and C), in order to provide a visual document of defleshing by insects and decomposition processes.

Since scavenging and hard winters are so characteristic of this region, we focused our first analysis on the scavenger-access pigs that had overwintered. Analysis of the camera images for these three pigs revealed heavy scavenging by small and medium scavengers through the winter, as well as surprising variation in the scavenger guild involvement for each pig. We produced a short video (provided with this report via DVD or digital file) to document these new findings.

Metadata from the pig experiments and images were used to create flat file (Excel 2007) datasets to analyze progression of predicted ADD and actual ADD against PMI for individual pigs. In order to study regional differences in how decomposition progresses, particularly over Maine winters, we examined the pigs via their images at 100-ADD benchmarks and at PMI benchmarks and tracked their condition using Total Body Scores (Megyesi 2005).

Un-caged Pigs Accessible to Scavengers

Six un-caged pigs simulate bodies exposed outdoors with scavenger access. The un-caged pigs were placed in sites similar to most forensic cases, within about 15 m of an unpaged access road and out of site from the road. They were located at least .8 to 1.6 km (.5 mile to 1.0 mile) away from each other. Each un-caged pig was dressed in donated clothing, to more closely resemble the smell of humans (Figure 5).

Figure 5. Modal un-caged pig site approximately 15 m from an unpaved access road and out of site from the road. This pig is located in a mixed evergreen-deciduous forest. Trail cameras can be seen attached to two trees (seen in this image at the back center and to the right). The white ventilated housing seen to the right is fashioned from a one-gallon milk carton. It protects the temperature and humidity data logger from direct sun and precipitation, has ventilation slits on all sides, and is positioned on a pole at about 1.7 m from the ground as dictated for standard weather stations.

Caged Pigs Without Scavenger Access

Caged pigs simulate bodies exposed outdoors without scavenger involvement. The three caged pigs were housed in 6ft x 8ft x 8ft cages, constructed of 2"x4" lumber and 1"x1" wire mesh fencing (Figure 6). Two-level electric fencing deters disturbance by larger scavengers such as bears, which could damage the cages. Three-foot-wide quarter-inch wire mesh skirts were placed on the ground around each caged-pig to prevent burrowing scavengers from accessing the cage interior.

The caged decomposition study pigs are located geologically in the Boyd Lake Quadrangle of Maine in a well-drained area with little slope. Pig 522 (weight 84 kg) was placed in a mowed Field with nearly 100% grass and no canopy on November 5, 2010. Pig 521 (weight 64 kg) was placed in an evergreen (balsam fir and spruce overstory) woods environment with 95% canopy cover and no shrub or herb layers on November 5, 2010. Pigs 522 and 521 were put at their sites on the same day, varying the amount of canopy cover. Pig 166 (weight 87 kg) was placed in a deciduous woods environment on May 8, 2011 with about 80% canopy cover.

Figure 6. Example of a caged pig located in a mixed deciduous-evergreen woods. Cage has a 3-foot skirt surrounding the cage to prevent access by burrowing animals. Two cameras are present, one inside and one outside the cage. An electrical fence surrounds the site. The white temperature and humidity data logger housing is at the top right of this image.

Forensic Case Series

Outdoor forensic cases from Maine and New Hampshire with a known PMI were considered for inclusion in the case series. We initially selected cases that had been referred to the forensic anthropologist. Since that dataset tended to have few cases with a very short postmortem interval, we decided to include non-anthropology medical examiner cases found outdoors. Since the maximum postmortem interval in the pig experiments was two years, we focused only on cases up to 24 months PMI. Since the pig experiments included only surface depositions, we focused only on cases found in surface deposits, excluding water environments. This includes a few cases that were initially in a shallow grave, but which were removed by scavengers. Images and reports from these cases were scanned into a digital data reference set. Using either point data coordinates or a centroid township[1] GPS location, cases were processed into the Taphonomy GIS to enable mapping, production of an environmental profile, and calculation of ADD.

Cases were organized into simple flat-file Excel datasets, including links to representative images from the scene and the exam. Basic case variables included date of death, season of death, date found, location, GPS, environmental data from scene, predicted ADD, calculated ADD, calculated AHD, decomposition phase, and body region decomposition features, TBS from Megyesi et al. 2005, scavenging evidence, and insect evidence.

The case series dataset was then sorted to locate subsets of more homogeneous cases with which to explore certain issues. For example, we mapped cases into the Taphonomy GIS to consider the process of selecting the "nearest weather station" from which to calculate ADD (Figure 7).

We also selected a subset of unscavenged cases with a PMI under one year for which to assess "Total Body Score" (Megyesi et al. 2005) and their predicted ADD value, then compare to the actual ADD. The total unscavenged sample size is 20.

[1] Note that counties are very large in northern New England, differing from other regions. Thus township polygons provide the smallest spatial GIS location beyond a single point.

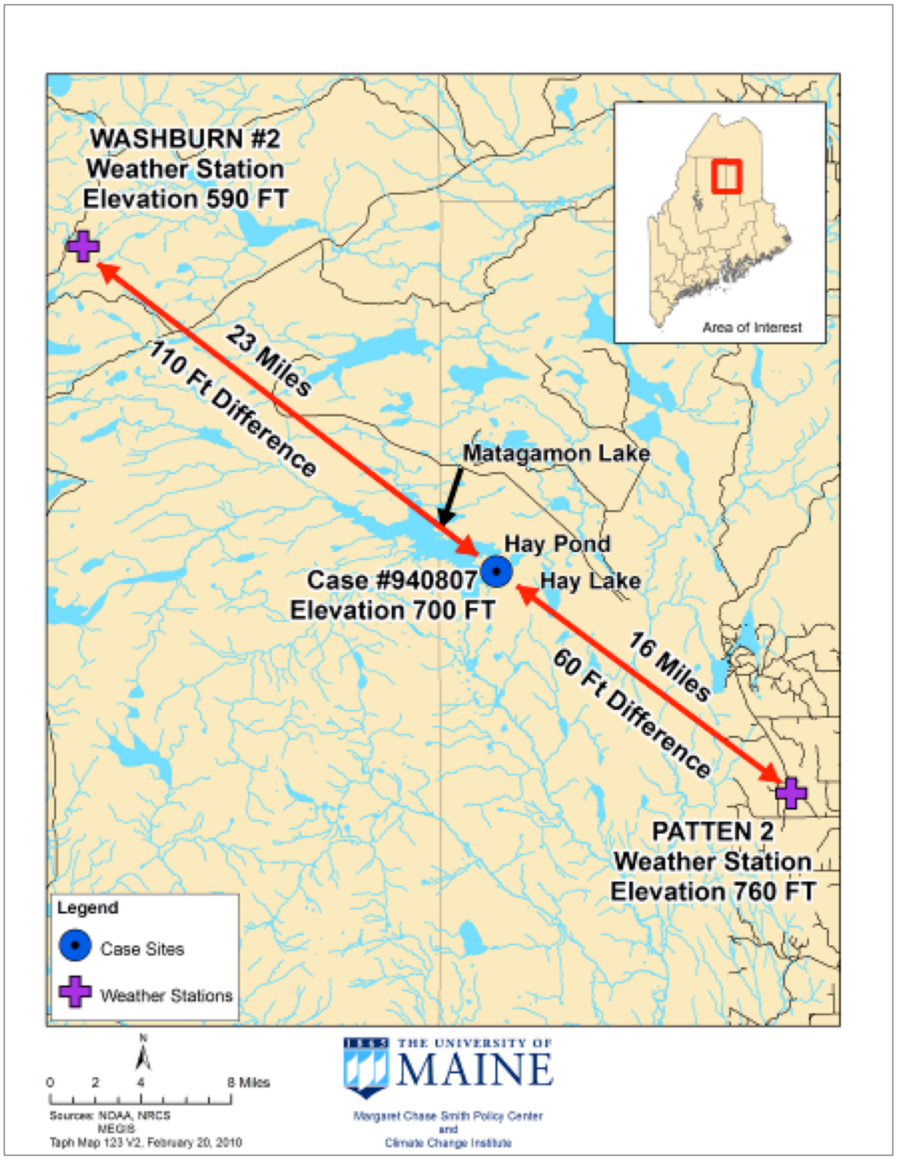

Figure 7. Considering which weather station to choose for calculating ADD for case #940807 (center of map), with the need to choose an environmentally similar site.

Chapter 3 Results

This project addresses the need for taphonomic models by focusing on outdoor terrestrial forensic contexts in northern New England (Maine, New Hampshire and Vermont), within the temperate broadleaf and mixed forest biome, and including the two Level II Ecosystems: the Atlantic Highlands and the Mixed Wood Plains (ftp://ftp.epa.gov/wed/ecoregions/cec_na/NA_LEVEL_II.pdf). The climate for this region is characterized as temperate/humid continental climate under the Koppen-Geiger System (Peel et al. 2007).

Characteristics of a Regional Forensic Taphonomy Model for Northern New England

This project has successfully demonstrated the steps and tools that are helpful for the ongoing development of a regional forensic taphonomy model for northern New England, which can be used as an example by other regions. Northern New England's climate (cold temperatures, moderate humidity and precipitation, characteristic freeze/thaw patterns in fall and spring, heavy snow cover for several consecutive months each year), biogeography (heavy, pervasive forests of evergreen, deciduous, or mixed tree taxa, high scavenger density, large and variable scavenger guild, moderate topographic contrasts, and low human population density constitute a characteristic environmental profile that strongly affects postmortem (taphonomic) processes. These key variables should be considered in interpreting body condition and context in outdoor forensic cases.

The northern New England regional taphonomy structure includes three central components: (a) a regional geographic information system (GIS), (b) a regional forensic case series dataset; and (c) experimental data from actualistic studies exploring regional patterns. The GIS contains environmental data layers combined with computer-assisted links to weather station datasets throughout the region (including experimental site weather station). The data forensic cases includes digitized written reports and photo-documentation of the GPS location, the condition of the body and the environmental context of the scene taken from both the scene and the laboratory.

Regional Geographic Information System Links Environmental and Case Data

Geographic Information System software (in this case, Arc-GIS) was used to aggregate and link environmental and orthophoto data specific to the northern New England to the forensic cases and to the experimental "cases." Environmental and weather station data were readily available in state and federal public datasets. Arc-GIS is readily available although not widely used by forensic anthropologists. It is relatively expensive to maintain software updates and technical expertise to utilize this system. Nevertheless, we have found this system quite helpful for multi-case analysis and for new case investigations.

Environmental data layers (e.g., rainfall, soil types, etc.) and aerial orthophoto layers were combined with layers locating forensic cases from the area[2], location of weather stations, as well as experimental site locations. We are using the GIS system to create basic environmental profiles for forensic case locations, and to produce maps and orthophotographic images (leaf on and leaf off) of the specific area and/or scene.

The environmental profile and orthophoto and map generating capability is useful for new forensic cases, particularly for planning the resources needed to process a scene. The system has been used for a handful of new cases, usually at the request of the State Police. The Maine State Police and officials from other states are also requesting these environmental data for non-taphonomic investigations as well, when climatic or spatial variables for a particular area or time period are needed, e.g., to confirm information taken from an informant.[3]

The GIS is useful to identify regional environmental patterns, compare forensic cases in terms of their environmental characteristics, compare cases in the forensic case series to experimental cases, compare weather stations to select the best one, archive and build a regional case series, and archive experimental data. The weather station data (hourly temperature and humidity values for three states going back to 1980) takes a great deal of disk space, so we have associated it with a separate ACCESS database tool, rather than link it directly into Arc-GIS.

Historic Forensic Case Series Data in the GIS

In building the forensic case series, we found that cases older than ten years tended not to have a point GPS location, so the system has not been used as much as anticipated with the case series analysis. We are still working out the best format to store historic case data, given the frequent missing values. Availability of scene data, body condition descriptions, and photographs tended not to be systematic across all cases. We are working with the Maine State Police Evidence Response Team and the Offices of Chief Medical Examiner in Maine and New Hampshire to construct more homogeneous scene processing protocols, so the data on new cases going forward are more complete.

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[2] Ideally, linked cases should utilize a GPS point location. This improves the accuracy of the environmental profile and the topography. If point data are not available, the system can use a centroid point in a township or other polygon.

[3] Currently our project staff has the only working version, and we are called when there is a need for data. However, if a northern New England jurisdiction has a license for ARC-GIS, and for Microsoft ACCESS, they could utilize our GIS system on their computer, if they have adequate disk storage for weather station data. Demonstration datasets from our original case series and experimental series data could also be provided.

Constructing Forensic Case Data Protocols

The interdisciplinary team workshops allowed us to do a sort-of tabletop test of some of the proposed protocols, e.g., for botany and entomology, with the result that these had to be simplified. For example, we found that some sort of botanical assessment was helpful to consider site access to heat and moisture due to vegetation, including canopy cover from trees, and to appreciate the variable morphology of the cadaver decomposition islands (CDIs). Being able to identify the CDIs, including those that no longer have remains present, can be very helpful in reconstructing the scene and making decisions about where to search for remains.

The full insect data collection protocol was very expensive and logistically difficult. The minority of cases that require forensic entomology (when enhanced PMI information is critical for a criminal or civil matter) makes it unrealistic to routinely arrange for insect identifications for all cases with insect activity in our region. These samples must be sent out of state. The insects are difficult to keep alive and the materials difficult to ship. We do record basic characteristics of insect activity (e.g., presence/absence of live larvae or pupae from flies vs. beetles), and we collect specimens of all life stages at the scene and at autopsy, should additional analysis be called for. It is ultimately the medical examiner's decision whether a full forensic entomology assessment will be done, since that involves additional resources from that office's budget.

The most helpful aspect of geological assessment was identifying the slope of the land and its impact on scavenger scatter patterns as well as soil porosity. The GIS environmental profile was also helpful in providing data on the porosity of the soil and its potential impact on scent hydrology for the cadaver K-9s.

When we are doing a search for scattered remains, we also focus on locating the original deposition site, which generally requires more extensive processing. Cadaver dogs and human searchers both help with this.[4] We included photographs of decomposition islands and a discussion of the importance of slope in our training sessions for the Evidence Response Team.

Forensic Case Series Construction

The Importance of Scavenging

We found that most of the northern New England forensic anthropology cases had been scavenged: 75-80% in all forensic anthropology cases and 69% in the study sample with known PMI under two years. That is, they showed significant bone modification and scattering of remains, and there was often substantial loss of bone elements.[5] Even those cases that had initially been buried did not stay buried,

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[4] We use only certified cadaver dog teams and follow the principles of scent cone interpretation related to vegetation and topography used for air scent K-9s (Rebmann et al. 2002).

[5] It is important to note that Maine and New Hampshire have well-trained search teams and certified K-9s that assist in cases with scattered remains. We often search as much as .5 mile radius with K-9s and human shoulder-to-shoulder search teams. Thus, the frequency of missing elements is due to scavenging and not deficient searches. The Maine model of wilderness search management involves

due to scavenger activity, unless the graves were several feet deep. Buried cases were not included in our case series.

Unless scavenging damage and element loss was minimal, these forensic cases could not appropriately be used to assess decomposition phase or do ADD to PMI estimates using currently accepted methods. For example, in some cases only a few heavily modified skeletal elements might be recovered. In other cases, remains had been defleshed, but temperatures had not been warm enough for decomposition or insect infestation.

As discussed later, we realized that methods such as the one proposed by Megyesi et al. (2005), in which one assesses a Total Body Score (TBS) in order to estimate the postmortem interval (PMI), would not work for scavenged cases. We checked with those investigators and confirmed that the Megyesi et al. case series did not include cases that were known to be scavenged (Stephen Nawrocki, personal communication). Thus, it became clear that it is important to discriminate between cases defleshed by scavengers and those defleshed due to decomposition and insect activity. A preliminary suggested protocol for this is presented later in this chapter.

Limitations of Forensic Case Series

The environmental documentation in reports and scene photographs were uneven across forensic cases in the series, and many of the earlier cases lacked point coordinates for precise GIS mapping. Although most of the cases had thorough descriptions of the condition of the remains, the descriptions were not symmetrical enough to treat as a large, quantifiable dataset, as we had expected. Combined with the loss of TBS data for many body regions resulting due to scavenger behavior, these missing data constituted a significant barrier to the type of quantitative analysis we had originally envisioned. In particular we had only a small, unscavenged sample (N=20) to compare to the caged pig sites, and these had had too much missing context data.

Decomposition and ADD in Northern New England: Does the Megyesi et al. Model Work?

One of the critical issues in northern New England regional taphonomy is whether variables such as long, snowy winters, hard freezes, multiple freeze-thaws and the lack of insects might interfere with using PMI estimation methods developed in other regions (e.g., Megyesi et al. 2005). After clarifying that, in order to apply this method to our case series, we needed to remove cases that had been scavenged, were incomplete, or were deposited in water, we filtered our case series to select only non-scavenged, terrestrial cases with a known PMI (n=20 cases from Maine and New Hampshire combined). We used the known PMI, selected the

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a very systematic, inter-agency mobilization of trained responders. Mapping specialists from the Wardens Service generally lead such searches, and an interdisciplinary team of cadaver K-9 teams, certified evidence response teams, anthropology, and police generally participate. The search is managed by an incident command structure, using fairly sophisticated digital systems to track the effort and develop strategies.

nearest weather station, and calculated the ADD for each case. Photographs and case reports were used to score the TBS for each, and the TBS was inserted into Megyesi et al.'s regression model. The model worked reasonably well to predict an ADD range that encompassed the actual ADD, but only in 12 of 20 cases (Table 6). In seven cases the estimated an ADD range was higher than the actual ADD, at one standard error; but in range at 95%, i.e., by doubling the standard error. More research will be needed to explore whether the cold climate systematically shifts the TBS to higher scores, compared to Indiana cases. One, a partly mummified hanging, yielded an estimate that was too low, even at 95%. All of the cases in which scores were too high died in warm months and were discovered prior to winter. Occult scavenger defleshing cannot be ruled out at this time, which would have made the TBS artificially high.

Table 6. Application of Megyesi et al. (2005) model to northern New England cases, estimates at 1 standard of error.

Case #	PMI	TBS	Est. ADD	Actual ADD	Lower at 1 s.e.	Upper at 1 s.e.	In 1 s.e. Range?
1980-1056	91	27	1854	1758	1465.84	2242.16	yes
1983-921	22	23	738	276	349.84	1126.16	no-high
1984-1047	573	31	5395	5675	5006.84	5783.16	yes
1984-766	37	25	1148	753	759.84	1536.16	no-high
1985-850	115	28	2388	1645	1999.84	2776.16	no-high
1988-652	20	21	492	407	103.84	880.16	yes
1988-896	41	22	600	599	211.84	988.16	yes
1989-980	183	28	2388	2440	1999.84	2776.16	yes
1992-781	43	22	600	693	211.84	988.16	yes
1993-691	235	16	210	2669	0.00	598.16	no-low
1994-760	31	24	916	377	527.84	1304.16	no-high
1995-603	406	31	5395	4352	5006.84	5783.16	no-high
2001-1198	39	25	1148	583	759.84	1536.16	no-high
2001-1218	62	24	916	1224	527.84	1304.16	yes
2005-1841	39	22	600	628	211.84	988.16	yes
2006-0205	210	27	1854	1699	1465.84	2242.16	yes
2006-1302	15	24	961	331	572.84	1349.16	no-high
2007-0446	8	4	70	41	0.00	458.16	yes
2009-0232	27	21	492	411	103.84	880.16	yes
2010-0374	50	17	244	512	0.00	632.16	yes

Caged Pig Decomposition

Among the caged pigs, we found both seasonal (cold versus warm weather) and microenvironmental (forest canopy versus open field) differences in decomposition rate. But these individual pig cases do not represent a statistical sample and the patterns would have to be tested in other studies before conclusions could be drawn regarding decomposition impacts. The canopy delayed decomposition in these particular specimens, including lower ADD and higher humidity. The open field sped decomposition for the overwintered cadaver by several days, but the sunlight contributed to mummification of some of the skin over the torso, which persisted through the rest of the year. In contrast, the overwintered cadaver under canopy became fully skeletal, with no mummification. As expected the two unscavenged, overwintered cadavers remained intact from November through early April, at which point they became infested with insects and rapidly decomposed.

Appendix A, B, and C document the process of decomposition for the three pigs protected from scavenging by a cage: two in the woods and one in a field. The atlases include pictures at 100-ADD benchmarks. Incorporated into the title of each image are the actual ADD and PMI.

Comparing Woods and Field at the Same PMI

Table 7 provides a comparison of the field and woods pigs at the same PMI. Both pigs were deposited on November 5, after temperatures were mostly below freezing. The ADD and AHD[6] demonstrate the difference the canopy makes in heat and moisture in these two cases. ADD and AHD were calculated with the ACCESS tool, using the data logger hourly recordings. The field site accumulates more heat and the woods site accumulates more moisture. Figure 8 compares the two sites at 100-ADD benchmarks, demonstrating the nearly constant humidity differential throughout the sequence.

We applied the ADD estimation method of Megyesi et al. (2005), and compared the predicted range to the actual ADD at 100-ADD benchmarks. Figures 9 and 10 illustrate the differences. Megyesi's technique performed better during the first 700-800 ADD, i.e. November through May for these two pig cadavers, but after that overestimated the ADD. The woods pig reached full skeletonization earlier than the field pig and drained the decomposition fluids earlier through the porous conifer needles on the forest floor. The field pig retained some desiccated hide, which shaded fully skeletal bones beneath. The field pig also retained some protection from sun due to the surrounding plant growth and had a less porous substrate. Nevertheless, the timing of their loss of soft tissue was quite similar. Figure 11

[6] AHD is used as an abbreviation for accumulated humidity days, a cumulative sum of the daily maximum and minimum relative humidity divided by two. In the ACCESS tool screen shots, the abbreviation RH is used for the same calculation.

compares Megyesi's TBS for all three caged pigs at 100-ADD benchmarks. The field pig never achieves as high a score as the other two.

Thus, the Megyesi model does not tend to work for the pig cadavers, two of which were deposited November 5 and overwintered, and one of which was deposited May 8. This model was developed for humans, not pigs, so this was not surprising. The fact that the pig head and trunk constitute such a large percent of the animal mass, and the limbs such a small percent, may be part of the problem. Also, the model is based on Vass's research on humans in Eastern Tennessee (1992) which found that volatile fatty acid (VFA) production ceased at 1285 ADD plus or minus 110. Megyesi did not test VFA production, but assumed it conformed to skeletonization as she describes in the TBS. She also does not consider humidity, as Vass does in his later 2010 model.

Despite the failure of the model in estimating the ADD, the TBS method seemed to work well as a consistent way to evaluate decomposition by body region.

Table 7. Comparison of ADD and AHD for the caged, fall-placement field and woods pigs, both placed November 5, 2010 after onset of colder weather.

Month	PMI (days)	Caged Field Pig ADD	Caged Field Pig AHD	Caged Woods1 Pig ADD	Caged Woods1 Pig AHD
Dec	31	120	2723	106	2654
Jan	62	162	5495	133	5395
Feb	93	179	8118	135	8053
Mar	121	211	10250	153	10181
Apr	152	337	12594	231	12568
May	182	591	14809	434	14772
Jun	213	1009	17261	831	17328
Jul	243	1567	19525	1329	19739
Aug	274	2243	21769	1943	22133
Sept	305	2869	24188	2510	24748
Oct	335	3337	26640	2935	27354
Nov	366	3633	29016	3198	29789

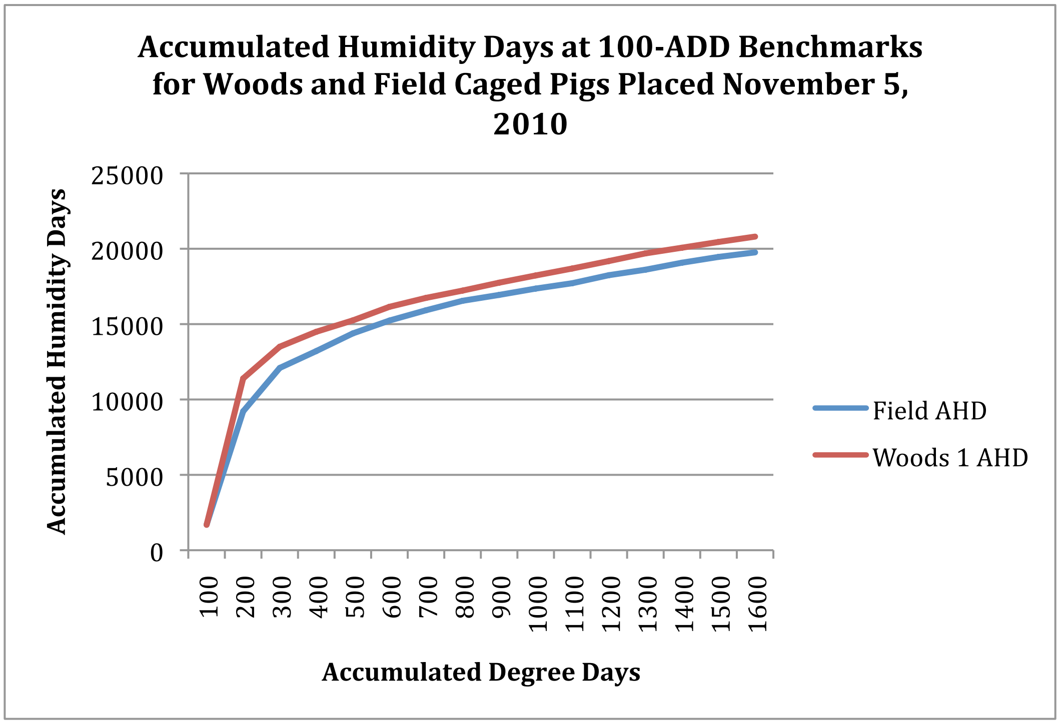
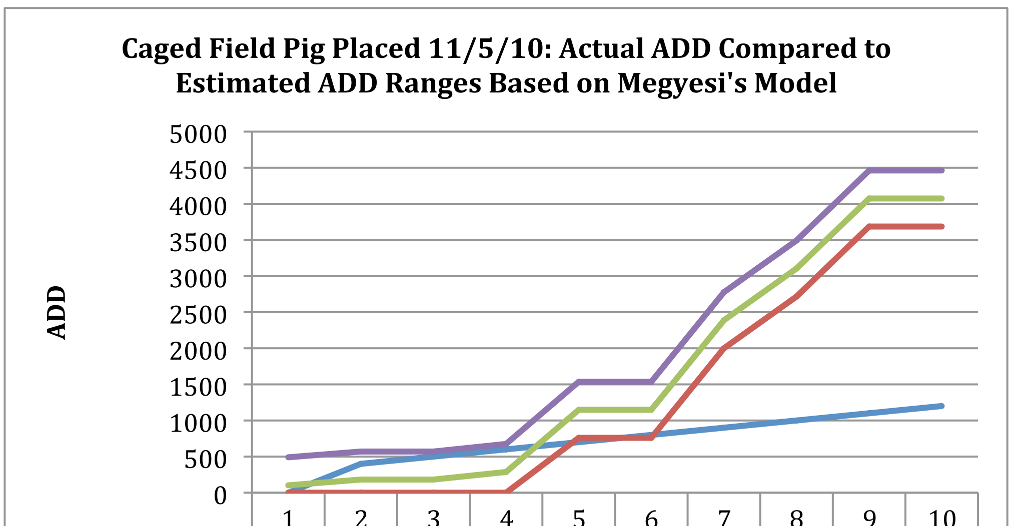
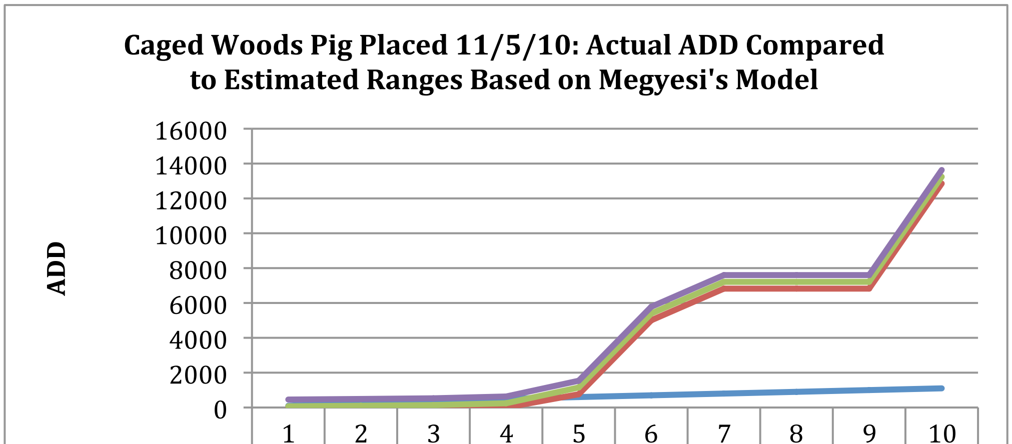


Figure 8. Comparing AHD of the caged field and woods pigs at 100-ADD benchmarks, both placed 11/5/2010



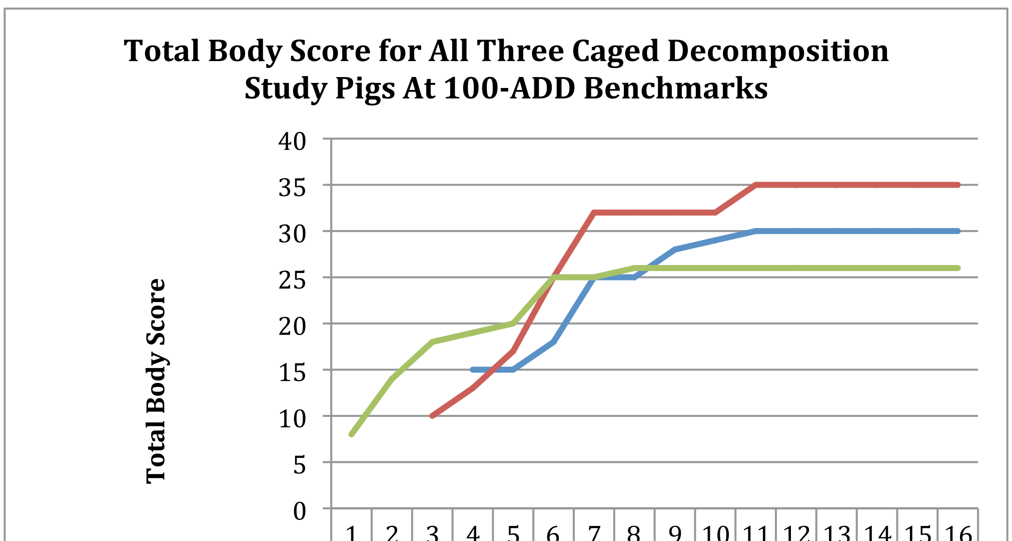
	1	2	3	4	5	6	7	8	9	10
Actual ADD	0	400	500	600	700	800	900	1000	1100	1200
Low Est.	0	0	0	0	760	760	2000	2716	3686	3686
Mean Est.	102	182	182	287	1148	1148	2388	3105	4074	4074
High Est.	490	570	570	675	1536	1536	2776	3493	4462	4462

Figure 9. Comparing actual ADD with estimated ranges based on Megyesi's model, caged woods pig placed 11/5/10. TBS observations are made at 100-ADD benchmarks. Data are missing due to snow cover prior to 400 ADD.



	1	2	3	4	5	6	7	8	9	10
Actual ADD	100	300	400	500	600	700	800	900	1000	1100
Low Est.	0	0	0	0	760	5007	6823	6823	6823	12855
Mean Est.	70	102	141	244	1148	5395	7211	7211	7211	13243
High Est.	458	490	529	633	1536	5783	7599	7599	7599	13632

Figure 10. Comparing actual ADD with estimated ranges based on Megyesi's model, caged field pig placed on 11/5/10.TBS observations are made at 100-ADD benchmarks. Data are missing due to snow cover at 200 ADD.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Fall Field TBS	10			15	15	18	25	25	28	29	30	30	30	30	30	30
Fall Woods TBS	4		10	13	17	25	32	32	32	32	35	35	35	35	35	35
Spring Woods TBS	8	14	18	19	20	25	25	26	26	26	26	26	26	26	26	26

Figure 11. Comparison of three caged pigs' decomposition progression using Megyesi's "Total Body Score" at 100-ADD benchmarks. Missing data is due to snow cover that prevents TBS assessment

Decomposition Islands

The decomposition island that develops under and immediately surrounding the decomposing corpse can be a helpful sign of the primary body location, even when scavengers remove the remains. Presence of the decomposition island tends to rule out defleshing by mammals. The persistence of the island, however, depends on the type of vegetation underneath. When a body decomposes in a location with vegetation ground cover, the plants are killed due to the acidity, viscous fluid cover, and high levels of nitrogen. As time goes by, latent seeds that had been in the soil, particularly those that can tolerate the altered chemistry, may germinate and grow; however, these are likely different species than what was there before. Not only will the island have different plants, but also the color of the foliage may be darker than surrounding plants due to the high nitrogen. Figures 12 and 13 show examples of the developing decomposition islands.

Conifer based decomposition islands and those in a meadow are fundamentally different. The conifer needle forest floor does not have latent seeds. The stained area regains its original color after about a year, and the island can no longer be recognized. The island in a field or meadow, however, shows a clearly delineated difference, which persists longer, even after the bones are gone. This is due to the new plant species in that area.

Figure 12. A decomposition island can barely be seen around this pig skeleton at 11 months PMI, because the leaf litter is primarily conifer needles, which are quite porous. The conifer canopy and pine needle forest floor limit herbaceous layer plant growth.

Figure 13. A decomposition island can be seen surrounding this pig skeleton at 6 months PMI. Meadow plants were killed by the decomposition chemistry and solar shielding of fluids, and there is no re-growth or replacement of the herbaceous layer.

Bodies that Overwinter

The chemical and histological effects of a long, cold winter on bodies are complex and extend beyond the scope of this project. But we did notice some taphonomic changes that may be particular to our region. The pigs that were deposited in early November, with the day temperature averaging 4°C or below, did not get infested with insects until late April (PMI about 5 months), when the temperature approached the 10°C or above. However, it was clear that some autolysis and putrefaction were going on during the winter months, despite the nearly constant freezing temperatures outside the body and the deep snow surrounding the body. Thus, overwintering of bodies may set the conditions for decomposition without scavenging by insects, mammals or birds. Figure 14 illustrates that as soon as the snow melts enough to expose the abdomen, one can see it is already quite discolored due to decomposition. And at the body-soil interface, there is substantial breakdown of abdominal tissues, including some hydrolysis; a descriptive term we have used informally is "edge-melt" (see Figure 15). Identification of the first wave of insects on overwintered bodies shows some species that are more common with a longer PMI, such as the latrine fly (*Themira putris).*

Figure 14. Pig at 5.25 months PMI shows abdominal discoloration, having overwintered with freezing temperatures throughout most of the PMI, and temperatures below 4 degrees C for almost all of it.

Figure 15. Pig at 5.5 months PMI after overwintering shows breakdown of abdominal tissues at the body/soil interface. Temperature this day is -3 degrees C., and it has just snowed.

Comparing Scavenged and Unscavenged Pig Cadavers

Scavenging can occur any time during the postmortem interval. Mammalian and avian scavengers can deflesh a body prior to insect infestation and consumption of soft tissues. Or it can occur after insects have consumed soft tissue. Some scavengers, such as vultures, feed during insect infestation.

Scavenging in Winter

This project has demonstrated the surprising findings that, during winter, mammalian and avian scavengers may completely deflesh a body under deep snow cover. Because temperatures are cold, these scavengers can consume flesh in a leisurely fashion, without having to compete with insects. The mammals more often feed at night, and the birds in the daylight.

Thus, freezing of the remains and heavy snow cover does not prevent scavenging. At two of three winter pig cadaver sites, when snow cover was approximately 1 m deep, raccoons were observed building snow tunnels to feed on the pig cadaver. When the tunnels were periodically covered by additional snowfall, both the raccoons and the bobcat were observed reopening the tunnels for feeding. At both sites two to three tunnels connected to a small cave enclosing the pig remains. The ravens used the tunnels during daylight.

At one site five raccoons worked together over a period of two months, feeding nightly, consuming all of the internal organs and meat. Other species utilized the raccoons' snow tunnels as well, including bobcat, fisher, raven, and turkey vulture. After 60 days, when snow melted, the pig cadaver was seen to be completely defleshed, with some bones (e.g., much of the spine) still articulated, and a small amount of scattering of skull and ribs; a small part of the hide remained.

At a second site, two raccoons were responsible for building a snow tunnel during late winter. This pig's head and shoulders had been defleshed by a pine marten and raccoons prior to the first snowfall. After the snow melted, the condition of the remains was similar to the first site mentioned: defleshed during 60 days of under-snow feeding, with minimal articulation, and a small amount scatter under 15 m.

Some cadavers may not be modified at all, even when scavengers have access to the body over many months. At one site an experimental pig cadaver placed in the woods in late October remained untouched for six months. In early May it became infested with insects and was simultaneously skeletonized. Substantial feeding was done by three turkey vultures, which also scattered the remains and the clothing.

Insect infestation can delay mammalian scavenging. In warmer seasons, there is competition until the skeletonization has occurred. Once a body is fully engaged with insect larvae, most mammalian scavengers avoid it until the soft tissue is gone, according to wildlife ecologists. There are exceptions to this, with animals that can tolerate decomposition bacteria such as the turkey vulture, or animals that like to consume insect larvae, such as bear or raven.

Four pig cadavers deposited in warm weather (spring or early fall deposition) underwent a fairly homogenous sequence of insect infestation, followed by vulture involvement, and then coyote scattering of the already-defleshed bones. Coyotes did not deflesh any of the pigs, despite their abundance in the area.

Scavenging with defleshing can potentially interrupt or even preclude decomposition and insect infestation. Scavenging potentially interferes with models of PMI estimation based on skeletonization by decomposition and insect feeding (Megyesi, 2005; Vass 2010). It becomes very important to discriminate scavenger-mediated defleshing from decomposition or insect-mediated soft tissue removal in forensic cases. If temperatures are below 4°C, there is no confusion. But in warmer temperatures some relatively occult scavenger defleshing and insect-involved decomposition may occur in parallel, generally including insect infestation and avian feeding.

A comparison of four pig cadavers <u>at about 600 ADD</u> (Figure 16-19) illustrates the variability. These four pigs were all placed on the ground within 15 days of each other in late fall, after cold weather had arrived.

- Figure 16. <u>Un-caged pig in woods with scavenger access: by 600 ADD there is no defleshing and no substantial insect infestation</u>. This un-caged pig cadaver remained intact for the entire winter and early spring, October 20 through May 2). At 600 ADD, it is still mostly intact, but has just began to have insect infestation and turkey vulture scavenging visits in late April, after temperatures had begun to warm. Both the vultures and the insects would ultimately be responsible for the defleshing, with <u>no bone chew marks</u>.
- Figure 17. <u>Un-caged pig in woods with scavenger access: by 600 ADD there has been full defleshing without insect infestation</u>. This un-caged pig was partly defleshed in the head and neck by a pine marten just prior to snow cover, with no insects involved, then the remainder of flesh had been removed by raccoons, raven, and bobcat via snow tunnels while under 1 m of snow, also without insect involvement (November 20 through May 11). At 597 ADD, the remains are almost fully skeletal with some vertebral cartilage, some movement out of anatomic position, and minimal scatter distances, but <u>almost no bone chew marks</u> except by the pine marten on the mandible.
- Figure 18. <u>Caged pig in a field with no scavenger access: by 600 ADD there is some bone exposure on the head and some visible hydrolysis at soil-body interface, with beginning insect infestation in both of those locations</u> (November 5 through May 8). At 600 ADD, the body is still mostly fleshed and fully articulated but early decomposition is underway.
- Figure 19. <u>Caged pig in the woods with no scavenger access: by 600 ADD most bones have been exposed by decomposition and insects</u> (November 5 through May 11). At 600 ADD, the body is mostly defleshed and partly articulated, with insect infestation beginning to subside.

Figure 16. Un-scavenged pig at M Site, at 600 ADD and 5.5 months PMI. Pig was placed on 10/20/10.

Figure 17. Scanvenged pig at O Site at 597 ADD and 5.75 months PMI. Pig was placed on 10/20/10.

Figure 18. Caged field pig at 600 ADD and 6 months PMI, placed on 11/5/10.

Figure 19. Caged woods pig at 600 ADD and 6.5 months PMI, placed on 11/5/10

Defleshing

Defleshing details of three un-caged pigs, all placed with scavenger access on the same day (10/20/10), within 1.6 km (1 mile) of each other in comparable wooded environments, demonstrates great variation. It is important to note, however, that these are non-canid patterns. Table 8 compares these three cadavers by documenting the date most bone is exposed (range six days and 134 ADD), the date the body is fully skeletonized (range 14 days). The first date of scavenging ranged from 10/29/10 to 4/26/11.

Table 8. Comparing dates of defleshing for three un-caged pigs that were all placed at their wooded sites, about 1.6 km (1mile) apart, on 10/20/10.

	Earliest Date Skeletonization Achieved		
Pig	**With Articulation**	**Without Articulation**	**ADD**
M Site	5/17/11	6/1/11	769
N Site	5/4/11	6/14/11	535
O Site	5/11/11	6/1/11	597

Table 9 provides provisional guidance in discriminating defleshing due to scavengers from skeletonization by insects and decomposition. This is very important in order to judge whether to utilize either the Megyesi et al. (2005) or Vass (2010) models for PMI estimation. Note that this guidance is based on our pig case studies; it has not been statistically tested.

Table 9. Guidelines for discriminating defleshing by scavengers from defleshing by insects and decomposition.

Defleshing by Decomposition and Insect Infestation

If the case is defleshed and has most of the following characteristics, the remains have probably been defleshed by decomposition and insect infestation, and not mammalian/avian scavenging. PMI assessment techniques of Megyesi et al. (2005) and Vass (2010) may be applied.

- The bones are within 5-10 cm of anatomical position, although they may be disarticulated due to the loss of ligaments and larval activity. Cartilage may be present or absent. Mummified skin may or may not be present.
- There is a decomposition island, especially in areas with grassy or other ground cover vegetation
- There may be a decomposition island surrounding the remains in areas with pine needles or deciduous leaves covering the ground. With some drying of the remains located on pine needles, that island may be less visible.
- There is evidence of a substantial insect infestation. Pupa cases may be found attached to the remains, in the soil around the remains, or in ground vegetation within a few feet.

Defleshing by Decomposition and Insect Infestation with Later Scavenger Involvement

If case is defleshed and has most of the following characteristics, the remains have probably been defleshed by decomposition and insect infestation, but were modified and scattered after that by mammalian and/or avian scavengers. If the head, most of the axial skeleton, and at least one side (right or left) of the appendicular skeletal elements can be located nearby and is nearly complete, PMI assessment techniques of Megyesi et al. (2005) and Vass (2010) may be applied.

- Mummified skin may or may not be present

- There is a decomposition island in areas with grassy vegetation
- There may be a moist decomposition island surrounding the remains in areas with pine needles or deciduous leaves covering the ground. With some drying out of the remains on pine needles, that island may not be visible.
- There is evidence of a substantial insect infestation. Pupa cases may be found attached to the remains, in the soil around the remains, or in ground vegetation within a few feet.
- The remains are out of anatomical position by more than 5-10 cm.
- There may be scattering of remains, missing elements, and/or chew marks on bones. Generally the bone surfaces have acquired a stain and chew marks expose unstained bone.

Defleshing by Small and Medium Scavengers Without Insect Involvement

If case is defleshed and has most of the following characteristics, especially in the spring, with temperatures still below 50 in the days, the remains have probably been defleshed by small or medium scavengers or omnivores (mammals and/or birds). PMI assessment techniques of Megyesi et al. (2005) and Vass (2010) should not be applied.

- The bones are still moist, and appear fresh, with fats present, with or without cartilage remaining
- The bones are mostly free of canid-type modification (pits, punctures, grooves, scalloping, channeling), although some small dentition marks or rodent incisor scrapes may be present
- Insects are (eggs, larvae, pupa cases) absent or scant
- There is no decomposition island
- Temperatures have been below 4°C recently and for a period of time
- The remains are fairly complete
- The remains may be partly out of anatomical position, beyond 5-10 cm, but scatter is generally less than 15 m.

Bone Modification and Scattering

Most of the bone modification involving pig cadavers was done by two species, porcupine and coyote. But these animals do not get involved until after the body is skeletal. The coyotes modify and scatter the bone, but the porcupines modify the bone at the site. Bone modification occurred after, rather than during, defleshing. In some cases we are able to link a particular bone element with visual images of its modification (see Figure 20 and very short video clip entitled "Porcupine Gnaws Bone") in Appendix G.

The defleshing seen in our pig studies was accomplished by pine marten, raccoons, bobcat, and raven, or by turkey vulture in collaboration with insect infestation. Warm weather defleshing occurred only by vultures and ravens. Due to the snow cover, we could not view the sequence of the cold weather defleshing, except that it began with the head and neck area.

Scavenger Guild: Succession Pattern Depends on Season

It is important to note that most (un-caged) pig cadavers were scavenged by more than one animal, although not at the same time. The group of animals in an area that is responsible for scavenging is termed the *scavenger guild*. Appendix E shows images of the scavenger guild.

There are three patterns of scavenging observed in our experimental research. The first succession cold weather scavengers, defleshing without insect involvement with very little bone modification were the marten, raccoon, bobcat, fisher, ermine, raven, crow, blue-jay, chickadee. The first succession warm weather scavengers, defleshing with insect involvement were the turkey vulture and the raven. The second succession bone modifying scavengers, which were active in both cold and warm weather after skeletonization, were the coyote and porcupine predominantly. In some cases we are able to document modification of a specific bone (see Figure 20 and Digital video clip file called Porcupine Gnaws Bone). We have also documented snow shoe hare gnawing on the bones, a surprising finding.

Figure 20. Pig femur from N Site, gnawed by the porcupine, as shown in the associated video clip in Appendix G.

Chapter 4 Conclusions

Research Goals and Impact

Our project research goal was to develop regionally specific standards for taphonomic data collection and interpretation in northern New England, to be used in the recovery and interpretation of human skeletal remains. The objectives included analysis of a 30-year outdoor forensic case series and the controlled observational studies of nine pig cadavers to illuminate key components of the model.

The research improves death investigation practices by improving the regionally appropriate evidence base for recovering human remains and interpreting their condition within the local context. There is an associated impact on policy and procedure decisions regarding body recovery and scene processing which particularly affect forensic anthropology, forensic pathology, and law enforcement. Critical variables in northern New England environments include a colder climate, more forested contexts, and a greater likelihood of scavenger modification of the remains. The taphonomic effects of these regional differences in temperature, humidity and scavenging influence the type of environmental data that should be collected at the scene, the conduct of searches, and the choice of methods to estimate postmortem interval.

The model we present is based on case study analysis of 58 forensic cases with known PMI under two years and controlled observations of nine pig cadaver cases. We selected a more qualitative, broad-based approach that would be appropriate for the proposed regional scope, one that explored several key taphonomic variables. Although the data and sample sizes do not allow statistical conclusions and inferences, the research did provide findings sufficient to propose a taphonomic model for the region. More research using the model is needed to in order to generate testable hypotheses and improve it.

Discussion of Findings

Northern New England Taphonomic Complex

We are proposing the term *Northern New England Taphonomic Complex* as a shorthand umbrella for the model, which includes the following key traits: (a) five to six months of average temperatures below 4°C with a corresponding absence of necrophagous insect activity; (b) forests covering more than 75-80% of the land, low population density in most of the area covered; (c) precipitation above 127 cm a year on average; and (d) a high level of scavenger exposure around 70-75% of cases. These factors influence the body's access to heat, moisture, and scavenging, and should be considered in interpreting body condition and context in outdoor forensic cases. The independent variables in the complex constitute macroenvironmental, regional characteristics that one can expect to find; these are associated with a cluster of dependent variables, i.e., taphonomic features more frequently seen in individual cases from that region (see Tables 10 and 11 for a summary of the model components).

In general, climate, weather, and ecological characteristics of one region are different from others, potentially altering the speed and details of decomposition in forensic cases, thus justifying the need for regionally specific taphonomic research. Table 12 illustrates differences in average temperature by month, comparing the three northern New England states in our study with Indiana and Tennessee during the period October 2010 through September 2011. Indiana and Tennessee were chosen because two commonly referenced models of decomposition have utilized cases and/or experimental data from these locations. Note, for example, that in only two months of the twelve does Tennessee's average temperature dip below 4°C, whereas it does so during six contiguous months in Maine and five in New Hampshire and Vermont. These important temperature differences signal a critical difference in the taphonomic context.

Another important factor is forest canopy cover and vegetation (Table 13). Maine has about 90% of its land covered with forest, New Hampshire 84% and Vermont 79%. Tennessee, in comparison, has only 55% and Indiana 20%. Forest, combined with low population density, also shown on this table, both contribute to longer body exposure times, and forest canopies increase microenvironmental moisture retention and reduce temperature. In Maine, for example, snow stays on the ground until mid-April in the woods, even when temperatures are above freezing generally and the snow has melted in the fields and residential areas.

In colder climates, such as exist in northern New England, there is a higher risk of freeze/thaw damage due to long, cold winters. This can particularly affect the integrity of the outer layer of soft tissue, potentially making it more vulnerable to cellular breakdown. For overwintered cases outdoors, there is increased exposure to water in the form of the overburden of snow and melting snow over several months, as well as reduced evaporation in more forested landscapes, increasing the possibility of adipocere formation. In northern New England, in inland areas and higher altitudes, there is often over 250 cm (100 inches) of snow each year, compared with just a few inches in Tennessee. Although decomposition speed is certainly reduced due to the slower accumulation of degree-days in colder climates, the elapsed time is nevertheless elongated, potentially increasing the exposure to other agents of chemical breakdown, scavenging, and resulting variations in decomposition progress.

Table 10. Northern New England Taphonomic Complex terrestrial model characteristics and associated taphonomic effects

Key Taphonomic Independent Variables	Macroenvironment and Climate Characteristics	Associated Taphonomic Impacts Observed in Case Studies
Cold Temperature	AVERAGE TEMPERATURES: Five to six months of average temperatures below 4 degrees C FOREST CANOPY: Forests covering more than 75-80% of the land	• Slows decomposition • Increased time needed to accumulate the same degree-days potentially exposes the body to more taphonomic effects • Reduces necrophagous insect activity
High Moisture	AVERAGE PRECIPITATION: Precipitation above 114-127 (45-50 inches) a year on average, including heavy snowfall	• Speeds decomposition • Snow maintains moisture surrounding body • Deep snow delays the discovery and recovery of remains
Seasonal Necrophagous Insects	INSECT ACTIVITY: Five to six months of average temperatures below 4 degrees C	• Reduces necrophagous insect activity • Increases opportunity for other scavengers
High density and opportunities for mammalian and avian scavengers	SCAVENGING: High prevalence of mammalian and avian scavenger exposure, around 70-75% of cases	• Can preclude or interrupt or preclude decomposition • Can deflesh with or without bone modification, which mimics skeletonization by decomposition • Can modify bone • Can disarticulate and scatter remains • Can obscure trauma • Can be active under snow using tunneling
Pervasive Forests	FOREST CANOPY: Forests covering more than 75-80% of the land: evergreen, deciduous or mixed	• Evergreen canopy maintains solar shield in winter; deciduous does not • Can reduce temperature • Can increase moisture, potentially speeding decomposition and/or enhancing the possibility of adipocere formation • Can increase scavenger density
Low Human Population Density	HUMAN POPULATION DENSITY: Low population density in most of the area covered	• Can reduce changes of body discovery and prolong PMI • Can increase land availability for scavengers

Table 11. Potential impacts of northern New England Taphonomic Complex on forensic anthropology protocols

- Plan for body recoveries which take scavenger scatter patterns into account: may need certified cadaver scent K9s in combination with human searchers
- Assess whether scavenging has been involved;
- Avoid using decomposition models that assume no scavenging if scavenging evidence is observed
- Consider possibility of occult scavenger defleshing (defleshing without bone modification) which can bias assessment of decomposition phase and PMI estimation or render PMI models inapplicable
- Adjust for the impact of canopy cover or other vegetation solar shields on temperature and moisture when using data from nearest weather station.
- Consider the type of canopy and leaf litter type when searching for a decomposition island; porous shields such as pine needles, tend to lose their stain much earlier
- Expect buried bodies not to stay buried due to high scavenger density

Compared to warmer and less seasonal biomes and ecologies, insect involvement in northern New England is greatly reduced or absent during about five to six months of the year, when temperatures stay below 4°C, as mentioned above. Additionally, the fluctuations into and out of insect-viable temperatures may further reduce initial infestation success for some species due to repeated egg or early instar mortality, though this has not been demonstrated. In other experimental studies (Simmons et al. 2010a), the speed of skeletonization from decomposition has been shown to be reduced without insect involvement.

The absence of insect infestation during cold months extends the exposure time of the soft tissue to scavengers, potentially increasing the probability mammalian and avian species will choose to feed. During the winter, some species, such as migrating turkey vultures or hibernating bears, may not be present, changing the scavenger guild dynamics. But there is year-round potential involvement of other omnivores (raccoons, rodents, members of the weasel (mustelid) family). Heavy forest canopy and undergrowth may reduce the involvement of some scavenging species that depend on eyesight rather than olfaction to find food, such as eagles.

A More Detailed Picture of Scavenging Revealed

Our research demonstrates important ways in which forensic cases in northern New England are characteristically different from other regions. One of the most important differences is the very high prevalence of scavenging found in our case series, affecting about 69% of forensic cases exposed outdoors. This high level was also validated in our pig cadaver experiments; all six of the un-caged pigs were scavenged. Observations from the case series and the experiments allow us to paint a much more fine-grained picture of forensic scavenging, particularly issues surrounding defleshing by mammalian and avian species.

Table 12. Twelve-month comparison of average temperature and average precipitation for northern New England, Tennessee, and Indiana, with temperatures below 40 highlighted.

	MEAN TEMPERATURE F.					
YEAR	MONTH	ME	NH	VT	IN	TN
2010	OCT	45	47	45	56	58
2010	NOV	**35**	**37**	**35**	43	50
2010	DEC	**24**	**23**	**21**	**24**	**32**
2011	JAN	**16**	**18**	**16**	**24**	**34**
2011	FEB	**16**	**20**	**18**	**31**	43
2011	MAR	**27**	**30**	**28**	42	50
2011	APR	**39**	43	42	53	61
2011	MAY	52	56	56	62	65
2011	JUN	61	63	63	72	76
2011	JUL	68	70	69	79	80
2011	AUG	65	67	66	73	78
2011	SEP	60	62	61	64	68

Source:
www.ncdc.noaa.gov/oa/climate/research/cag3/cag3.html

Table 13. Northern New England Taphonomic Complex characteristics, compared to Tennessee and Indiana

		NORTHERN NEW ENGLAND				
		ME	NH	VT	IN	TN
TEMPERATURE 2010-11	NO. OF MONTHS <40 DEGREES AVE.	6	5	5	3	2
FOREST COVER 2002	PERCENT OF LAND	90	84	79	20	55
POPULATION DENSITY 2010	# PER SQ.MI.	43	147	68	181	154
PRECIPITATION 2011	AVE. IN. PER YR.	50	56	56	55	62

Source: www.ncdc.noaa.gov/oa/climate/research/cag3/cag3.html
Source: US Census 2010
Source: www.nrs.fs.fed.us/pubs/gtr/gtr_nc241.pdf

Scavengers are able to locate food even when it is out of sight, by smell. And they successfully access food that is buried, whether in soil or snow, particularly in more porous contexts. Our forensic case experience tells us that shallow clandestine graves are usually unearthed by scavengers. And visual documentation of the experimental cases in this project demonstrate that multiple species not only locate food under snow, but they can consume it under the snow by building snow tunnels and snow caves.

Defleshing by scavengers can superficially mimic skeletonization by decomposition and insect activity to the untrained forensic investigator. Our pig case studies show that defleshing can occur in the absence of bone modification, particularly when flesh is removed by small to medium scavengers, such as pine marten, raccoons, and bobcat. Defleshing processes may even be associated with some insect activity, although the level of that activity is greatly reduced due to the reduced flesh. Defleshing can also occur without the hallmark scavenger signs of disarticulation and scatter.

It is important to differentiate scavenger defleshing from decomposition-induced skeletonization in estimating PMI. To do so requires careful scene processing: (a) documenting the extent of disturbance of anatomical order; (b) locating scattered remains up to .4 km (quarter mile) or more; (c) documenting the extent and pattern of scatter; (d) locating and investigating the decomposition island(s) and (e) insect remains if present (including those within the soil); and (f) investigating the ADD/PMI issues.

Bone modification, on the other hand, can be entirely unrelated to defleshing. It can occur after skeletonization, and, based on our research, involves coyotes, porcupines, and even snowshoe hares. There is a temptation to attribute defleshing responsibility to the animals that leave marks on the bones, but this can be an error.

Scavenging in northern New England, particularly during colder months, involves multiple species, termed the scavenger guild. Some of them leave marks on bone, but others do not. Furthermore, one cannot rule out decomposition skeletonization just on the basis of seeing that bones are gnawed or scattered. Bone modification may obscure information about decomposition, which might have provided clues about PMI. Data from our forensic case series demonstrates that all soft tissue, including cartilage and ligaments, is gone by 24 months, except in cases of extreme mummification by desiccation or adipocere formation.

All scavenger food sources are not created equal. Larger scavenger species, particularly those that can cover distance easier, have more of a choice and, according to the wildlife experts on our team, they stick with familiar foods. Deceased humans (or pigs) are not familiar carrion they encounter in the woods of northern New England. They smell different from their normal foods, even when decomposing.[7] And, if the human or pig is wearing clothing, that odor of unfamiliarity may be enhanced. Coyotes avoided entirely eating the soft tissue of the six pig cadavers in our study, in both wooded and field locations, although they availed themselves of the bones from all of the pigs after all the soft tissue was gone. It is important to note that coyotes prefer deer and snowshoe hare rather than carrion, and these two species have been plentiful in Maine and at our research sites. Vultures and ravens ate pig soft tissue in warmer months, even when insects were fully involved. There were many more species involved in eating soft tissue in winter, although not simultaneously: raccoons (night), bobcat (night), corvids -ravens, crows, blue jays- (dusk or day), and mustelids -marten, ermine, fisher- (day and night). We have seen the following four basic scavenging sequences (Table 14).

[7] We know this because air scent cadaver K9s can be readily trained to give alerts to human but not nonhuman decomposition scent.

Table 14. Four seasonal scavenging sequences/patterns

Scavenging Sequences Seen in Pig Case Studies	
Death in late fall/early winter (cold), version I	• Temperatures are below 4°C and there is no significant insect activity prior to winter • Defleshing by small to medium-sized mammals and corvids occurs during cold and snowy weather, with little scatter • Minimal insect activity occurs with the now-skeletal remains when temperatures warm • Involvement by coyotes (bone modification and scatter) and porcupines (bone modification without scatter) occurs at this point
Death in late fall/early winter (cold), version II	• Temperatures are below 4°C and there is no significant insect activity prior to winter • No scavenger involvement until after winter; cadaver stays "buried" under snow • Insects infest the remains as soon as the snow melts and the temperature rises. • Turkey vultures become involved concurrently with the insects and decomposition and skeletonization results • Involvement by coyotes (bone modification and scatter) and porcupines (bone modification without much scatter) occurs with skeletonization
Death in warm weather (spring or late summer/early fall)	• Temperatures are above 4°C and insects infest the remains right away • Concurrently turkey vultures and corvids become involved in defleshing and consumption of larvae, and decomposition and skeletonization result • Involvement by coyotes (bone modification and scatter) occurs with skeletonization • Other animals may be involved with scattered remains, but we would not have captured this activity on video
Death in all seasons, warm or cold	• A minority of (human) cases across all seasons have no apparent scavenger involvement. Their remains are in anatomical position, undisturbed, and there is no bone modification. This can occur with nude as well as clothed bodies.

It is very clear that more research needs to be done on scavenging. Indeed, more processing of the data collected in this project could be done to improve our understanding of how this critical issue impacts forensic findings. One of the most important findings from this project is that thorough defleshing can be done without significant bone modification, particularly by small and medium-sized scavengers when the body is relatively fresh, and particularly during the winter. We believe these cases that are scavenged can be erroneously misinterpreted as having decomposed, including cases that may have been used for data in the published literature. This potentially reduces the precision of models to estimating PMI that are based on decomposition processes. Scavenging can interrupt or preclude decomposition. It can also expose elements to more drying, which might slow decomposition processes. For all of these reasons it is critical to improve our ability to identify and better understand scavenging.

We have provided a draft protocol to identify defleshing by animals, even in the absence of bone modification. This approach requires additional data collection at the scene. Examining soil around and under the corpse, for example, has long been suggested as a part of forensic entomology processes, and can also help investigators identify cases that are less likely to have been defleshed. Carefully describing scatter patterns is also important, perhaps especially when there is very little scatter (such as might occur with smaller scavengers).

Experience with Case Series Data

Initial analysis of outdoor forensic anthropology cases with a known PMI revealed the presence of important regional characteristics that influence postmortem taphonomic processes. It revealed that most of the cases had been scavenged and were incomplete, and that most cases were found in or near woods. But the historical case series files had limitations, mainly sample size and missing data (from a research perspective, not an investigative perspective).

Using a forensic case series provides a potentially meaningful source of data with which to check the real-world validity of taphonomic models developed from the pig cadaver decomposition experiments. Our regional case files were not, however, homogeneous enough to become the foundation of quantitative regional models themselves. Data from actual forensic cases investigated by multiple investigators and jurisdictions can potentially be combined into datasets large enough for quantitative comparisons. But case heterogeneity, differences in investigator approaches, and small subcategory sample size (especially unscavenged remains) produced significant barriers to our initially proposed use of the northern New England case series. For example, there were only twenty cases in the series that were apparently unmodified by mammalian and avian scavengers with which we could check the validity of decomposition models.

In future research, we will be improving the protocols for processing these cases, and the systematic documentation of findings, emphasizing the variables and protocols illuminated in this report

Pig Cadaver Controlled Observations

Using an actualistic pig cadaver outdoor case series that controls for the involvement of scavengers, we have found that both regional factors, such as seasonal temperature fluctuation, and microenvironmental site differences, such as the amount of a forest canopy and the level of moisture retention, impact the rate and character of decomposition.

Two unscavenged caged pigs and one initially unscavenged un-caged pig provided insight into the effects of overwintering, which we feel needs more research. For example, the species of insects attracted as the snow melts indicates some decomposition may have occurred during the winter when temperatures were generally below freezing.

The scavenged un-caged pigs have allowed us to offer a hypothetical typology of scavenging sequences by season and by scavenger type. We were surprised that coyotes were not involved in defleshing, and that the patterns in winter were so different from those in spring and fall.

Scavenging presents a severe forensic challenge in our region. It impairs our ability to judge postmortem interval from body condition. For example, one (scavenged) body region may not be a good proxy for other body regions. If there is some soft tissue or cartilage attached, that at least places it in a two-year PMI window. But scavenging that involves bone modification can remove whatever flesh may be remaining, and may cause bone elements to weather more quickly and appear older than they are.

Some scavengers and necrophagous insects tend to be mutually exclusive. These cases featured scavenger defleshing or skeletonization by decomposition and insect infestation, but not both. Exceptions involve insects and birds, such as turkey vultures and corvids, which eat insect larvae as well as decomposing flesh, and may therefore be attracted to insect-infested carrion.

We found no problems with processing the pig cadavers, placing them in their research sites, utilizing the cages, weather stations, and cameras. But there has not been enough time to process the images, well over 40,000 of them. We will have tagged all of them with key words, and developed atlases for them at ADD benchmarks, decomposition event benchmarks, and we will be able to do one for scavenging benchmarks, but there is much more analytical work that needs to be done with this rich database.

Much of the process of executing the project from start to finish has been documented on (unedited) video, including interviews with subject matter experts, the interdisciplinary workshops, and the process of doing the pig placements and observations. To the extent that the northern New England taphonomy information system approach would work for other regions, this videographic archive could be developed into training pieces, or could become the basis of a longer piece on regional taphonomy.

The individual pig cadaver subjects worked well as a proxy for human bodies to consider body decomposition as a whole. But they do not seem to work for the Megyesi et al. system of TBS related to ADD. This is not surprising, since the TBS depends to some degree on what could be termed decomposition allometry. And the pigs' legs are disproportionately small.

Pig cadaver subjects and processing is very expensive, with the result that sample sizes are really too small to do quantitative analysis. The forensic case series studies really are necessary, so we have to solve the missing data problem by systematizing our taphonomic protocols.

Building a Regional Taphonomy Information System: This Project Viewed as a Demonstration

This project developed a dynamic system to observe, document, and test regionally specific models of taphonomic change relevant for improving forensic death investigation. The Northern New England Regional Taphonomy Project utilized a combination of publicly available datasets, geographic information systems, forensic case information, and experimental research, which was archived and analyzed via commonly available software applications. This regional taphonomy information system approach can be adopted in other regions, with the potential of data comparison across regions.

The project focused on several key areas needed to reflect regional features, including the following: (a) environmental variables that would have maximum impact on the progress of decomposition: access of the body to heat, moisture, and scavenging; (b) local forensic anthropology cases with known postmortem interval in order to understand the patterns and variables that were common, and problems that recurred; (c) modal features of context seen in the forensic cases in terms of where bodies were commonly found in that environment; (d) modal features of the condition of the remains, e.g., most cases in this series had been scavenged and were typically incomplete.

Because of the importance of taphonomic context, we made a decision to use geographic information systems (GIS) as a key structural feature of the regional taphonomy information system. This approach has served us well. It provided a way to link environmental datasets, such as weather station data, soil characteristics, and vegetation to particular global positioning system (GPS) localities and hence particular cases. Statewide orthophotographic image layers (aerial photographs) added a visual component, frequently very helpful for forensic investigations, e.g., considering access to the area or designing search strategies.

In order to utilize historic weather station data, e.g., to calculate accumulated degree days (ADD) for a certain postmortem interval (PMI), it was necessary to build some calculators to automate this process. We chose to use ACCESS 2007, a commonly available application, so that our system design could be adopted by other regions. This tool has been enormously helpful. For example, in adding a forensic case to the case series, the user can enter the "last seen alive" date and the "found" date into the tool and the PMI is calculated. Then the user can view a map of the weather stations in the system and select the one nearest to the site in question. The tool utilizes the archived temperature data and calculates the ADD.
A similar tool was developed for the data from the pig cadaver experimental sites. This application works with data downloaded from the Omega data logger, and would work for any digital data logger. The user enters a beginning and end date, and the tool returns the PMI and ADD.

Implications for Policy and Practice

Impact on the Criminal Justice Community and Forensic Practice

In northern New England, seasonal insect absence, high moisture, seasonal deep snow, and heavy forest vegetation affect decomposition rates and sequences, insect activity, scavenger access and scavenger behaviors. Thus, they have a substantial impact on the postmortem fate of human remains and on their recovery and interpretation.

Our research has already changed the way we process outdoor scenes in Maine and to potentially in New Hampshire. The State Police Evidence Response Team works with the anthropologist and the medical examiner to document scatter patterns, search for decomposition islands, and pay closer attention to microenvironemental factors that limit heat or scavenging. This is now happening even if the anthropologist is unable to participate in a body recovery. The anthropologist is consulted more often by the medical examiner about PMI estimations, even in non-skeletal cases. We are using the guidelines for discriminating scavenger defleshing from skeletonization due to decomposition and insect activity.

We have presented a draft protocol for outdoor scene processing to the State Police Evidence Response Team in Maine (see example of microenvironmental assessment checklist and protocol components in Tables 15 and 16). We were invited to use data from this project in training the death investigators in New Hampshire. And we have been invited to deliver a lecture on "Regional Taphonomy" to the medical examiners (national) at the Colby Forensic Sciences Summer Course. A number of anthropologists have seen the short winter scavenging video at the NIJ Conference and the AAFS Meeting, and we have had several requests to use this video for their classroom teaching.

The impact of developing a functioning regional/national taphonomy network is has already been the subject of a multiple discussions with others who are interested in doing their own regional taphonomic approaches, searching for areas of overlap, and networking to improve collaboration and practice. Scavenging, for example, is also important for regions in which bodies are more often found outdoors, and where delays in body discovery are more common. Thus, scavenging may disproportionately affects regions with low population densities, or those where population centers abut undeveloped areas. The composition of the scavenger guild will differ from region to region, introducing variation. On the other hand, some characteristics, like precipitation levels or low population density, will be similar across areas, inviting comparative research.

We are using the regional model to improve forensic practice. Project efforts, and the limitations with taphonomic case data they revealed, have created an impetus to improve and standardize attention to both body condition and environmental context in death investigations. Although a number of "body farm" facilities have sprung up around the country, there needs to be effort to systematize their efforts, or to make the regional approach explicit and comparable. By putting in place structures to collect, archive, and utilize regional data, forensic scientists build a foundation for ongoing research, both experimental and applied. The effort to construct such a system should be seen as an ongoing endeavor of quality improvement.

We have not had much discussion in the literature regarding systematic interdisciplinary protocols to record details of the taphonomic environment; this should be done. If those protocols are focused on regional character, particular attention should be given to those factors that reflect and characterize the regional biogeography, climate, and human modifications to that environment. Documenting those regional factors that limit exposure of the body to heat, moisture, insects and scavengers is key. Additional taphonomic environment factors include noting the slope of the land in relationship to scatter patterns of remains, paying attention to seasonal and decomposition-mediated plant characteristics, and understanding scavenger guild access. These observations should be a routine aspect of outdoor scene processing. This will improve future case series datasets. We have suggested ways to archive and index images and reports, and link these case data to the broader environmental context provided by the GIS. We have suggested methods to discriminate defleshing by decomposition and insects from defleshing by scavengers.

Implications for further research

Regional Taphonomy Network

As we make the protocols more effective and data quality improves, we recommend there be some data sharing across taphonomic regions. We organized a symposium at AAFS in February, 2013, focused on regional taphonomy issues (Table 17). We are preparing an invited prospectus for an edited volume that would be built from this symposium, with contributions from additional investigators that were unable to present at this AAFS venue.

We would like to propose forming a virtual network of regional taphonomy centers, which would be linked digitally, sharing information and expertise, as well as building a database of cases and experimental data, and develop research designs to test shared phenomena with combined datasets. We will be meeting with other investigators in February to explore this idea at the AAFS meeting.

Northern New England Taphonomy

Further Analysis of Existing Data. This project has generated a tremendous amount of data that can undergo further analysis and leverage additional studies, with reduced data collection costs. With our findings come other, related questions. For example, clarifying the issues around overwintering and the impact of undergoing freeze/thaw cycles, the improvement and further testing and replication of our scene processing protocols, the effect associated with decomposition in northern New England fresh or saltwater settings, and ongoing efforts to analytically relate scavenged remains to their ADD (and ultimately their PMI).

Overwintering. Is it possible to examine remains found in the spring and identify whether they have overwintered, or are more recent? For example, using existing data, we would like to document pattern of the freeze/thaw cycles: how many spring and fall in and out of insect-viable temperature zones. We would like to engage forensic entomologists interested in weighing in on this issue, including the temperature vulnerability of eggs and instars, as well as whether a body that has been under snow and becomes freshly exposed in spring would attract a slightly different group of insect species.

Scavenging. We now have more than 40,000 still and video images of scavenging, each associated with precise temperature, ADD, humidity, accumulated humidity, and time. We would like to analyze the patterns by species, and consider whether there are any biological clock-type sequences or behaviors, or whether there are any timing-related phenomena that could assist in estimating PMI.

Aqueous Environments. Maine has a wealth of expertise on marine and lacustrine biology that would be helpful in making progress in this area. Comparing our terrestrial cases to others found in water-related environments would be a good next step. We have already published on marine decomposition (Sorg et al., 1997), and would build on this case series analysis, using cases identified in the course of building the case series for this project.

Northern New England Forensic Taphonomy Complex –a Monograph. As a next step, however, we believe we should develop a print and digital monograph with the project products that could better reach the criminal justice communities, including forensic anthropology. In addition to the atlases and the videos, the monograph would include a demonstration of how to set up a regional information system, which would include a GIS component with environmental layers, building a regional case series archive, and conducting experiments on issues of regional importance.

Table 15. Scene processing guidelines for taphonomically relevant environmental assessment

TAPHONOMIC CONTEXT. Quick assessment of taphonomically relevant terrestrial microenvironment characteristics for bodies on the surface

1. Type of site
    a. Forest, glen, meadow, lowland, roadside, road surface, beach, riverbank, field without vegetation
2. Human proximity. Characterize approximate distance from the built environment and to human habitation, including the following:
    a. Distance from nearest road
    b. Distance from nearest inhabited structure
    c. Presence/absence of signs of regular human use of the site
3. Vegetation
    a. Characterize the vegetation and its capacity to shield remains from the sun or from heat at the site, including the following:
        i. Canopy density (approximate percent of leaf cover)
        ii. Canopy type (whether predominantly evergreen, deciduous, or mixed)
        iii. If deciduous trees in autumn, percent of leaf fall
        iv. Density of shrub layer (very dense, moderately dense, relatively open, absent)
        v. Density of herbaceous layer (very dense, moderately dense, relatively open, absent)
        vi. Height of herbaceous layer, e.g., grass in a meadow (waist high or more, knee high, ankle high, or very low)
    b. Characterize the ground cover in terms of its porosity and likelihood to maintain decomposition fluids on its surface
        i. Evergreen needles, deciduous leaves, grass, open ground
4. Geological characteristics
    a. Characterize the surface in terms of tendency to retain moisture
        i. Well-drained, poorly drained
    b. Characterize the sediment in terms of its likely porosity
        i. Predominantly sand, loam, or clay
    c. Characterize the topography
        i. Flat, slightly sloped, very sloped
        ii. Distance from nearby body of water
        iii. Distance from nearby prominent landform (e.g., hill, cliff)
5. Body/environment interface**.** Taphonomic details that could be helpful in estimating postmortem interval or body location
    a. Contact between body and terrestrial surface
        i. Decomposition island without new vegetation present/absent
        ii. Decomposition island with new vegetation present/absent
        iii. Body on top of surface or partially covered by natural forces
        iv. Leaf/needle fall under or on top of remains
    b. Soil surrounding remains
        i. Presence/absence of insects that have migrated to pupate, data useful for PMI estimation as well as differentiating decomposition from defleshing in skeletal cases
    c. Scatter pattern
        i. Distance from original location of skull/mandible, upper limbs, lower limbs, axial elements
        ii. Map spatial relationship among elements

Table 16. Draft northern New England taphonomy protocol for outdoor terrestrial forensic scenes involving decomposition and/or skeletonization of remains

Forensic procedural objectives

1. **Use methods to assure maximum recovery** of remains and associated evidence to enhance ability to do identification of remains, discriminate postmortem from perimortem damage to the remains, and assist the certifier (medical examiner/coroner) establish cause and manner of death
2. **Find and assess primary deposition location** to enhance investigation of events surrounding death, refine the estimate of postmortem interval, and inform additional search activities
3. **Conduct a taphonomic assessment of the environment** to enhance accuracy of postmortem interval estimate
4. **Conduct a taphonomic assessment of the remains** to enhance accuracy of postmortem interval assessment and to inform further search activities

Methods for Recovery Expansion Search or Focused Speculative Search

Conducted by interdisciplinary team, with involvement of anthropologist

1. Spatial profile developed for the scene: used to generate working maps, identify nearest weather station
2. Environmental profile developed for the scene: used to plan resources to be used, develop map, identify nearest weather station
3. Interdisciplinary team:
    - i. Wardens Service Search Specialists
    - ii. Certified cadaver K-9 search teams
    - iii. Medical examiner
    - iv. Forensic anthropologist
    - v. State Police Evidence Response Team
    - vi. Other specialists as indicated
    - vii. Trained search and rescue searchers if needed
4. Area baseline is established with search corridors
    - a. Overall search incident command headed by Wardens Service
    - b. Remains recovery headed by anthropologist and medical examiners office working together
5. Certified cadaver K-9 teams search corridors first
    - a. Remains flagged
    - b. Human elements identified by anthropologist
    - c. Human remains are mapped
    - d. Areas of K-9 alerts without remains are also flagged
    - e. Forensic anthropologist to identify high and low probability areas
        - i. Identify remains
        - ii. Assess scatter pattern
        - iii. Assess alert areas without remains as possible decomposition islands
    - f. High probability areas protected from general search activity
6. Trained human search teams search corridors in lower probability areas
    - a. Remains flagged
    - b. Human elements identified by anthropologist
    - c. Human remains mapped
    - d. Forensic anthropologist identifies remains and assesses scatter pattern to identify high and low probability areas
    - e. High probability areas protected from further general search activity

(cont.)

Methods for Recovery Expansion in High Probability Area Conducted by anthropologist, with assistance from Evidence Response Team)

1. Secure and assess high probability areas, including areas immediately downslope from primary deposition site if identified
2. Limit general human access; establish site entrance/exit path
3. Conduct a more detailed assessment of the high probability area
4. Evaluate the scope of the search based on assessments below, and expand or intensify as indicated
    a. If remains at the site are incomplete, assume a variety of scavenger species may be involved. Evaluate whether the search for remains is large enough (minimum of 152 m (500 feet) radius; as much as a 1.6 km (1 mile) maximum with canid involvement). Do not rule out small/medium animal involvement close to the primary deposition site.
5. Conduct high-intensity search of the high probability area by Evidence Response Team (e.g., hands and knees)
    a. Flag, identify, and map remains
    b. Scan with metal detector
6. Locate the probable original deposition site, if possible
    a. Utilize probable proximity to access roads
    b. Utilize maps developed by incident command
        i. Scatter pattern (identify skeletal elements and relative locations) of remains and artifacts
        ii. Identify game trails
        iii. Identify decomposition islands
7. Conduct environmental taphonomic assessment
    a. GPS primary deposition site, if identified
        i. Decomposition island assessment
            1. Size
            2. Potential remains imbedded (may require excavation)
            3. Botanical changes within the island (differentiate color and plant types from surrounding vegetation, initial plant mortality, latent seed germination and plant development)
            4. Insect evidence: larvae, pupa cases
            5. Presence of decomposition fluids, adipocere
        ii. Evaluate whether there is environmental evidence for decomposition involving an insect infestation, and take insect samples (there are protocols for this)
            1. Egg masses
            2. Larvae
            3. Pupa cases in clothing, under remains, in soil beneath the remains, in ground-level vegetation within several feet of the remains
        iii. Temperature and humidity assessment
            1. Measure at the site
            2. If the site has vegetation canopy, measure also at the nearest access road or field without vegetation canopy shield. Locate data logger in an area with a vegetation clearance about 9 m on all sides and no overhead canopy. Locate device about 1.7 m above ground, and shield from sun.
        iv. Assess vegetation and canopy
            1. Amount of canopy cover (none, small, medium, large)
            2. Evergreen vs. deciduous. Note whether pine needles or leaves, or a combination, cover forest floor
            3. Note what kind of detritus covers the remains

(cont.)

4. Note ground cover vegetation.

v. Assess access to water and saturation of the site, or evidence of seasonal flooding

vi. Assess site slope. If remains have been scattered, ensure careful search downslope from the primary deposition area

8. Conduct field taphonomic assessment of condition of remains leading to postmortem interval estimate.

i. Assess defleshed remains to rule out defleshing by mammals or birds (see protocol for this)

1. Disturbance of anatomical position
2. Scavenger bone modification signatures
3. Scatter pattern and bones missing

ii. If defleshing has been done by decomposition and insect involvement, measure the "Total Body Score" (Megyesi et al. 2005)

Table 17. Regional taphonomy symposium scheduled for the annual meeting of the American Academy of Forensic Sciences

<u>Symposium Title</u>: Developing Frameworks for Regional Forensic Taphonomy Research and Practice: A Multi-Regional Symposium

<u>Symposium Introduction</u>

Sorg, Haglund & Marden: Developing Frameworks for Regional Forensic Taphonomy Research and Practice: A Multi-Regional Symposium

<u>Theoretical Issues</u>

- Nawrocki and Latham: Modeling Human Decomposition
- Dirkmaat and Cabo: The Taphonomic Revolution
- Metcalf: Microbial Communities of Decomposing Corpses
- Damann: PMI and Bacterial Metagenomics
- Simmons: Decomposition Rate Consistency: ADD and TBS
- Sharplin: Effect of Microclimate, Clothing on Decomposition

<u>Regional Patterns</u>

- Urzel: NRM of Bone
- Dabbs and Martin: The Rate and Pattern of Soft Tissue Decomposition in Southern Illinois
- Galloway and Zephro: California Central Coastal Morphology, Microenvironments and Human Decomposition
- Westcott et al.: Regional Factors in Central Texas Affecting Postmortem Decomposition
- Milligan, Willey and Bartalink: Regional Taphonomy and Estimations of the Postmortem Interval from Northern California
- Connor and France: Taphonomy in Mesa County, Colorado
- Anderson and Bell: Comparison of Faunal Colonization and Taphonomic Changes in Pig Carcasses Submerged in a Deep Coastal Marine Environment in Spring and Fall
- Westling and Pokines: Freshwater Decomposition in Eastern Massachusetts
- Sorg Wren Parker: Regional and Microenvironmental Taphonomic Variation and Decomposition in Northern New England

Chapter 5 - References Cited

Anderson GS, Cervenka VJ. 2002. Insects associated with the body: Their use and analysis. In: Haglund WD, and Sorg MH, editors. *Advances in Forensic Taphonomy: Method, Theory, and Archaeological Perspectives*. Boca Raton, FL: CRC Press, p 173-200.

Anderson GS, VanLaerhoven SL. 1996. Initial studies on insect succession on carrion in southwestern British Columbia. *Journal of Forensic Sciences* 41(4):617-625.

Archer MS. 2004. Rainfall and temperature effects on the decomposition rate of exposed neonatal remains. *Science and Justice* 44(1):35-41.

Bachmann J, Simmons T. 2010. The influence of preburial insect access on the decomposition rate. *Journal of Forensic Sciences* 55(4):893-900.

Bass, WM. 1997. Outdoor decomposition rates in Tennessee. In: Haglund WD, and Sorg MH. *Forensic Taphonomy: The Postmortem Fate of Human Remains*. Boca Raton: CPR Press, pp. 181-186.

Benninger LA, Carter DO, Forbes SL. 2008. The biochemical alteration of soil beneath a decomposing carcass. *Forensic Science International* 180(2-3):70-75.

Blumenschine RJ. 1986. Carcass consumption sequences and the archaeological distinction of scavening and hunting. *Journal of Human Evolution* 15(8):639-659.

Bonnichsen R, Sorg, MH. 1987. *Bone Modification.* Orono ME: Center for Early Man.

Bunch AW. 2009. The impact of cold climate on the decomposition process. *Journal of Forensic Identification* 59(1):26-44.

Carson EA, V.H. Stefan, J.F. Powell. 2000. Skeletal manifestations of bear scavenging. *Journal of Forensic Sciences* 45(3):12.

Carter DO, D. Yellowlees, M. Tibbett. 2008. Using ninhydrin to detect gravesoil. *Journal of Forensic Sciences* 53(2):4.

Carter DO, Yellowlees D, Tibbett M. 2007. Cadaver decomposition in terrestrial ecosystems. *Naturwissenschaften* 94(1):12-24.

Carter DO, Yellowlees D, Tibbett M. 2010. Moisture can be the dominant environmental parameter governing cadaver decomposition in soil. *Forensic Science International* 200:7.

Christiansen P, Wroe S. 2007. Bite forces and evolutionary adaptations to feeding ecology in carnivores. *Ecology* 88(2):11.

Davis JB, Goff ML. 2000. Decomposition patterns in terrestrial and intertidal habitats on Oahu Island and Coconut Island, Hawaii. *Journal of Forensic Sciences* 45(4):836-842.

Dirkmaat DC, Cabo LL, Ousley SD, Symes SA. 2008. New perspectives in forensic anthropology. *Yearbook of Physical Anthropology* 51:33-52.

Duraes N. 2010. Comparison of adipocere formation in four soil types of the Porto (Portugal) District. *Forensic Science International* 195:168-173.

Goff ML. 2009. Early postmortem changes and stages of decomposition in exposed cadavers. *Experimental Applied Acarology* 49:21-37.
Galloway, A. 1997. The process of decomposition: A model from the Arizona-Sonoran Desert. In: Haglund WD, and Sorg MH. *Forensic Taphonomy: The Postmortem Fate of Human Remains.* Boca Raton: CPR Press, pp. 139-149.
Haglund WD. 1991. *Application of Taphonomic Models to Forensic Investigations* [Dissertation]. Seattle: University of Washington.
Haglund WD. 1997a. Dogs and coyotes: Postmortem involvement with human remains. *Forensic Taphonomy: The Postmortem Fate of Human Remains*. Boca Raton: CRC Press. p 367-381.
Haglund WD, Reay DT, Swindler DR. 1988. Tooth mark artifacts and survival of bones in animal scavenged human skeletons. *Journal of Forensic Sciences* 33(4):985-997.
Haglund WD, Reay DT, Swindler DR. 1989. Canid scavenging/disarticulation sequence of humans in the pacific northwest. *Journal of Forensic Sciences* 34(3):587-606.
Haglund WD, Sorg MH. 1997. *Forensic Taphonomy: The Postmortem Fate of Human Remains*. Boca Raton: CPR Press.
Haglund WD, Sorg MH. 2002a. *Advances in Forensic Taphonomy: Methods, Theory, and Archaeological Perspectives*. Boca Raton: CRC Press. 435-450 p.
Haglund WD, Sorg MH. 2002b. Human remains in water environments. In: Haglund WD, and Sorg MH, editors. *Advances in Forensic Taphonomy: Method, Theory, and Archaeological Perspectives*. Boca Raton, FL: CRC Press.
Haskell NH, Hall DW, Cervenka VJ, Clark MA. 1997. On the body: Insects' life stage presence, their postmortem artifacts. In: Haglund WD, and Sorg MH, editors. *Forensic Taphonomy: The Postmortem Fate of Human Remains*. Boca Raton, FL: CRC Press. p 415-448.
Haslam TCF, M. Tibbett. 2009. Soils of contrasting pH affect the decomposition of buried mammalian skeletal muscle tissue. *Journal of Forensic Sciences* 54(4):5.
Hobischak NR, VanLaerhoven SL, Anderson GS. 2006. Successional patterns of diversity in insect fauna on carrion in sun and shade in the Boreal Forest Region of Canada, near Edmonton, Alberta. *Canadian Entomologist* 138(3):376-383.
Jaggers KA, T. Roggers. 2009. The efects of soil environment on postmortem interval: A macroscopic analysis. *Journal of Forensic Sciences* 54(6):1217-1224.
Joy JE, Liette NL, Harrah HL. 2006. Carrion fly (Diptera: Calliphoridae) larval colonization of sunlit and shaded pig carcasses in West Virginia, USA. *Forensic Science International* 164(2-3):183-192.
Kjorlien YP, Beattie OB, Peterson AE. 2009. Scavenging activity can produce predictable patterns in surface skeletal remains scattering: Observations and commments from two experiments. *Forensic Science International* 188:103-107.

Komar, DA. 1998. Decay rates in a cold climate region: A review of cases involving advanced decomposition from the medical examiner's office in Edmonton, Alberta. *Journal of Forensic Sciences* 43(1):57-61.

Marden, K, Sorg, MH and Haglund, WD. 2012. Taphonomy. In Elizabeth A. DiGangi and Megan K. Moore, Editors, *Research Methods in Human Skeletal Biology.* New York: Academic Press, 241-262.

Marden KA, Sorg MH. 2011. Potential Impacts of Regional Ecologies on the Estimation of Postmortem Interval: Case Comparisons from Northern New England. *Proceedings of the American Academy of Forensic Sciences* 17:388-389. (extended abstract

Megyesi MS, Nawrocki SP, Haskell NH. 2005. Using accumulated degree-days to estimate the postmortem interval from decomposed human remains. *Journal of Forensic Sciences* 50(3):618-626.

Merbs C. 1997. Eskimo skeleton taphonomy with identification of possible polar bear victims. In: Sorg MH, and Haglund WD, editors. *Forensic Taphonomy: The Postmortem Fate of Human Remains.* Boca Raton: CRC Press. p 249-262.

Michaud, J-P, Moreau G. 2011. A statistical approach based on accumulated degree-days to predict decomposition-related processes in forensic studies. *Journal of Forensic Sciences* 56(1):229-232.

Micozzi MS. 1986. Experimental study of postmortem change under field conditions: Effects of freezing, thawing and mechanical injury. *Journal of Forensic Sciences* 31:953-961.

Micozzi MS. 1997. Frozen environments and soft tissue preservation. In: Sorg MH, and Haglund WD, editors. *Forensic Taphonomy: The Postmortem Fate of Human Remains.* Boca Raton: CRC Press. pp. 171-186.

Murmann DC, Brumit PC, Schrader BA, Senn DR. 2006. A comparison of animal jaws and bite mark patterns. *Journal of Forensic Sciences* 51(4):846-860.

O'Brien RC, Forbes SL, Meyer J, Dadour I. 2010. Forensically significant scavenging guilds in the southwest of Western Australia. *Forensic Science International* 198(1-3):85-91.

Parsons HR. 2009. The Postmortem Interval: A Systematic Study of Pig Decomposition in West Central Montana. Master of Arts Thesis, University of Montana.

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

Peel MC, Finlayson BL, McMahon TA. 2007. Updated world map of the Koppen Geiger climate classification. *Hydrol. Earth Syst. Sci.* 11:1633-1644.

Pickering, TR, Dominguez-Rodrigo M, Heaton JL et al. 2012. Taphonomy of ungulate ribs and the consumption of meat and bone by 1.2-million-year-old hominins at Olduvai Gorge, Tanzania. *Journal of Archaeological Science,* doi: 10.1016/j.jas.2012.09.025.

Rebmann A, David E, Sorg MH. 2002. *Cadaver Dog Handbook: Forensic Training and Tactics for the Recovery of Human Remains.* Boca Raton FL: CRC Press.

Schroeder H, Klotzbach H, Puschel K. 2003. Insects' colonization of human corpses in warm and cold season. *Legal Medicine (Tokyo)* 5:S372-374.

Sharanowski BJ, Walker EG, Anderson GS. 2008. Insect succession and decomposition patterns on shaded and sunlit carrion in Saskatchewan in three different seasons. *Forensic Science International* 179(2-3):219-240.

Simmons T, Adlam RE, Moffatt C. 2010a. Debugging Decomposition Data—Comparative Taphonomic Studies and the Influence of Insects and Carcass Size on Decomposition Rate. *Journal of Forensic Sciences* 55(1):8-13.

Simmons T, Cross PA, Adlam RE, Moffatt C. 2010b. The Influence of Insects on Decomposition Rate in Buried and Surface Remains. *Journal of Forensic Sciences* 55(4):889-892.

Sorg MH. 1986. Scavenger Modification of Human Remains. *Proceedings of the Annual Meeting of the American Academy of Forensic Sciences.*

Sorg MH. 2012. Scavenging Impacts on the Progression of Decomposition in Northern New England. *Proceedings of the American Academy of Forensic Sciences* 17:384-385. (extended abstract)

Sorg MH, David E, Rebmann AJ. 1998. Cadaver dogs, taphonomy, and postmortem interval in the northeast. In Reichs KJ, editor, *Forensic Osteology: Advances in the Identification of Human Remains.* Springfield IL: Charles C. Thomas, pp.120-144.

Sorg MH, Haglund WD. 2001. Advances in Forensic Taphonomy: Purpose, Theory, and Process. In: Haglund WD, and Sorg MH, editors. *Advancing Forensic Taphonony: Method, Theory and Archaeological Perspective*. Boca Raton, FL: CRC Press.

Sorg MH, Haglund WD, Wren JA. 2012. Current research in forensic taphonomy. In DC Dirkmaat, editor, *A Companion to Forensic Anthropology.* West Sussex UK: Wiley-Blackwell, pp. 477-498.

Sorg MH, Wren JA. 2011. Taphonomic impacts of scavenging in northern New England. Poster presentation at National Institute of Justice 2011 Conference. Arlington, VA.

Stokes KL, Forbes SL, Tibbett M. 2009. Freezing skeletal muscle tissue does not affect its decomposition in soil: Evidence from temporal changes in tissue mass, microbial activitiy and soil chemistry based on excised samples. *Forensic Science International* 183(1-3):6-13.

Steadman DW, Worne H. 2007. Canine scavenging of human remains in an indoor setting. *Forensic Science International* 173(1):78-82.

Tibbett M, and Carter DO, editors. 2008. *Soil Analysis in Forensic Taphonomy: Chemical and Biological Effects of Buried Human Remains*. Boca Raton, FL: CRC Press.

Vass AA. 2010. The elusive universal post-mortem interval formula. *Forensic Science International* 204(1-3):34-40.

Vass AA, Barshick SA, Sega G, Caton J, Skeen JT, Love JC, Synstelien JA. 2002. Decomposition chemistry of human remains: a new methodology for determining the postmortem interval. *Journal of Forensic Sciences* 47(3):542-553.

Vass AA, Bass WM, Wolt JD, Foss JE, Ammons JT. 1992. Time since death determinations of human cadavers using soil solution. *Journal of Forensic Sciences* 37(5):1236-1253.

Wang J, Li Z, Chen Y, Chen Q, Yin X. 2008. The succession and development of insects on pig carcasses and their significances in estimating PMI in south China. *Forensic Science International* 179(1):11-18.
Wilson AS, R.C. Janaway, A.D. Holland, H.I. Dobson, E. Baran, A.M. Pollard, D.J. Tobin. 2007. Modelling the Buried Human Body Environment in Upland Climes Using Three Contrasting Field Sites. *Forensic Science International*(169):13.
Wilson-Taylor RJ. 2013. Time since death estimation and bone weathering. In Tersigni-Tarrant MTA and Shirley NR, editors, *Forensic Anthropology: An Introduction*. Boca Raton FL: CRC Press, pp. 339-380.

Chapter 6 - Dissemination

Professional Roles

The PI/PD is the consulting forensic anthropologist for the Maine and New Hampshire Offices of Chief Medical Examiner, consulting on all anthropology cases for these two northern New England states (as well as other states). She has recently begun to cover Delaware and Rhode Island as well. These states have state medical examiner systems, unifying response to death investigation. The PI/PD works very closely with the Offices of Chief Medical Examiner on all forensic anthropology cases, conducting her investigations in collaboration with the Chiefs or Deputy Chief Medical Examiners.

The PI/PD is also a cooperating member of the Maine State Police Evidence Response Team, which responds with her for forensic anthropology scene recoveries. She is part of the faculty for the Evidence Response Team training. The Evidence Response Team operates in conjunction with the Maine State Police Crime Laboratory, which is cooperating with this research project. Protocols developed for this project are being shared with the Evidence Response Team, and are implemented as needed in forensic anthropology cases. Some protocols may involve the Crime Lab directly (e.g., for soil testing), and these are under discussion. Currently three cold cases are under examination with the project GIS system, in collaboration with the Maine Department of Attorney General and Maine State Police. New forensic cases are now being routinely run through the project GIS system.

The PI/PD often consults for the New Hampshire State Police, particularly the Major Crimes Unit, and the New Hampshire Attorney General's Office. Protocols developed as a result of this grant are being applied gradually implemented in cases in Maine and New Hampshire.

The methods and outcomes have been disseminated nationally via forensic professional organization (e.g., American Academy of Forensic Sciences) conferences and publications. In addition, the PI/PD is a member of the FBI Scientific Working Group for Anthropology, Taphonomy Committee, which will be developing standards in forensic taphonomy.

Presentations

Sorg, Marcella H., William D. Haglund, Edward David, Sarah A. Kiley, William Parker, Harold Borns, John Burger, John Dearborn, Ann Dieffenbacher-Krall, Deborah Palman, and Touradj Solouki

(2010) Developing a Regional Forensic Taphonomy: Environmental and Climatic Inputs. Annual Meeting of the American Academy of Forensic Sciences, Seattle WA.

Sorg, Marcella H.
(2010) Bog Brook Bugs and Weather: Forensic Entomology and Brief Overview and Discussion of Maine Taphonomy Research Project, Maine State Police Evidence Response Team Meeting, June 2010 at Bog Brook Military Facility, Gilead, ME

Sorg, Marcella H.
(2011) Scavenging Impacts on the Progression of Decomposition in Northern New England. *Annual Meeting of the American Academy of Forensic Sciences,* Seattle, WA.

Marden, Kerriann and Marcella H. Sorg
(2011) Potential Impacts of Regional Ecologies on the Estimation of Postmortem Interval: Case Comparisons from Northern New England. *Annual Meeting of the American Academy of Forensic Sciences,* Seattle, WA

Sorg, Marcella H. and Scott A. Bryant
(2011) Standardized Regional Taphonomy Approach: Improving Evidence Recovery and PMI Interpretation. NIJ Conference 2011, Arlington, VA

Sorg, Marcella H. and Andrew Collar
(2011) Scavenger Guild Involvement with Pig Cadavers in the Maine Woods: Taphonomic Analysis. Developing and Validating Regional Taphonomic Standards. Video/DVD. NIJ Conference 2011, Arlington, VA

Marden, Kerriann and Marcella H. Sorg
(2011) Seasonal Differences in Scavenger Impacts and PMI Estimates in Two Maine Cases. NIJ Conference 2011, Arlington, VA

Sorg, Marcella H. and Jamie A. Wren
(2011) Taphonomic Impacts of Scavenging in Northern New England. NIJ Conference 2011, Arlington, VA

Sorg, Marcella H.
(2011) Decomposition Study: ERT Issues, Assessment, Procedures. Annual Training Event for the Maine State Police Evidence Response Team. Maine Criminal Justice Academy, Vassalboro, ME.

Sorg, Marcella H.
(2011) Developing Biological Profiles for Decomposed and Skeletal Remains. New England Seminar in Forensic Sciences, Colby College, Waterville ME.

Sorg, Marcella H., William D. Haglund, Jamie A. Wren, and Andrew Collar
(2012) Taphonomic impacts of small and medium-sized scavengers in northern New England. American Academy of Forensic Sciences, Atlanta GA.

Sorg, Marcella H. and Edward David
(2012) Human Remains Outdoors: Search and Recovery Protocol. Annual Training Event for the Maine State Police Evidence Response Team. Winter Harbor, ME.

Sorg, Marcella H.
(2012) Outdoor Scenes: Issues in Recovery and Estimating Postmortem Interval. New Hampshire Deputy Medical Examiners Training, Concord NH.

Regional Forensic Taphonomy Network Symposium – Scheduled for 2013 AAFS

Sorg, Marcella H., William D. Haglund, and Kerriann Marden, Symposium Organizers. *Developing Frameworks for Regional Forensic Taphonomy Research and Practice: A Multi-Regional Symposium,* scheduled for the AAFS annual meeting.

Regional Taphonomy Interdisciplinary Team Workshops

Maine Regional Taphonomy Project (June, 2009) Seminar/Workshop at the Maine Criminal Justice Academy, Vassalboro, Maine.

Two-day seminar and site visit workshop, including members of the interdisciplinary project team (anthropology, biology, wildlife management, botany, medical examiner, cadaver K-9 handler, geographic information systems). Introduction to the project and to each other, and visits to the initially proposed pig experiment location. Discussion about proposed experiments and how to set them up (locations, materials, impact at the scene, scavenger protection). Scheduled presenters and their assigned topics are listed below:

MARCELLA SORG (anthropology): Overview of project & typical scenes
WILLIAM HAGLUND (anthropology): Decomposition basics, variation, and role of external agents, especially scavengers
JOHN BURGER (entomology): Very brief overview of forensic entomology within ME & NH, including some case examples
JOHN DEARBORN (marine biology): Very brief overview of the aquatic environment, its role for decomposition, and how it can be assessed via GIS or at the scene
ANN DIEFFENBACHER-KROLL (botany): Very brief botanical overview of Maine: types of environments that may impact detection or decomposition and how they can be assessed via GIS or at the scene
CHRISTOPHER MONTAGNA (chemistry): Lisa Garland case
WILLIAM PARKER (GIS technician): Overview of environmental GIS maps & overlay of case locations

DAVID GIAMPETRUZZI (project management): The Academy property and site selection possibilities, and the proposed cages.
JOHN DEARBORN: Brief aquatic assessment (at the site)

HENRY RYAN (medical examiner): Outdoor scenes and the interdisciplinary team
HAROLD BORNS (geology): Very brief geological overview of Maine: types of environments that may impact detection or decomposition and how they can be assessed via GIS or at the scene
HAROLD BORNS (geology): Brief geological assessment (at the site)
JOHN BURGER (entomology): Brief entomological assessment (at the site)
ANN DIEFFENBACHER-KROLL (botany): Brief botanical assessment (at the site)
EDWARD DAVID (K-9 trainer): Cadaver dog basics in the outdoor scene
DEBORAH PALMAN (K-9 trainer): Environmental constraints in the outdoor scene

Maine Regional Taphonomy Project (August, 2010) Seminar and Workshop on Scavenging and its Impact on Recovery and Interpretation of Forensic Remains, University of Maine, Orono, Maine.

Two-day seminar and field trip workshop, including members of the interdisciplinary project team (anthropology, biology, wildlife management, botany, medical examiner, cadaver K-9 handler, geographic information systems) and experts in scavenging from wildlife management and the Maine Guides Association.

"Developing a Regional Taphonomy: Overview" (Marcella H. Sorg) Providing a conceptual framework for the interdisciplinary seminar and workshop on regional forensic taphonomy and scavenging.

"The Taphonomy GIS System" (William Parker, University of Maine) Update the interdisciplinary team on the functioning of the Regional Taphonomy GIS, illustrating its use in select cases.

"Taphonomy and the Regional Scavenger Guild" (Marcella H. Sorg) Present results of preliminary research on the concept of the scavenger guild, and its relevance for forensic investigation.

"Scavenging and Search Strategies" (William D. Haglund) Review of research on developing search strategies to recover remains in the presence of scavenging.

"Potential Botanical Responses to Cadavers" (Christa Schwintzer) Informal discussion of the responses of plants to the presence of decomposing flesh.

"Soil Responses to Cadaver Presence" (Jamie Wren) Review of literature on changing soil patterns in the presence of decomposing flesh.

"Canid Scavenging" (William D. Haglund) Review of research on canid scavenging.

"Coyotes in Maine" (Gerald Lavigne) Provide wildlife management perspective on coyotes and coyote scavenging behavior.

"Bear Baiting and Bear Behavior" (Robert Howe) Informal discussion of how bears respond to human scent, bear bait, and other observations of bear behavior.

"Cadaver Dog Search Strategies" (Edward David) Overview of issues of scent in developing search strategies for cadaver dogs.

"Cadaver Dog Search Strategies: Case Study" (Deborah Palman) Forensic case study of cadaver dog search strategies used in a New Brunswick death investigation."

"Examination of a Two Active Scavenging Bone Yards" (Marcella H. Sorg) Field trip to examine, photograph, and take samples at a working taxidermy bone yard in use for 20 years and a coyote bait site in use for about 10 years.

Maine Regional Taphonomy Project (June 2011) Seminar and Workshop on Findings from Pig Cadaver Taphonomy Experiments: Decomposition and Scavenging and its Impact on Recovery and Interpretation of Forensic Remains, University of Maine, Orono, Maine.

Two-day seminar and field trip workshop, including members of the interdisciplinary project team (anthropology, biology, wildlife management, botany, medical examiner, cadaver K-9 handler, geographic information systems)

"Developing a Regional Taphonomy: Overview" (Marcella H. Sorg) Providing a conceptual framework for the interdisciplinary seminar and workshop on regional forensic taphonomy and scavenging.

"Decomposition and Scavenging Overview" (William D. Haglund) Providing a review of basic concepts regarding decomposition processes and rodent versus carnivore scavenging.

"The Taphonomy GIS System: Environmental Profiles and the ADD Tool" (William Parker, University of Maine) Update the interdisciplinary team on the functioning of the Regional Taphonomy GIS.

"Dead Pigs and Geology" (Alice R. Kelley) Present results of preliminary research on geological and soil assessment at the pig field sites.

"Seasonal Differences in Scavenger Impacts Comparing Two Maine Cases" (Jamie A. Wren) Comparing the environmental profiles and scavenger modification for two Maine cases with similar ADD and very different condition.

"Total Body Score Applied to Maine and New Hampshire forensic Cases" (Jamie A. Wren) Using Megyesi method to estimate PMI when there is scavenging.

"Prospectus on Monitoring Protein Degradation with Mass Spectroscopy" (Touradj Solouki) Prospectus on pilot study of protein racemization to develop a biological clock to estimate postmortem interval.

"Vegetation and Pigs: Mutual Impacts" (Ann Dieffenbacher-Krall) Present analysis of botanical responses to pig cadavers and cadaver responses to vegetation at the pig field sites.

"Insects and ADD at Pig Rupture Event" (Tamara Labanowski) Assessment of ADD comparisons and insect identifications by Dr. John Burger" Analysis of photograph images, ADD calculations, and insects present, comparing pigs in different environments when they rupture.

"Carnivore Modification Comparing Pig Cadavers with Forensic Case Series" (Marissa Lopez) Comparisons between the pig cadavers at the scavenging sites with forensic cases at the same ADD.

Abstracts In Published Proceedings

Sorg, Marcella H., William D. Haglund, Edward David, Sarah A. Kiley, William Parker, Harold Borns, John Burger, John Dearborn, Ann Dieffenbacher-Krall, Deborah Palman, and Touradj Solouki
(2010) Developing a Regional Forensic Taphonomy: Environmental and Climatic Inputs. *Proceedings of the Annual Meeting of the American Academy of Forensic Sciences* (www.aafs.org/pdf/2010proceedingsseattle.pdf)

Sorg, Marcella H.
(2011) Scavenging Impacts on the Progression of Decomposition in Northern New England. *Proceedings of the Annual Meeting of the American Academy of Forensic Sciences.* (extended abstract)

Marden, Kerriann and Marcella H. Sorg
(2011) Potential Impacts of Regional Ecologies on the Estimation of Postmortem Interval: Case Comparisons from Northern New England. *Proceedings of the Annual Meeting of the American Academy of Forensic Sciences.* (extended abstract)

Sorg, Marcella H., William D. Haglund, Jamie A. Wren, and Andrew Collar
Taphonomic impacts of small and medium-sized scavengers in northern New England. *Proceedings of the Annual Meeting of the American Academy of Forensic Sciences.* (extended abstract)

Publications

Sorg, Marcella H., William D. Haglund, and Jamie A. Wren
(2012) Current Research in Forensic Taphonomy. In Dirkmaat, D.C., Editor, *A Companion to Forensic Anthropology.* Boston: Blackwell Publishing, pp. 477-498.

Marden, Kerriann, Marcella H. Sorg, and William D. Haglund
(2012) Taphonomy. In Elizabeth A. DiGangi and Megan K. Moore, Editors, *Research Methods in Human Skeletal Biology.* New York: Academic Press.

Video - DVD

Sorg, Marcella H. and Andrew Collar
(2011) Developing and Validating Regional Taphonomic Standards. Waterville, ME: DigitalSpiritMedia.

Computer Applications

- ADD Calculator and GPS Taphonomy Environmental Profile Tool Using Forensic Site Data. (Beta Version) Regional Taphonomy GIS Environmental Layers (Maine and New Hampshire). During this reporting period Vermont environmental layers have been added to the GIS for northern New England.

- ADD Calculator and Taphonomy Environmental Profile Tool Using Weather Station Data. (Beta Version) ADD Calculation Tool for Use with public use NOAAA data

- (Under development) Public Use Version of Outdoor Forensic Case Series Database

Videographic Documentation

Andrew Collar

Videographic documentation of project workshops, interviews, field trips, and pig cadaver experiments.

- One DVD has been produced (being sent to NIJ program monitor)
- Images from field sites have been uploaded and are being tagged with key words for analysis.
- Images from forensic case series are being selected for inclusion

List of Digital Files Associated With This Report

Appendix A. (PDF) Decomposition Atlas – Caged Field Pig Late Fall.
Filename: Caged Field Late Fall.pdf (53 MB)

Appendix B. (PDF) Decomposition Atlas – Caged Woods Pig Late Fall.
Filename: Caged Woods Late Fall.pdf (50 MB)

Appendix C. (PDF) Decomposition Atlas –Caged Woods Pig Spring.
Filename: Caged Woods Spring.pdf (32 MB)

Appendix D: (ACCESS FILES) Additional Data Processing Tools
ACCESS 2007 FILE: Calculate ADD Weather Stn.
Allows user to select a weather station location in Maine, New Hampshire, or Vermont and calculate ADD by inserting the PMI dates.
(173 MB)

ACCESS 2007 FILE: Calculate ADD Pig
Allows user to calculate ADD and accumulated humidity for any of nine research pig cadaver sites at Concord (6 un-caged pigs with scavenger access) or Orneville (3 caged pigs without scavenger access.
(34 MB)

Appendix E. (PDF) Scavenger Guild in Northern New England
Filename: Guild Collage.pdf (10 MB)

Appendix F. (VIDEO) Developing and Validating Regional Taphonomic Standards
Filename: Taphonomy Video.mp4 (105.2 MB, 12 minutes)
Focuses on three un-caged pigs which were placed on site November 5, 2010, and which overwintered. Shows winter interaction with the scavenger guild, including construction of snow tunnels and caves to access the pig cadaver, built and used by multiple species.

Appendix G. (VIDEO CLIP) Porcupine Gnaws Bone
Filename: Porcupine Gnaws Bone.mp4 (5 MB, 10 seconds)
Video clip of porcupine gnawing a femur, which accompanies still photo of femur showing resulting bone modification marks.

List of Appendices

Appendix A: Decomposition Atlas: Caged Field Pig, Late Fall

See associated digital file: Caged Field Late Fall.pdf

Appendix B: Decomposition Atlas: Caged Woods Pig, Late Fall

See associated digital file: Caged Woods Late Fall.pdf

Appendix C: Decomposition Atlas- Caged Woods Pig, Spring

See associated digital file: Caged Woods Spring.pdf

Appendix D: Additional Data Processing Tools

See associated digital files:

- Calculate ADD Weather Stn.accdb
- Calculate ADD Pig.accdb

Appendix E. Scavenger Guild in Northern New England

See associated digital file: Guild Collage.pdf

Appendix F. Video: Developing and Validating Taphonomic Standards

Appendix G. Video Clip: Porcupine Gnaws Bone