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A Descriptive Study of Forensic Implications of Raccoon Scavenging in Maine

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A DESCRIPTIVE STUDY OF FORENSIC IMPLICATIONS OF RACCOON SCAVENGING IN MAINE

by

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Abstract

This thesis is a case study of winter raccoon scavenging in Maine. The data used for my analysis came from a National Institute of Justice funded project on Regional Taphonomy done by Marcella Sorg from 2007 to 2012 (Sorg, 2013). I analyzed the photographic and videographic data from one pig cadaver site and identified raccoon scavenging “events.” This term is used to describe any period of time that one or more raccoons are scavenging. These events were then analyzed to investigate possible associations between scavenging behaviors and environmental variables, although none were positively identified. I adapted a method of describing soft tissue lost via animal scavenging from the “Total Body Score” system in Megyesi et al., 2005, which was written to describe levels of decomposition. Through the analysis of the data from this site, typical raccoon behavior was established. This includes nocturnal, winter defleshing without bone modification both individually and within groups. Although no connections were found with environmental variables, a high frequency of winter scavenging was found associated with the mating season and the availability of food.

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Introduction

Taphonomic research connected with raccoon scavenging is significant to the field of forensic anthropology because it helps define general taphonomic events (what happens to remains from the time of death to the time of discovery) in Maine (Haglund and Sorg, 2005). Research on this topic has already influenced the way death investigations are done, as well as the policy surrounding recovery of remains (see Marden and Sorg, 2011; Sorg and Marden, 2013). For example, understanding scavenging related to forensics provides details about what to expect while executing a death investigation, as well as how to estimate the length of time a set of remains has been exposed (Marden and Sorg, 2011; Sorg, 2011).

Forensic taphonomy is defined as the scientific study of postmortem change applied to forensic problems (Sorg and Haglund, 2002). It is a topic that has been studied in great detail in recent years, including the study of animal scavenging patterns and impacts on remains left exposed to the environment (see Haglund, 1997; Sorg, 2011; Sorg et al., 2012; Young et al., 2015). Studies focused specifically on scavenging by raccoons are limited, despite the fact that they are one of the primary scavengers in this region. Further study of the details of raccoon scavenging in Maine could provide valuable information for first responders who are estimating postmortem interval and the length of time a set of remains has been left exposed.

A larger study of forensic taphonomy in Maine has already been completed, and the data are readily available for further analysis (Sorg, 2013). This research has identified the potential importance of raccoon scavenging during the winter months using a pig (*Sus* scrofa) model, but more information is needed on the details of timing and impact on the remains. I have analyzed a subset of the photographic and videographic data from the Maine Regional Taphonomy project in order to gain perspective about details such as the frequency and timing of raccoon scavenging, as well as the manner of scavenging.

Literature Review

Forensic Taphonomy

The term "taphonomy" is defined as the "science of the laws of embedding or burial" which governs a number of site formation processes in archaeology (Lyman, 1994, p. 1). In forensic anthropology, the same term is used to describe the study of postmortem processes, which can include the preservation, observation, or recovery of dead organisms and the reconstruction of the circumstances of their death (Sorg and Haglund, 2002). In other words, forensic taphonomy refers to what happens to a body in the early postmortem period. Thus, the application of forensic taphonomy in formal death investigations is both necessary and invaluable.

Taphonomic change can include a wide variety of processes, but one of the most significant is animal scavenging. Animals may contribute a wide array of modifications to a body exposed to a specific environment, but the most common and drastic effects are defleshing, bone modification and disarticulation/scattering. Specific animals, or groups of animals, tend to modify remains in specific ways. This is called a "taphonomic signature." For example, carnivores have specific patterns of bone breakage and scattering, and they leave specific marks on the bones with their teeth and claws (Marshall, 1989). Defleshing can significantly alter the process of decomposition. Bone modification can consume or completely destroy whole bones or parts of bones, which could impact an anthropologist's ability to identify specific bones or to apply methods of analysis that lead to identification. Scattering of bones could lead to the inability to recover an entire skeleton from a clandestine site (this could also be due to complete consumption of certain bones by scavengers).

As stated above, groups of animals have specific taphonomic signatures. An example of this is the difference between scavenging by animals in the orders Carnivora and Rodentia. Each group has its own pattern of bone modification and scattering. This includes which specific bones are generally scavenged, which parts of those bones are generally scavenged, what the marks on the bones look like, and their likeliness to take specific bones away from the site, or out of anatomic position (Haglund, 1997). One may find more than one taphonomic signature on one set of bones, depending on the environment and the amount of decomposition. The group of animals that is specific to a region and act upon a single specimen is called the "scavenger guild" for that area. For example, in Maine, coyotes, raccoons, turkey vultures, as well as other carnivores and rodents are all part of the scavenger guild (Sorg, 2013).

Another significant factor of forensic taphonomy is decomposition (Gill-King, 1997). The rate of decomposition can vary depending on environmental factors, such as temperature; during the winter months in Maine, for example, it is generally too cold for decomposition to take place. Cold temperatures prevent insects from colonizing the remains and stop most or all chemical breakdown that accelerates the decomposition process. Thus, in warm to hot temperatures, decomposition takes place fairly rapidly. Interference by animal scavengers may also slow decomposition (Sorg, 2013; Synstelien, 2005). This can take place by animals feeding on insect larvae or by feeding directly on the remains, preventing insects from invading it. The latter example would leave the skeleton exposed to finish decomposing (drying out), without the presence of flesh.

Research on Animal Scavenging

Although raccoons are some of the most common scavengers in the United States, very little research has been done on their contribution to forensic taphonomy. However, extensive research has been done on other carnivores and omnivores in a variety of regions. In more recent years, research on raccoons is becoming even more common, (for example, see Jeong, 2014 and Young et al., 2015). Some taphonomic studies focus on a larger taxonomic category comprising multiple species, rather than focusing on any single species.

One of the most common groups of scavengers in taphonomy research is the order Carnivora. Research studies on carnivore scavenging describe the method of scavenging, which includes flesh and bone consumption, and large scattering of bone (for example, Camaros et al., 2012; Haglund, 1977; Moraitis et al., 2010; Rippley et al., 1983; Young et al., 2015). Carnivores generally consume the flesh and organs of remains. They also modify bone, including marks on the bone that could include punctures (from canines), gnawing marks on long bones (which sometimes can resemble sharp-force trauma), and extensive fractures to bones. The remains can also be disarticulated and scattered up to 3.2 kilometers, but usually does not exceed 100 meters (Haglund, 1997). None of the articles viewed for this literature review noted information about the frequency or time of year of scavenging, nor did they include ecological information about the animals.

Scavenging research on the orders Rodentia and Artiodactyla are available, but in much smaller numbers than research on Carnivora. For example, a study on the modification of human remains by pigs (*Sus scrofa*) showed a similar result to early carnivore scavenging (Berryman, 2012). The main activity of scavenging was similar (to obtain the visceral organs), but the marks on the bones were very different. This taphonomic signature is categorized by long parallel lines, as if the molars were being dragged across the bone.

Maine Regional Taphonomy Project

Sorg completed a study in forensic taphonomy, which was funded by the Department of Justice, from 2007 to 2012 (Sorg, 2013). The objective of this project was to develop regional forensic taphonomic standards for Northern New England. The information gained from this study is meant to assist in death investigations in the State of Maine and other areas of New England, and has already been utilized in Maine and New Hampshire.

In this study, nine pig (*Sus scrofa*) cadavers were placed in forested environments in Maine. Six were open to all possible taphonomic agents. Three of the cadavers were caged to prevent scavenging and encourage normal decomposition as control specimens.

Each site was continuously monitored by video and still trail cameras that recorded data both on a timed schedule and by a motion sensor, producing a large amount of photographic and videographic data for analysis. Scheduled research visits were also made to each of the sites in order to change batteries on the trail cameras, record information not readily discernable from the trail camera data, as well as to photograph the remains more closely to analyze the condition at different times. These visits were made throughout the year, including times when the snow was as much as 2-3 feet deep, covering the bodies as well as times when there was little to no snow cover, so the remains could be easily seen.

During initial analysis, prior to the research summarized in this thesis, a tagging system in Adobe Bridge was applied to the image data to allow easier sorting, depending on specific study variables. Each file was tagged with environmental conditions (such as snow cover and precipitation), amount of disarticulation, scavengers present, specific scavenger activity, and amount of decomposition. Each file was also date and time stamped by the trail cameras at the time each photo or video was taken. Through this tagging system, it was possible to easily determine the most prevalent scavengers at each site, producing the scavenger guild analysis for Maine. The more frequent scavengers in this project include: coyotes, turkey vultures, raccoons, porcupines, rabbits, weasels, and ravens.

In addition to the formation of the scavenger guild, this study developed new standards for forensic death investigations in Northern New England. Some important findings included: (1) scavenger defleshing without bone modification needs to be discriminated from skeletonization by decomposition of soft tissue without scavenger involvement; (2) seasonality of scavenging by certain species is important; (3) multiple species may scavenge, but at different phases of decomposition; and (4) scavenging patterns can vary despite similarity of environment and timing. The results of this study have already influenced the way examination of remains is done during death investigations, as well as the policy surrounding recovery of remains and the estimation of postmortem interval of skeletonized remains in this area (Sorg, 2012; Sorg, 2013).

Raccoons

The common raccoon (*Procyon lotor*) is an omnivore species that populates North America, while other species within the Procyonidae family can be found all over the world. There are subspecies of raccoon, which differ geographically in their morphology (size, coat color, etc.) (Zeveloff, 2002). They are found in forested environments as well as urban areas, where they have been known to feed and scatter refuse materials, and where they can be, in general, a nuisance. The act of scavenging in urban areas, such as in garbage cans, is rather easy for the common raccoon, because it has five digits on each foot, allowing careful manipulation of devices. The raccoons' ability to manipulate devices also contributes to their method of scavenging on fresh human cadavers, as found by a recent study at the University of Tennessee (Jeong, 2014), which will be mentioned later in this section.

Living arrangements for the common raccoon are generally solitary and they are incredibly creative in finding places to den. Young raccoons may live with the mother for a period of time before leaving the area, even after they begin to forage for solid food on their own (16 weeks to a few months) (Zeveloff, 2002). Raccoons are considered juveniles from approximately 0-10 months, yearlings from approximately 10-22 months, and adults at greater than 22-24 months (Gehrt and Fritzell, 1996). These categories vary slightly with each study, although it is reported that raccoons do not reach full size until the second year. (Zeveloff, 2002) Their mating period lasts generally from January to March, with the highest activity in February, and pregnancy usually lasts 60-65 days with some variation (Zeveloff, 2002). Raccoons are not very sexually dimorphic, even into adulthood, except for some differences in size (Zeveloff, 2002).

Occasionally, a group of two or three adults may reside together, and this is quite common during the winter months, or when food is scarce. They may congregate, "to take advantage of certain foods, such as fruit or *carrion* (dead animals), which can become available in substantial amounts." (Zeveloff, 2002, p. 191) Raccoons are nocturnal, meaning most of their activity happens at night, and they have been recorded to forage for food around midnight, with activity rarely beginning within an hour before sunrise (MacClintock, 1981). The home range is generally one to three kilometers, but this depends on various biological and sociological factors, such as sex and age, habitat features, and population density. It has been recorded as well that some territoriality can occur, especially among the males (Zeveloff, 2002).

Since raccoons are omnivores, their diet changes depending on the food that is readily available to them. This is another reason they have been flourishing in urban areas as well as in more natural habitats. As stated before, raccoons will take advantage of dead animals that are left exposed to the environment, making them likely scavengers on human remains as well. The maxillary and mandibular dental formula for the raccoon is 3.1.4.2, which is very similar to most carnivores. (MacClintock, 1981) It is worth noting the similarities between the raccoon and some other small mammals, such as the red fox (*Vulpes vulpes*), which are categorized as carnivores, and not omnivores. A major example is territoriality (Macdonald, 1983).

Raccoon Scavenging

Research studies on raccoons as taphonomic agents are very scarce. I will be evaluating the available literature in this section, although it is limited. Each study will be described, and similarities and differences to the findings of the regional taphonomy project in Maine will be noted. A total of four studies will be described in this section. Three of them are studies in forensic taphonomy, and one is a purely ecological study.

Jeong, University of Tennessee

A study of raccoon scavenging was recently completed in Tennessee (Jeong, 2014). A total of 178 human cadavers were placed at the ARF (Anthropological Research Facility) at the University of Tennessee Knoxville in a caged environment, but open to raccoon, and other small animal scavenging. The human subjects were placed in the facility for purposes other than Jeong's research, and at varying time periods. Scavenging data was collected with daily photographs. According to the results section, three conclusions were made: (1) scavenging activity increases in the summer (or warmer) months; (2) scavenging occurs immediately and lasts a relatively short amount of time; and (3) scavenging often results in mummification of the remains. A new manner of defleshing was also described. The raccoons would make a small hole in the skin on one of the limbs and pull muscle tissue through the hole to consume it, thus making the limb effectively hollow. Jeong attributes the raccoons' behavior to winter rest, food searching, and reproduction.

Synstelien, University of Tennessee

Another study completed at the Anthropological Research Facility in Tennessee on raccoon activity found that more often than not, raccoons were feeding on the larvae that had colonized, rather than on the remains that were left (Synstelien et al., 2005). The consumption of the larvae interfered with normal decomposition phasing, and left the impression that little to no scavenging had occurred on the remains, which is in agreement with the Maine study. It also increased the likelihood of mummification. There is relatively little information about this study, because it is unpublished. The only information available for it is in an extended conference abstract (Synstelien et al., 2005).

Calce, University of Toronto

Another anthropological study in forensic taphonomy described raccoon activity similar to coyote activity as contributing largely to scatter and burying the remains (Calce et al., 2007). This study was done with pig remains (ten pig heads), and the focus was on more than one species of scavenger. The project was done at the University of Toronto at Mississauga. It also documented the effects of the decomposing pigs on the surrounding areas. The purpose of this study was to document the varying effects of scavenging by more than one species, and did not include biological information pertaining to specific species (such as mating, or seasonality of scavenging). It is not stated in the article if scavenging was nocturnal. The result that raccoon behavior mimics coyote behavior is abnormal. This could be due to a lack of substantial results about raccoons in general. It appears as though they were seen scavenging at about the same time as the coyotes, so it was assumed that they contributed to the results in the same ways. Previous raccoon studies have stated that they contribute minimally to scatter and have no mention of burying remains.

Sharp, Nebraska

Another study of foraging by raccoons was completed in 1956 (Sharp et al., 1956). Ward and Louise Sharp set up a winter feeding station in Nebraska and recorded the feeding habits of raccoons that subsequently visited. Although this was not an anthropological study, it still provides valuable information regarding the foraging habits of raccoons in another part of the United States. They found that the raccoons were usually feeding at night, which makes sense, because they are nocturnal animals. It was also recorded that they fed more frequently in the winter months, which contradicts the findings of Jeong, who found that scavenging was more frequent in the summer months (Jeong, 2014).

Summary

These four studies show research in anthropology and ecological sciences related to raccoon scavenging. Synstelien's study in Tennessee was similar to Sorg's study in Maine, showing that after raccoon scavenging, there is little evidence of scavenger modification on the remains (Synstelien, 2005). Sharps' study in Nebraska also showed similarities to the known raccoon behavior of nocturnal winter scavenging (Sharp et al., 1956). However, Calce's article suggested raccoon scavenging behavior that was similar to coyote scavenging behavior, which has not previously been recorded. One problem with this study is the lack of substantial raccoon data (Calce, et al., 2007). Since little research has been done specifically on raccoon scavenging, the contradicting results of previous studies demonstrate a research gap partially addressed by this thesis.

Materials and Methods

Materials

The data for this thesis are coming from a multi-year research project on Regional Forensic Taphonomy in Maine, which was funded by the Department of Justice (Sorg, 2013). As stated in a previous section, Sorg's research involved placement of nine pig cadavers in forested and non-forested environments in Maine. Pigs are a suitable as proxies for human cadavers due to their similarities with humans: (1) they have similar internal anatomy; (2) they lack extensive fur; (3) because they are relatively easy to acquire. The pigs for Sorg's project were clothed to make them smell like humans. This broad taphonomy research produced photographic and videographic data of scavenging activities on pig cadavers, which were used as surrogates for human subjects. Video and still photo trail cameras, which were triggered by heat or motion, monitored each pig cadaver day and night. Environmental information such as temperature and humidity is available on the photos and videos, which are also date and time-stamped. A tagging system was previously applied to the collections of data, which has made the segregation of images in the data for this thesis much easier. Refer to Appendix A for a list of the terms used in this system. I used the data from one wooded site, the N-Site, for my analysis. This single pig was placed in an exposed environment on October 20, 2010, at the beginning of the cold winter temperatures, but before snowfall.

Methods

This thesis is a case study of one site involved in the aforementioned research project. In order to determine the seasonality of raccoon scavenging, I sorted the photographic and videographic data into "events" organized by date, time and duration of those events, as well as by the number of raccoons present and/or scavenging and the manner of scavenging. Other variables were included in the information gathered for each event to attempt to determine a reason for the periods of high or low scavenging. These included temperature, amount of snow cover, precipitation, estimated amount of decomposition, and the presence of scavengers of other species. These data have been combined to provide qualitative and quantitative information relating to scavenging by raccoons.

I focused on one pig that was deposited in a wooded environment during cold weather (October 20) and was accessible to scavengers. The pig was placed within 15 m of an access road, similarly to many forensic cases. I recorded all of the information pertaining to raccoons in order to complete statistical analyses on the frequency and timing of raccoon scavenging. The dependent variables of this project include the frequency, duration, and manner of scavenging by raccoons on the pig cadavers. Although other species visited and occasionally scavenged this pig cadaver, raccoons were the primary scavenger at this particular site.

The independent variables specific to this project are the environmental factors of temperature, snow cover, and precipitation, as well as the presence of other scavengers. Defleshing will also be considered as an independent variable for the purposes of this project, as the rate and amount of defleshing could very likely affect the frequency and duration of animal scavenging in general. I have recorded all of these variables for each raccoon “event,” as well as logistical information about each image or video file (file name and type, date, time, etc) into an excel spreadsheet. Each row constitutes a specific event, defined below, and each column constitutes a specific event characteristic, most of them being the variables that have just been described.

All of the data have been organized into “raccoon scavenging events.” The term “event” in this context is defined as: any period of time in which raccoons are scavenging. Since most of the data occurred during the winter months with high snow cover, assessments were made about the meaning of “scavenging.” Activity other than eating remains (such as walking through the site, or interacting with each other) was not considered an event. During periods of high snow cover, events were only recorded when at least one raccoon was present in one of the tunnels or caves that were dug to access the pig cadaver. The minimum time needed to constitute an event is two minutes, and each event ends with a period of inactivity of at least thirty minutes. Each event can, and does, include multiple photographic and videographic files that are associated with it. The separation of data into events was influenced by previous articles on ethological methods, or using behavioral changes to organize data into discernable units (Monaghan, 1984). Frequency of scavenging is determined by recording scavenging events by date and calculating how these events are distributed over time. These frequency calculations can also be used to determine timing of scavenging.

Defleshing progress assessments were made for each image or video file and recorded in a specific column in the excel spreadsheet. This has been done using the Total Body Score (TBS) decomposition scoring system of Megyesi et al., (2005), initially proposed as a quantitative approach to estimating postmortem interval using decomposition phase to calculate a probable range of Accumulated Degree Days. Megyesi used data reconstructed from human forensic cases to document levels of natural decomposition over time (without scavenging). I use her Total Body Score system as a descriptive aid to assess loss of soft tissue due to defleshing. Each cadaver has been assessed for soft tissue loss at the head/neck area, the trunk, and the limbs, using a numerical scale. The head/neck area was scored from one to thirteen; a score of "one" indicating that it is fresh and a score of "thirteen" indicating that only dry bone is left. The trunk was scored from one to twelve, and the limbs were scored from one to ten. The final "Total Body Score" ranges from three to thirty-five; or fresh to completely skeletonized and dry.

There are potential problems that could arise from estimating decomposition and/or defleshing through visual media, including possible visual obstructions to the cadavers. Some TBS characteristics were impossible to observe from the photos and videos, but general assumptions were made. If visibility was obstructed in a certain file, there were several other files for the same date, which were assessed in its place.

During part of the study period, the snow cover was too high to assess the amount of defleshing on the remains. To remedy this, a linear model was produced; this is shown in the results section. This model is built with the assumption that a constant amount of defleshing occurred during the period of time of high snow cover, as inferred by daily visits by raccoons. The model line connects the defleshing score before snow obstruction with the defleshing score after the snow melted. This extrapolation line projects the likely trend in defleshing throughout the whole observation period.

Statistical analysis was done with among some of the variables. Pearson correlation coefficients (R-values) were calculated to measure the relationship between the number of events, as well as the average event length, with the average event temperature and the actual or projected amount of defleshing. These analyses were completed in order to find the strength of the relationships between specific event characteristics.

Results

As stated previously, I focused on one site from the Maine Regional Taphonomy project, the N-Site, in detail. I assessed several variables pertaining to raccoon scavenging at this site, and completed statistical analyses on those variables. The most important of those were the date and time of each event, the length of each event, the average temperature of each event, and the number of raccoons present and/or scavenging. Table 1 summarizes the statistical analyses that I completed.

As seen in the top portion of Table 1, raccoon scavenging at N-site began in February and ended in May, with a peak during the month of March. This includes the highest number of events (73) and the highest average length of scavenging events (135.9 minutes). From February to March, there is a sudden increase in both the total number of scavenging events and the length of time spent scavenging. Both of these variables seem to decrease gradually beginning in April. The changes in these monthly averages are illustrated in Figure 1.

Table 1. Statistical analysis of raccoon scavenging "events" at N-Site for each period. Months are in the top section and one-third months are in the bottom section.

Month	Number of Events	Average Event Length (Minutes)	Total Time Scavenging (Minutes)	Average Temperature	Longest Event	Shortest Event	Average No. of Raccoons Present Per Event	Average No. of Raccoons Scavenging Per Event
Oct-10	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0
Nov-10	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0
Dec-10	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0
Jan-11	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0
Feb-11	3.0	22.0	66.0	18.0	59 min	2 min	2.3	2.3
Mar-11	73.0	135.9	9923.0	21.7	426 min	7 min	2.4	2.0
Apr-11	41.0	51.5	2112.0	33.6	168 min	6 min	1.5	1.4
May-11	7.0	20.1	141.0	36.8	45 min	2 min	1.3	1.3
Jun-11	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0
Jul-11	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0
Aug-11	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0
Sep-11	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0
Total:	124	229.6 min	12,242 min					
One-Third Months Periods	**Number of Events**	**Average Event Length (Minutes)**	**Total Time Scavenging (Minutes)**	**Average Temperature (Degrees Fahrenheit)**	**Longest Event**	**Shortest Event**	**Average No. of Raccoons Present Per Event**	**Average No. of Raccoons Scavenging Per Event**
Feb 10-19, 2011	1.0	2.0	2.0	12.0	2 min	2 min	3.0	3.0
Feb 20-28, 2011	2.0	32.0	64.0	20.5	59 min	5 min	2.0	2.0
Mar 1-10, 2011	4.0	71.5	286.0	16.3	175 min	7 min	2.8	2.0
Mar 11-20, 2011	29.0	99.1	2873.0	22.7	322 min	7 min	2.3	1.8
Mar 21-31, 2011	40.0	169.1	6764.0	21.5	426 min	10 min	2.4	2.1
Apr 1-10, 2011	8.0	54.5	436.0	25.4	135 min	12 min	1.5	1.4
Apr 11-20, 2011	17.0	79.9	1359.0	29.0	168 min	10 min	1.7	1.5
Apr 21-30, 2011	16.0	19.8	317.0	42.6	37 min	6 min	1.0	1.0
May 1-10, 2011	7.0	20.1	141.0	36.8	45 min	2 min	1.3	1.3
Total:	124	229.6 min	12,242 min					

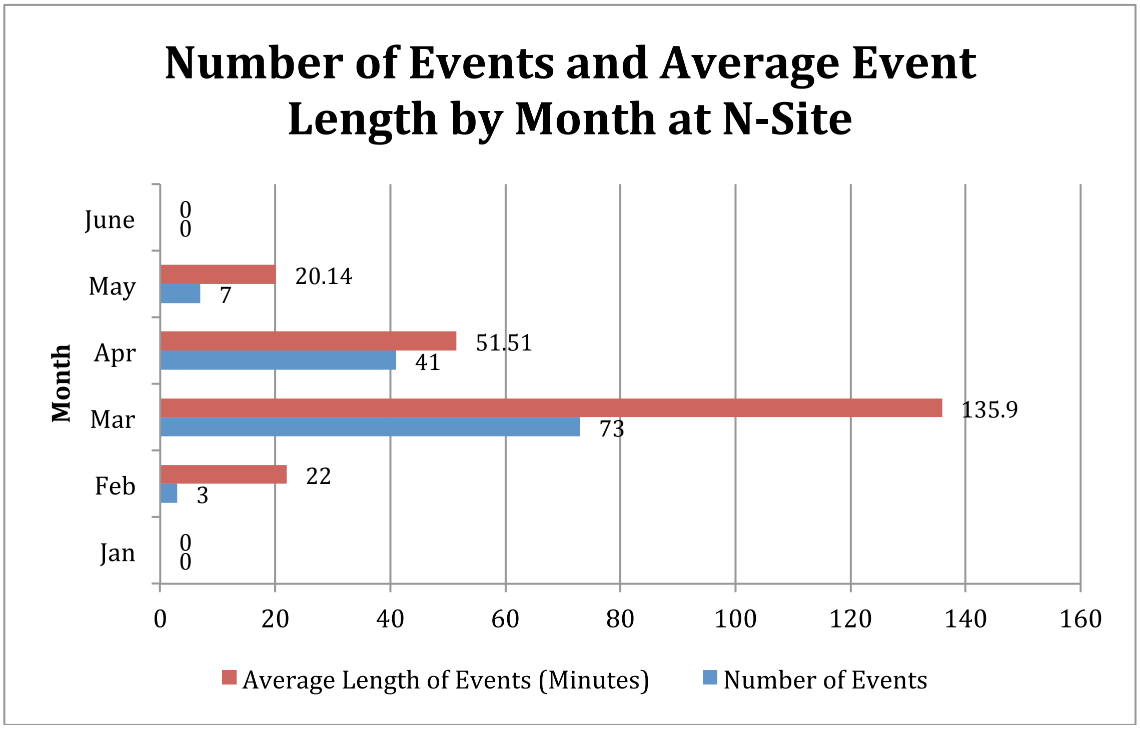

Figure 1. Number of raccoon scavenging events (blue bar) and average length of each event in minutes (red bar) for each month at N-Site.

In order to get a more detailed representation of the scavenging frequency at this site, I divided each month into three individual periods, starting with the first events in February and ending with the last events in May (Figure 2 and bottom portion of Table 1). This analysis showed a more gradual increase in both the frequency of events and the length of time spent scavenging between February and March. This activity increase ends with the major peak in the "March 21-31" time period, with 40 events and an average of 169.1 minutes for each scavenging event. There is a substantial decrease in these variables during the next period (April 1-10), followed by another increase to the minor peak in the "April 11-20" time period. This is the second-highest average length of scavenging at 79.9 minutes, and the third-highest number of events at 17. The second-highest number of events occurs in the "March 11-20" time period with 29 events.

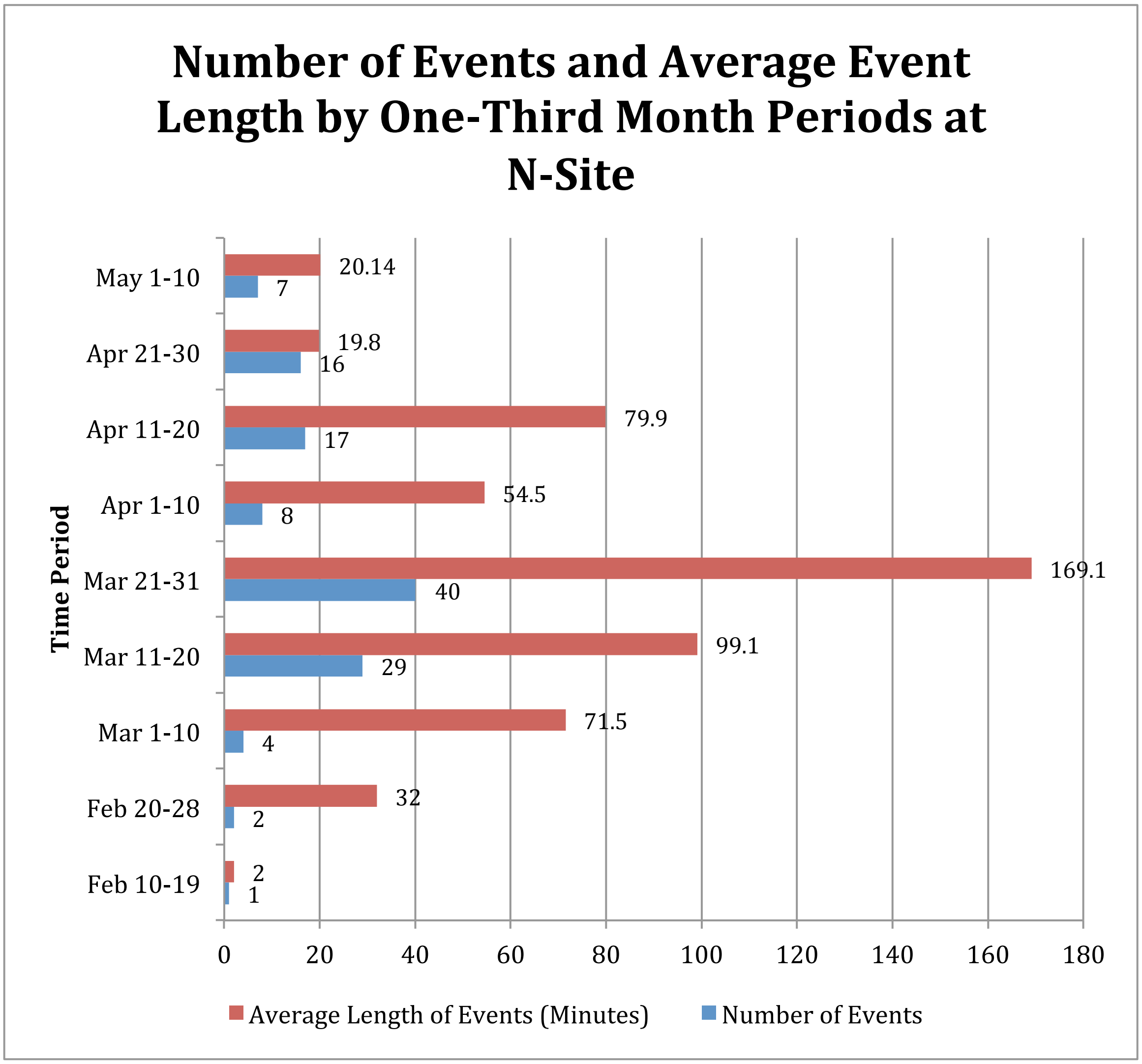

Figure 2. Number of raccoon scavenging events (blue bar) and average length of each event in minutes (red bar) for each one-third month period during the period of raccoon scavenging at N-Site.

The graph represented in Figure 3 is very similar to the graph in Figure 2; two of the variables are the same (Number of Events and Average Length of Events), but one more value is added (Average Temperature). After determining the frequency and duration of scavenging at this site, the next step is to investigate the reason for this frequency. Therefore, these data will be compared to the independent variables of the study, the first of which is temperature (Figure 3).

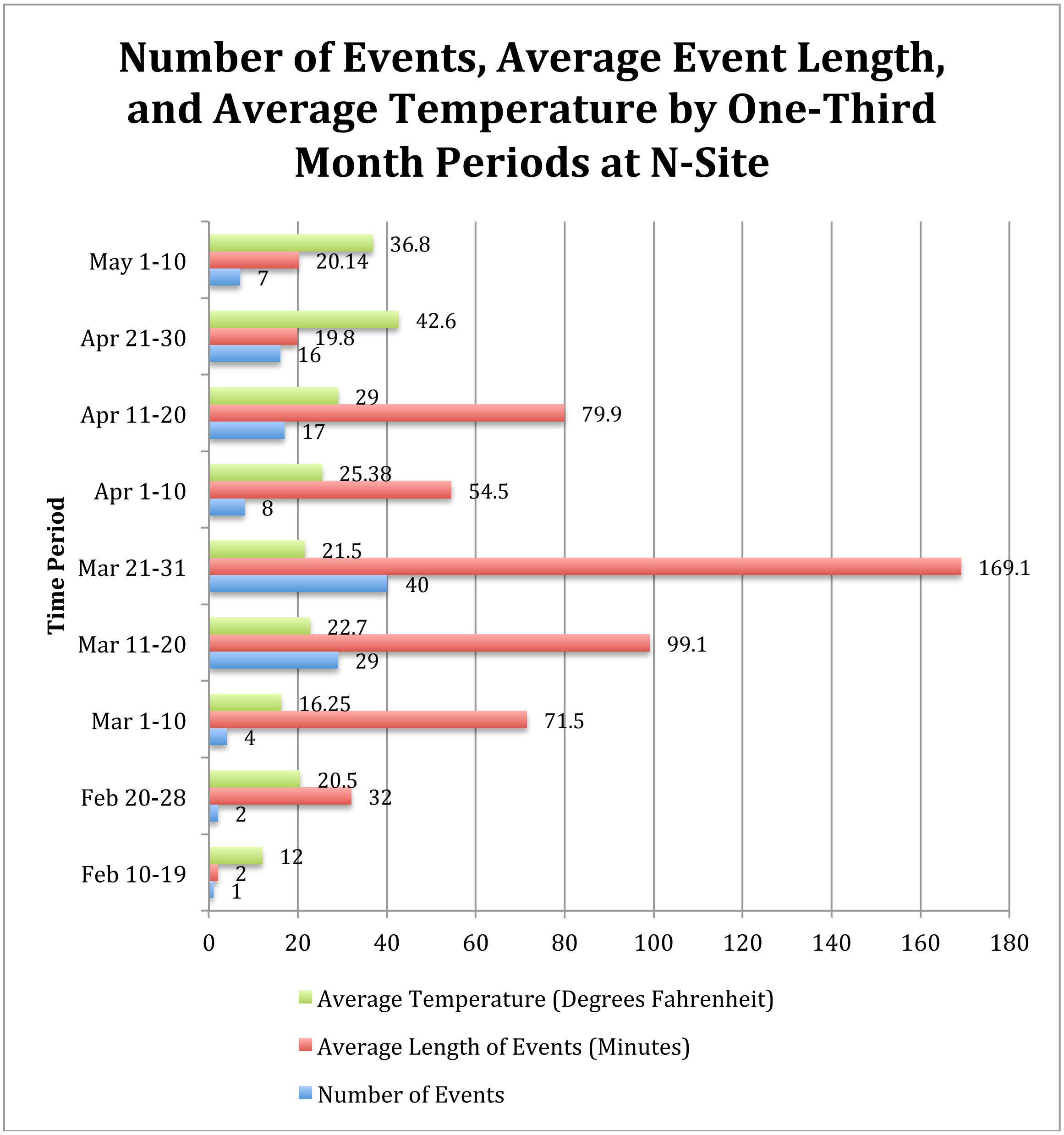

Figure 3. Number of raccoon scavenging events (blue bars), average length of each event in minutes (red bars), and average temperature in degrees Fahrenheit (green bars) for each one-third month period at N-Site.

The R-value for the Pearson correlation coefficient between the average temperature and the number of events (n=43) is 0.2335. This suggests that to a very small extent, as temperature increases, the number of events also increases. The R-value for the correlation coefficient between the average temperature and the average event length (n=43) is -0.3609 (p=0.0262), also indicating a moderate negative correlation. This suggests that to a moderate degree, as the temperature increases, event length decreases. The R-value between the estimated amount of defleshing and the number of events (n=43) is 0.3389. This is a moderate positive correlation (p=0.0174) suggesting as the amount of defleshing increases, the number of events increases. The R-value between the estimated amount of defleshing and the event length (n=43) is 0.1907. This suggests that as the amount of defleshing increases, the number of events increase moderately, but there is no significant correlation between the amount of defleshing and the event length. In any case, the correlation statistics cannot demonstrate a strong causal relationship. The frequency of scavenging visits, demonstrated by the number of events, increased both as it got warmer and as the cadaver lost flesh. The average duration of each event decreased as it got warmer. The raccoons were visiting the site more frequently as it got warmer and less flesh was available, but were staying longer at the site while it was colder and more flesh was available.

Table 2. Correlation coefficients between the number of events/average length of events and the average temperature/percent defleshed.

R-Values	Number of Events	Average Event Length
Average Temperature	0.2335	-0.3609 p= 0.0174
Estimated Percent Defleshed	0.3389 p= 0.0262	0.1907

The following table and graphs report descriptive statistics relating the two remaining independent variables (amount of defleshing and the amount of snow cover) and the dependent variables (the number of events and average event length) (see Table 3). The sample size was not large enough to calculate reliable R-values for these independent variables. The Percent Defleshed values were estimated using the Total Body Score system developed by Megyesi et al., 2005. This is a purely descriptive score. The amount of snow cover was assessed qualitatively (none, low, medium, high) for each photographic or videographic file.

Table 3. Number of events and average event length associated with the amount of snow cover and percent defleshed.

Percent Defleshed	Average Event Length (Minutes)	Number of Events		Amount of Snow Cover	Average Event Length (Minutes)	Number of Events
0.0	105.9	48.0		High	105.9	48.0
77.0	117.2	57.0		Med	161.8	32.0
91.0	20.3	18.0		Low	72.3	21.0
100.0	10.0	1.0		None	19.9	23.0

Table 3 is arranged to show the central tendency for the dependent variables (average number of events and average event length) according to each independent variable (percent defleshed and amount of snow cover) separately. The left three columns of the table shows the average length of events and the number of events associated with the percent defleshed estimate at each of four observation points. The right three columns of the table show the average length of events and the number of events associated with the amount of snow cover. For instance, by reading the left side of the table, it should be clear that at 0% defleshing, the average length of events was 105.9 minutes and there were 48 events. Similarly, by reading the right side of the table, during periods of Low Snow Cover, the average length of events was 72.3 minutes and there were 21 events. These data confirm what would be expected, i.e., that scavenging lasted longer while more flesh remained on the cadavers, and while snow cover was relatively high. Also, at low snow cover, after a large amount of defleshing had taken place, and less time was spent scavenging.

The reason for the large gap in the percent defleshing is because the remains were visibly obstructed by snow for most of the period of raccoon scavenging activity. At the time snow began to cover the remains, it had not been defleshed, but by the time the snow melted, it was clear that the remains had been mostly defleshed. Since the remains were visibly obstructed from 0% defleshed and the 77% defleshed, the timing of the defleshing could not be determined. A model to estimate the rate of defleshing between 0% and 77% will be provided below. This linear model will demonstrate the likely progress of defleshing using the timeline and the values available in the data.

It should also be noted that the amount of snow cover shown in the table is not meant to show change through time. The snow cover varied throughout the period of raccoon scavenging. These averages were calculated by adding together all of the events for each amount of snow cover (non, low, medium, or high), which produced the value for "number of events" and averaging the event lengths for each level, which produced the value for "average event length."

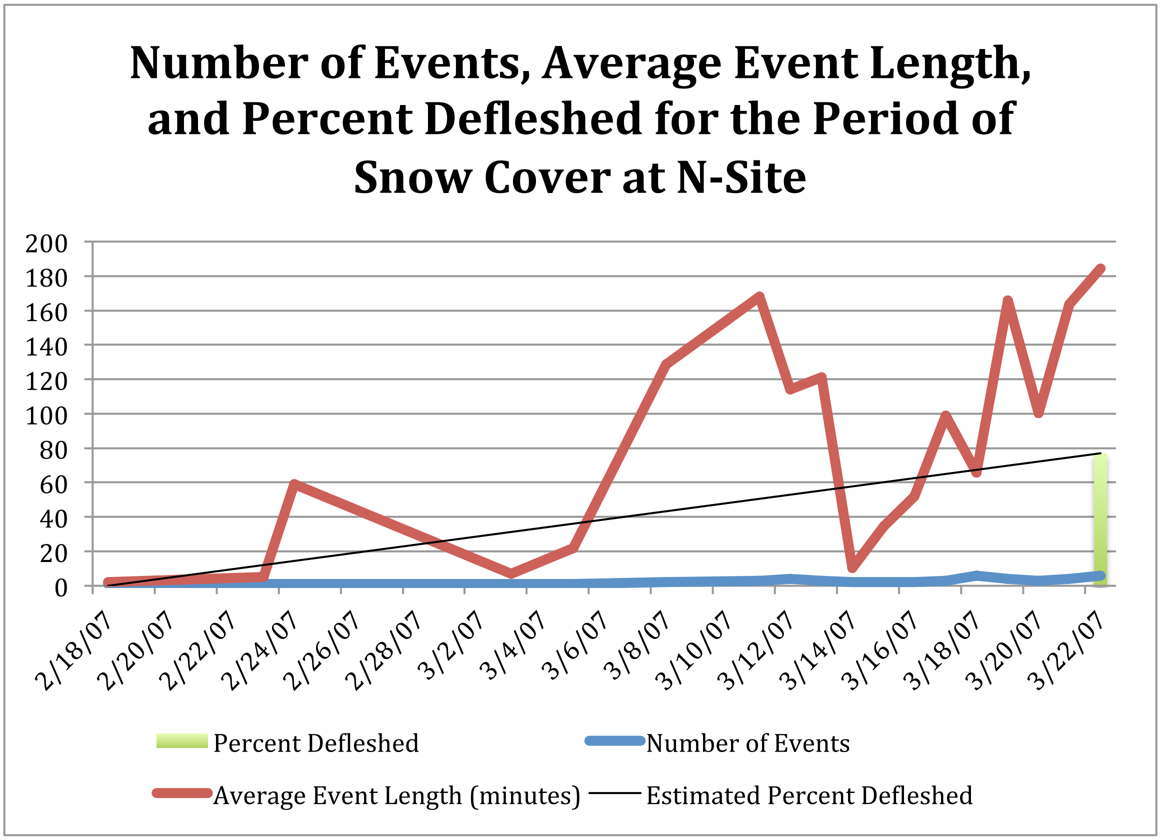

Figure 4. Number of events, average event length in minutes, and percent defleshed for the period of medium-high snow cover at N-Site.

Figure 4 shows the dependent variables graphed according to the estimated percent of defleshing, shown as a straight, solid line. It is important to note that this graph shows only the period of time that the pig cadaver was visibly obstructed by snow. The amount of defleshing was calculated using the Total Body Score system described in

Megyesi et al., 2005, and extrapolating the defleshing percentage between observational points. Each observational opportunity (when the pig cadaver could be visualized) was assigned a Total Body Score, and then the percent was calculated from that. For example, since 3 is the lowest TBS possible, then a TBS of 3 would be equivalent to 0% defleshing. This graph depicts the defleshing process using a simple linear model (black line) between the observational points of 0% and 77% defleshing (green bars). These were assessed before the snow completely covered the pig cadaver (0%) and after most of the snow had melted (77%). Between these two values, the snow cover was too high to be able to assess the amount of defleshing, therefore, the black line between the two green bars is a linear model estimated between the two (meaning it was not created with present data). This is proposing that since raccoons are scavenging on the remains, and there are two data points in time for percent defleshing, that the amount of defleshing should move in a fairly linear fashion from 0% to 77%. The red line on the graph represents the average event length and the blue line represents the number of raccoon scavenging events during this period of high snow cover. The number of events does not vary to a large extent, but a few larger increases can be seen as the event length reaches some major peaks. For example, on March 19, 2011, there are six events. Because these lines are not linear (they vary over time), it can be assumed that the amount of defleshing also varies in the same fashion as these other variables.

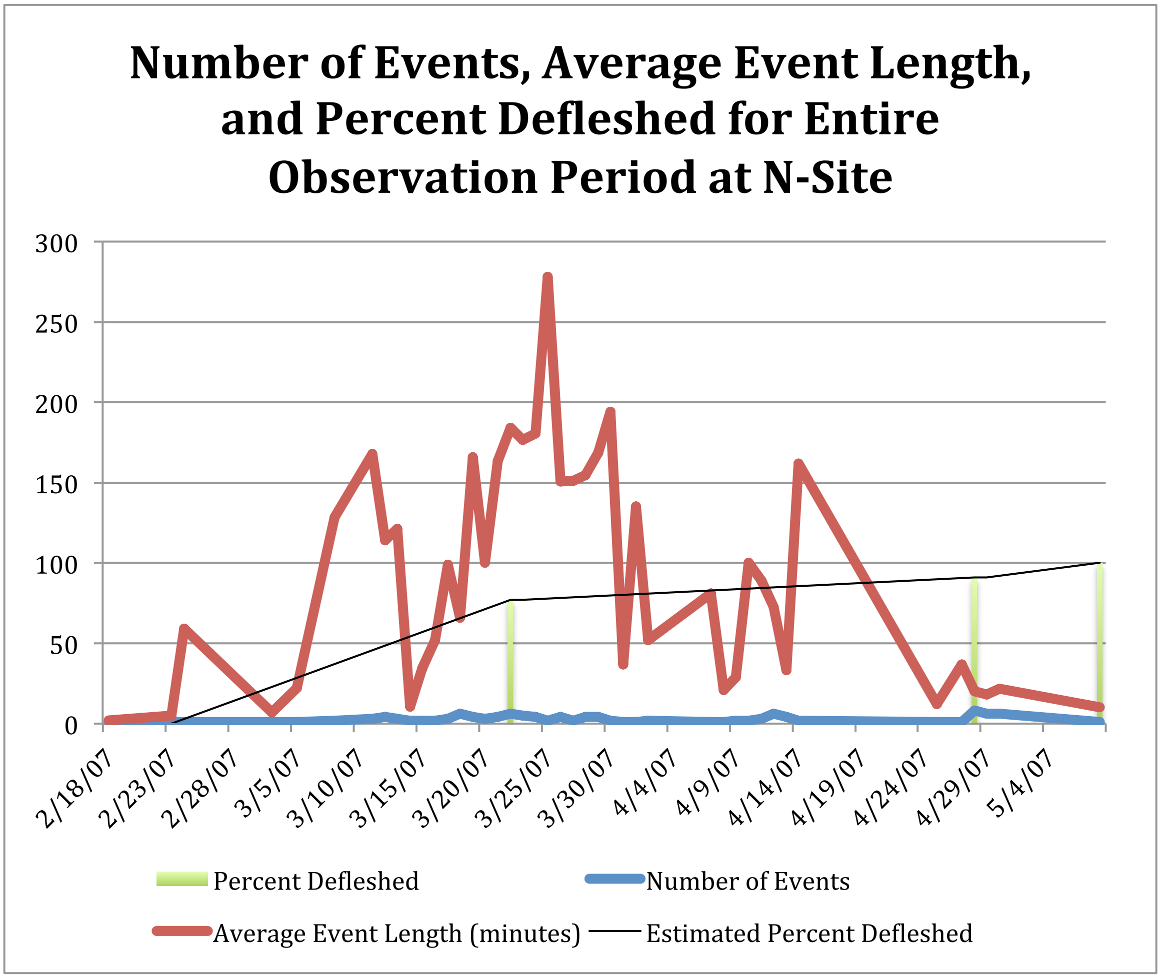

Figure 5. Number of events, average event length in minutes, and percent defleshed calculated daily for the entire observation period at N-Site.

Figure 5 is constructed with the same format as Figure 4, except that it is extended to show the activity of all of the events at N-Site. The red line represents the average event length and the blue line represents the number of events. The green bars represent the observed percent defleshed values at the first date they were assigned. For instance, the first file to be assessed as "77%" was on March 23, 2011, so that is where the green bar for that amount was placed. I continued the linear model, extrapolated for the entire period of scavenging to project the amount of defleshing between observation points. The

3/20/11 observation deviates slightly from the predicted value. The percent defleshed equals 77%, but the linear model predicted that it would be just over 50%. However, since raccoons were feeding longer and more frequently, the higher amount of defleshing during the earlier phase makes sense. The graph also shows the average event length decreasing as defleshing is nearly complete. The black line on the graph shows an averaged line using the data that is available, rather than showing the linear model, which caused these problems.

The final independent variable that was assessed was the amount of snow cover. Figure 6 shows the two dependent variables graphed according to the relative amount of snow cover visible during the viewing of the data. The values for snow cover are described as "High," "Medium," "Low," or "None" as relative qualitative terms. The periods of snow cover are intermittent. They do not reflect a sequential change over time.

The trend in values for Number of Events show the highest number events occurring during high snow cover and decreasing until low snow cover, and increasing slightly during a lack of snow cover. The average event length was highest during medium snow cover. Coincidentally, the periods of higher snow cover correlate with the mating season of raccoons. It is also possible that the decrease in these variables with decreasing snow cover is due to a decreasing amount of flesh on the pig cadavers. At the point of no snow cover, the cadavers are nearly defleshed, and there is essentially no reason for them to stay around if they have nothing to eat. The point of this section is to demonstrate that although there may appear to be a specific trend associated with the amount of snow cover, this is likely not the reason.

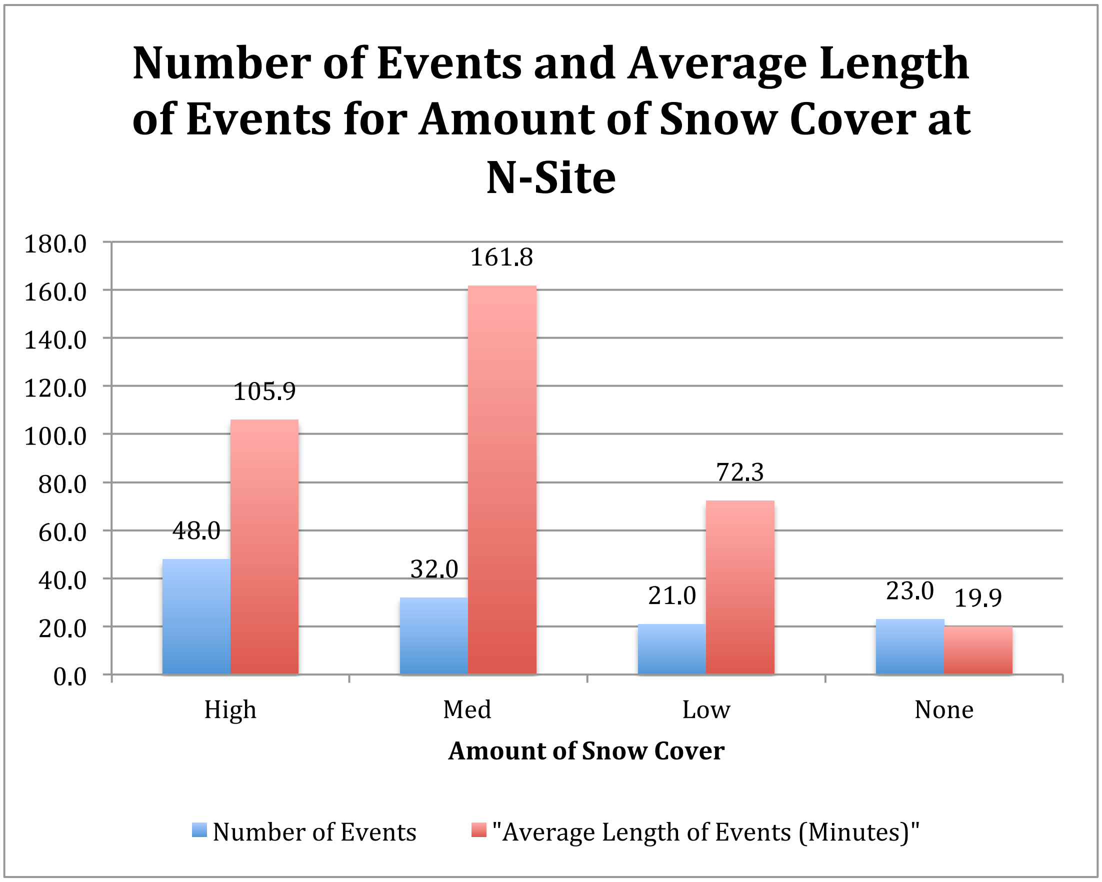

Figure 6. Number of events and the average event length in minutes for the amount of snow cover visible at N-Site.

The independent variable of day versus night scavenging is not represented in graph form. All of the scavenging done by raccoons occurred at night (between sunset and sunrise). There were no raccoon scavenging events occurring during daylight hours.

The independent variable of presence or absence of other scavengers is a nominal variable. No scavengers of other species were ever present during raccoon scavenging events. Animals of other species did scavenge quite extensively on the pig cadavers as well, but never at the same time as the raccoons.

The independent variable of precipitation refers to the presence of snowfall. Only three of the 124 scavenging events (about 2.4%) occurred during snowfall. The only dependent variable not represented is the manner of scavenging, whether involving flesh consumption or bone modification. Approximately 73% of scavenging was done visibly consuming flesh. About 27% appeared to be on bone, but it is possible that the raccoons could have been removing small pieces of muscle tissue or periosteum. No modified bone (e.g., chewed or marked) were seen or photographed during site visits following raccoon scavenging.

Discussion

The analysis of data for this study was modeled in part after a recent research project at the University of Tennessee Knoxville, which concluded that scavenging frequency was higher during the summer months, but that events generally lasted longer during the winter months (Jeong, 2014). The data for this thesis includes a case study of winter scavenging in Maine. Data from pigs deposited in warm weather were not used in my study, so a proper comparison with Jeong's project cannot be done.

The search for a correlation between dependent and independent variables in the data did not indicate an explanation for variation in scavenging frequency and duration. A literature search suggested the possibility of a correlation with the mating season, which happens during the winter months, generally from January to March. It is possible that the high level of raccoon activity was due to the availability of food, rather than the mating season, but it should be noted that scavenging by raccoons did not begin until about four months after the deposition date. Raccoons were observed at the site around the pig cadaver before this, but they were not eating. Minimal scavenging by other animals occurred before, and during raccoon scavenging (raccoons at night and other species during the day).

Environmental factors did not appear to be related to raccoon scavenging patterns. As stated previously, increasing temperature had a moderately negative correlation to event length, but no significant relationship to event frequency, although there were very few data points.

All of the scavenging events occurred at night, rather than during daylight hours, which makes sense because raccoons are nocturnal mammals. Also, the majority of scavenging events occurred during periods of no precipitation. Three out of 124 events, or about 2.4% showed precipitation in the form of snow. Another variable in this category is the presence of other scavengers. There are no events of raccoon scavenging in the presence of scavengers of other species, but at the N-Site, up to five raccoons are visible at one time.

At this time, a typical winter scavenging event by raccoons can be constructed. They occur at night and away from scavengers of other species, with medium to high snow cover, and with a peak in March. Most of the scavenging appears to be on flesh rather than bone. Up to five raccoons have been observed present at one time, but never more than four are scavenging at one time. Occasionally, one or more raccoons appear to stay off to one side, possibly waiting, while other individuals are eating. This could indicate a possible hierarchy in the group scavenging at this site. Scatter produced by raccoons at this site is minimal.

The mating season for the common raccoon in Northern states is from January to March, with a peak in February (Zeveloff, 2002). It is currently the most likely reason for the sudden increase in activity, including scavenging frequency and length. The data showed a moderate correlation between decreasing temperature and increasing event duration. However, the mating season and the change in temperature occur almost simultaneously, meaning that the trend could be correlated with the mating season, rather than simply the temperature. In more Southern states, the mating season lasts longer, and can potentially last until June (MacClintock, 1981). This could account for the difference in peak activity between the study in Maine and the study in Tennessee. Another strong contender for the difference in frequency and duration is the differences in seasonality in each region. In Maine, the average temperature is lower for much of the year, and experiences much stronger cyclic seasons, where in Tennessee, the seasons are much more mild. This may indicate that animals may have a stricter pattern of yearly activities, such as mating, in Maine rather than somewhere with a milder climate.

The amount of defleshing was one of the only variables that seemed to show a positive correlation with scavenging event frequency, although the relationship with event duration was not significant. These two dependent variables were at their highest around 77% defleshing.

As explained before, a model was constructed to project the amount of defleshing during the period of medium to high snow cover where the actual amounts could not be visibly assessed. A strictly linear model would suggest that higher scavenging occurred when the amount of defleshing was between about 30% and 80% defleshed. However, Figure 5 shows this is not exactly correct. The amount of defleshing varies with the amount of scavenging (times of high scavenging frequency are associated with more defleshing than more dormant times). In general, an increase of scavenging duration can be seen shortly after the beginning of the scavenging period. The duration remains high until the cadaver is about 80% defleshed, at which point, scavenging duration decreases until it is completely defleshed. This information allows us to reconcile the fact that scavenging may have begun as a result of the raccoon mating season, but continued due to the availability of food, and ended when food was no longer available.

Conclusions

This study included an in-depth analysis of one site, the N-Site. Several variables pertaining to raccoon (*Procyon lotor*) scavenging of pig (*Sus scrofa*) cadavers exposed to forested winter environments in Maine were assessed. The dependent variables included the frequency and average length of raccoon scavenging events, and the independent variables included environmental factors such as temperature, precipitation, amount of snow cover, and the presence of other scavengers. Loss of soft tissue, or defleshing, was also considered an independent variable.

Frequency of raccoon scavenging events, as well as the length of time spent scavenging was highest during the winter months, with the highest peak in March. This contradicts one other study on the topic. Activity patterns have been attributed to the environmental differences, which can affect the timing of cyclic life history events in mammals. The lack of significant correlation of the scavenging with environmental variables and the close alignment with the recorded raccoon mating season suggest that the peak of scavenging activity is related to the mating season rather than environmental factors.

The results of this study could hold strong implications for forensic death investigations in the state of Maine. Due to the timing of scavenging by raccoons, remains that are left exposed to the environment during the winter months could become skeletonized, possibly appearing (erroneously) to decompose much faster than the temperature would seem to allow. This could lead professionals to assume that a set of remains had been exposed longer than it actually had been left, resulting in larger postmortem interval estimations than what is correct. Also, because raccoon scavenging lacks bone modification that is characteristic of carnivorous and omnivorous mammals, investigators might (erroneously) think the soft tissue loss was due to decomposition rather than defleshing. An opportunity for further study of this subject is possible, and encouraged, by assessing raccoon scavenging in warmer months and comparing the results to the results of winter scavenging.

In addition to implications for the forensic science community, a similar impact could occur when assessing skeletal artifacts from archaeological sites. Scavenging by raccoons is not always easy to discern on skeletal materials, whether they are faunal or human remains. As stated previously, raccoons focus on defleshing aspects of scavenging and spend very little time relatively on bone modification. This leaves next to no marks on the bones that could help characterize postmortem taphonomic events or leave a long-term raccoon signature.

This study concluded that raccoons scavenge frequently during late winter in association with their mating season. They do not scavenge in the presence of scavengers of other species. The result of their scavenging is a loss of soft tissue without bone modification and minimal scatter, which could erroneously lead to the assumption that little scavenger activity had taken place.

References Cited

Berryman, HE. 2002. Disarticulation pattern and tooth mark artifacts associated with pig scavenging of human remains: a case study. In: Haglund WD, Sorg MH, editors. Advances in Forensic Taphonomy: Method, Theory, and Archaeological Perspectives. CRC Press, Boca Raton, FL. p 487-497.

Calce SE and Rogers TL. 2007. Taphonomic changes to blunt force trauma: a preliminary study. *Journal of Forensic Sciences* 52(3):519-527.

Camaros E, Cueto M, Tiera LC, Tapia J, Cubas M, Blasco R, Rosell J, Rivals F. 2012. Large carnivores as taphonomic agents of space modification: an experimental approach with archaeological implications. *Journal of Archaeological Sciences* 40:1361-1368.

Clark MA, Worrell MB, Pless JE. 1997. Postmortem changes in soft tissues. In: William D. Haglund and Marcella H. Sorg. Forensic Taphonomy: The Postmortem Fate of Human Remains. CRC Press, Boca Raton, FL. pp. 139-164.

Duhig C. 2003. Non-forensic remains: the use of forensic archaeology, anthropology and burial taphonomy. *Science & Justice* 43(4):211-214.

Gehrt SD and Fritzell EK. 1996. Second estrus and late litters in raccoons. *Journal of Mammology* 77:388-393.

Gill-King H. 1997. Chemical and ultrasonic aspects of decomposition. In: William D. Haglund and Marcella H. Sorg. (Editors.) Forensic Taphonomy: The Postmortem Fate of Human Remains. CRC Press, Boca Raton, FL. pp. 93-108.

Haglund WD. 1997. Dogs and Coyotes: Postmortem involvement with human remains. In: Haglund WD, Sorg MH, editors. Forensic Taphonomy: The Postmortem Fate of Human Remains. CRC Press, Boca Raton, FL. pp 367-381.

Haglund WD and Sorg MH (Editors). 1997. Forensic Taphonomy: The Postmortem Fate of Human Remains. CRC Press, Boca Raton, FL.

Haglund WD and Sorg MH (Editors). 2002. Advances in Forensic Taphonomy: Method, Theory, and Archaeological Perspective. CRC Press, Boca Raton, FL.

Haglund WD and Sorg MH. 2005. Taphonomy. In J. Payne-James (ed.) Encyclopedia of Forensic and Legal Medicine. Academic Press, New York, NY.

Jeong Y, Jantz LM, Smith J. 2014. Investigation into seasonal scavenging patterns of raccoons on human decomposition. Unpublished manuscript, University of Tennessee Knoxville.

Lyman RL. 1994. Vertebrate Taphonomy. Cambridge: Cambridge University Press.

MacClintock D. 1981. A Natural History of Raccoons. New York: Scribner.

Macdonald DW. 1983. The ecology of carnivore social behaviour. *Nature* 301:379-384.

Marden K and Sorg MH. 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* 17:388-389.

Marshall LG. 1989. Bone modification and the "laws of burial." In: Bonnichsen R, Sorg MH, editors. Bone Modification. Center for the Study of the First Americans, Orono, ME. pp 7-24.

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.

Monaghan P. 1984. Applied ethology. *Animal Behavior* 32:908-915.

Moraitis K, Spiliopoulou C. 2010. Forensic implications of carnivore scavenging on human remains recovered from outdoor locations in Greece. *Journal of Forensic and Legal Medicine* 17:298-303.

Rippley A, Larison NC, Moss KE, Kelly JD, Bytheway JA. 2012. Scavenging behavior of *Lynx rufus* on human remains during the winter months of Southeast Texas. *Journal of Forensic Sciences* 57(3):699-705.

Sharp WM and Sharp LH. 1956. Nocturnal movements and behavior of wild raccoons at a winter feeding station. *Journal of Mammology* 37(2):170-177.

Sorg MH. 2011. Scavenging Impacts on the Progression of Decomposition in Northern New England. *Proceedings of the Annual Meeting of the American Academy of Forensic Sciences* 17:384-385. (Extended abstract)

Sorg MH. 2013. Developing regional taphonomic standards. Unpublished Manuscript, University of Maine, National Institute of Justice.

Sorg, MH, David E, Rebmann A. 1998. Cadaver Dogs, Taphonomy, and Postmortem

Interval in the Northeast. In: Kathleen J. Reichs. (ed.) Forensic Osteology: Advances in the Identification of Human Remains. Charles C. Thomas, Springfield, IL, pp. 120-144.

Sorg, MH and Haglund WD. 2002. Advances in Forensic Taphonomy: Purpose, Theory, and Process. In: William D. Haglund and Marcella H. Sorg (ed.), Advances in Forensic Taphonomy: Method, Theory, and Archaeological Perspective. CRC Press, Boca Raton, FL, pp. 3-29.

Sorg MH, Haglund WD, Wren JA. 2012. "Taphonomic impacts of small and medium-sized scavengers in northern New England." *Proceedings of the Annual Meeting of the Academy of Forensic Sciences* 18:400.

Sorg MH and Marden K. 2013. Developing Frameworks for Regional Taphonomy Research and Practice: A Multi-Regional Symposium. *Proceedings of the Annual Meeting of the American Academy of Forensic Sciences* 19:454-455.

Sorg MH, Wren JA, Parker WD. 2013. Regional and Micro-Environmental Taphonomic Variation and Decomposition in Northern New England. *Proceedings of the Annual Meeting of the American Academy of Forensic Sciences* 19:463.

Synstelien, JA, Klippel WE, Hamilton MD. 2005. "Raccoon (*Procyon lotor*) foraging as a taphonomic agent of soft tissue modification and scene alteration." *Proceedings of the Annual Meeting of the American Academy of Forensic Sciences* 11:333-334.

Young A, Marquez-Grant N, Stillman R, Smith MJ, Korstjens AH. 2015. An investigation of red fox (*Vulpes vulpes*) and Eurasian badger (*Meles meles*) scavenging, scattering, and removal of deer remains: forensic implications and applications. *Journal of Forensic Sciences* 60(S1):S39-S55.

Zeveloff SI. 2002. Raccoons: A Natural History. Smithsonian Institution Press, Washington.

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Appendix A

Adobe Bridge Tagging Keywords

Bird Presence
- Bird Eating
- Blue Jay
- Chickadee
- Multiple Bird
- Partridge
- Raven
- Robin
- Turkey
- Turkey Vulture

Camera Source
- Andy Still
- Trail Cam Still
- Trail Cam Video

Decomposition, Soft Tissue Loss
- All Disarticulation
- Bloat
- Bone Exposure: All
- Bone Exposure: Large
- Bone Exposure: Medium
- Bone Exposure: Small
- Bone Movement: Large
- Bone Movement: Medium
- Bone Movement: Small
- Defleshing: Large
- Defleshing: Medium
- Defleshing: Small
- Bone modification/consumption
- Flesh modification/consumption
- Decomposition fluids present
- Some Disarticulation
- Visible Decomposition Island

Insect Involvement
- Flies present
- Larvae present

Mammal Involvement
- Multiple Species

Black Bear
Bobcat
Chipmunk
Coyote
Deer
Domesticated Dog
Ermine
Fisher Cat
Flying Squirrel
Gray Squirrel
Lynx
Mammal Digging
Mammal Eating
Mouse
Multiple Mammals
Pine Marten
Porcupine
Rabbit
Raccoon
Red Squirrel
Skunk

Research Visit

Site Names

Site M-Oct 10
Site N-Oct 10
Site O-May 11 Spring Woods
Site O-Oct 10
Site O-Sep 11 Fall Field
Site O-Sep 11 Fall Woods

Weather

Full Snow Cover
Partial Snow Cover
Snowing

Personal Biography

Ashley Hannigan was born and raised in rural Houlton, Maine from November 1991 and graduated third in her class from Houlton High School in 2010. Her enrollment at the University of Maine began in the fall of 2010. She will graduate with her Bachelor's degree in Anthropology with a minor in Biology in 2015, and will soon be beginning work on her Master's degree in Anthropology, concentrating specifically on Biological Anthropology at the University of Alaska Anchorage.