Forensic Science International xxx (2009) xxx–xxx

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

Scavenging activity can produce predictable patterns in surface skeletal remains scattering: Observations and comments from two experiments

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ARTICLE INFO

Article history:
Received 1 August 2008
Received in revised form 13 February 2009
Accepted 21 March 2009
Available online xxx

Keywords:
Taphonomy
Scavenger activity
Scattered remains
Dispersed remains

ABSTRACT

In forensic contexts, surface deposited remains are frequently found that have been scattered by various taphonomic processes. In an effort to develop strategies to improve recovery rates, this study evaluates whether patterns can be detected in the scattering of remains due to scavenger activity. In two experiments, 24 human analogues (pig carcasses) were placed in two adjacent but differing environmental contexts: 12 in wooded and 12 in open grassland. Six carcasses in each of these contexts were dressed in human clothing. Elapsed time and direction of movement information for each carcass and its parts were collected and analyzed. Unclothed carcasses and carcasses in open contexts exhibited scavenger activity sooner than the others. Scattering of remains occurred along game trails and was directed away from human population and activity. Due to the highly variable nature of scavenger activity, daily observations during a research project are the key leading to a better understanding of the development of these patterns.

1. Introduction

Past research in the area of surface scattered human remains relating to forensic identification and evidence recovery issues has been mainly of an anecdotal or cross-sectional nature [1–5]. As they generally do not involve an investigation and evaluation of the processes involved, these studies have not been successful in explaining, or not focused on determining, what may be the patterns in the scattering of remains due to scavenger activity.

It is postulated here that knowledge of any real patterns in the scattering of scavenged remains would enable a more focused and productive manner of conduct in the searching of a crime or death scene. It is also logical to suggest that the recovery rate of skeletal remains would increase as a result.

To investigate the possibility that discrete and distinctive scattering patterns are produced during animal scavenging activities on surface deposited remains, a longitudinal study was designed and carried out using a sample of 24 deceased pigs (*Sus scrofa*). In 2002, and over a period of 105 days from 3 May to 15 August, 12 pigs were placed in an outdoor context located at a secure University of Alberta field research facility located in south Edmonton, Alberta, Canada. Using the same locations and roughly the same seasonal time frame, the experiment was repeated in 2004, this time over a period of 99 days from 18 May to 25 August. The results of this research are reported here.

2. Methods

The methods and materials were originally conceived and organized in May 2002 as a pilot study and the basis for the primary author's graduate thesis. Building on the results of this initial research, and with the goal of increasing the sample size, the experiments were repeated with minor modifications in May 2004.

The study site is located in south Edmonton at the Ellerslie Research Station (ERS) on 60 ha (ca. 150 acres) of land (Fig. 1). In 2002 suburban housing developments had approached to within 5 km, and by 2004 new housing construction had been initiated within 1 km. The research station is an agricultural farm with one residence and several supplies and machinery buildings. The facility is leased and operated by the University of Alberta and is considered private land; signs are posted around the fenced perimeter and clearly mark the boundaries to visitors and passers-by. The land has been substantially cleared of forested areas to accommodate the needs of ongoing agricultural studies; however, there are some large areas that have been left wooded and are not used by the members of the facility. The study area for this project included two of these wooded areas and the adjacent open grassland.

All pig carcasses used in the experiments were obtained from a commercial meat processing plant within 24 h of death. Pigs were industry casualties, and none were killed for this project. Although exact weight was not determined, the selected pig carcasses were of approximately equal size and estimated to be within the 35–45 kg range. Pigs have been established as viable human analogues in decomposition studies [6,7], and their use in scattering experiments is becoming standard [1,4,8–11]. With data obtained by Toots [12], Hill [13], and Hill and Behrensmeyer [14], Haglund [15] has demonstrated that the major difference between the disarticula-

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doi:10.1016/j.forsciint.2009.03.022

Fig. 1. Aerial photograph of the study site, Ellerslie Research Station, Edmonton, Alberta, showing the 12 alphabetically identified location sites for the 2002 and 2004 experiments. Scale: the distance from B to K is 700 m. (adapted; reproduced with permission, Government of Canada, 1995).

tion patterns of quadrupedal mammals and humans is the timing in disarticulation of the hindlimbs and forelimbs. While pigs were not included in these studies, it is reasonable to assume that disarticulation patterns would be similar to other quadrupeds and, therefore, humans. As the current studies were naturalistic, very few variables could be controlled, and, in some cases, isolated and identified. The current experiments used pigs as human analogues to control for decomposition and disarticulation patterns.

A sample of 12 pigs was placed in outdoor settings in May of 2002. Six pigs (3 dressed in human clothing, 3 unclothed) were placed in open, grassland, non-shaded locations (Fig. 1, locations A, B, C, D, L, M), and 6 pigs (3 dressed, 3 unclothed) were placed in wooded, shaded locations (Fig. 1, locations E, F, G, H, J, K). Clothing was selected to reflect seasonal wear (i.e. late Spring) and included a mix of cotton and synthetic shirts, dresses and long pants. Underclothing was not used. Time since death (TSD) was taken as zero at the time of placement, and the condition of each carcass was noted and photographed. Subsequent data collection of scavenger activity, movement of the carcass and/or parts, and decomposition information were accomplished through planned daily visits by one of us (YPK) to the site, though some observation days were lost due to severe weather and a small number of unforeseen circumstances. Movement of each carcass and its parts was measured from previously set and surveyed control points established across each site.

In May of 2004, and following removal of the remains from 2002, the experiment was repeated with another 12 pigs of comparable sizes, using the same locations.

3. Results

Scavenging activity caused by birds tended to precede other scavenging activity and the eventual movement of the carcasses. Crows and magpies were characteristically seen flying away from the carcasses as the researcher approached. Tissue damage associated with bird pecking [8] was also observed on some carcasses.

Prior research and ongoing observations at the research facility had identified canids as the primary scavengers. They are the only indigenous animals present at the site that could move the 35+ kg carcasses, and the nature of the gnawing and serrated appearance of the damaged tissues supports this observation [3]. Coyotes in close proximity to the carcasses were photographed with a tree-mounted TrailMaster® Infrared Trail Monitor consisting of a weatherproof 35 mm camera triggered by a motion detecting infrared beam. The infrared beam was set to trigger the camera if animals came onto the site between the hours of 11 PM and 5 AM. Unfortunately, no animals were observed directly interacting with the carcasses, but the circumstantial evidence is clear.

Once the canid scavenging began, carcasses were quickly consumed or transported from the site. Movement of the carcasses occurred in 1 event on 1 day or in several events over the course of a few days.

Skeletal element categories used in these studies followed the disarticulation grouping pattern established by Haglund [15]. The disarticulation patterns observed in 2002 and 2004 were consistent with those reported by Haglund [15], Toots [12], Hill [13] and Hill and Behrensmeyer [14]. The scattering of skeletal elements consequently was influenced by this disarticulation pattern; for example, limbs were not indicative of the original placement point because the humerus or femur usually disarticulated from the torso before the ribs. The ribs and vertebrae were indicative of the original placement point as they were the last to disarticulate.

In 2002, all carcasses exhibited scavenging activity and movement. Four of 12 carcasses (33%) were distributed in a random manner and variable distances from the original location (the starting point), or were minimally moved. In randomly scattered remains, no discernable pattern or direction of movement of the remains was observed. Eight of 12 carcasses (67%) were moved in a non-random manner. In non-randomly scattered remains, a specific direction or a pattern was observed in the movement or scattering of the remains. This direction of movement was often clearly visible as a path through the foliage either made by the scavengers dragging the carcass, or representative of an existing game trail. In either case, the path was usually scattered with remains, including flesh and clothing. In all cases in 2002, the non-random movement was in a southerly to westerly direction. This direction corresponds to travel away from human activity, and towards more natural shelter. Although no dens were discovered, it is suspected that coyotes approached the site from the South.

In 2004, all carcasses exhibited scavenging activity and movement. All carcasses and parts thereof followed the non-random pattern observed in 2002, that is, all movements were in southerly to westerly directions, with one exception. This exception (location/pig L) moved to the North and West, away from shelter and towards the centre of the research facility. As in 2002, paths delineating direction of movement were observed and consisted of existing as well as newly made game trails.

When the carcasses were moved in a random, non-directional manner (the 4 in 2002), more bone elements were found in close proximity to the original placement point than when carcasses were moved in a non-random manner (Tables 1 and 2). Ribs and vertebrae were the most common bone element categories located

Table 1
Bone element categories (I–IV) remaining within 100 m^2 of original deposition point (2002).

	Cranium (I)	Ribs/Vert. (II)	U. Limbs (III)	L. Limbs (IV)
Non-random sites				
Bloating				
Location/Pig D	0	0	0	0
Deflation				
Location/Pig G	0	X	X	X
Location/Pig K	0	X	X	0
Active decay				
Location/Pig B	0	X	X	0
Location/Pig C	0	X	0	0
Location/Pig E	0	X	0	X
Location/Pig H	0	X	0	X
Location/Pig M	X	X	X	0
Random sites				
Active decay				
Location/Pig F	X	X	X	X
Location/Pig J	X	X	X	X
Advanced decay/ skeletonized				
Location/Pig A	X	X	X	X
Location/Pig L	X	X	X	X

X = bone element of category found; 0 = no bone element of category found. *Note*: Decomposition stages as cited in Anderson and VanLaerhoven [5] are used as a general guideline.

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Table 2
Bone element categories (I–IV) remaining within 100 m^2 of original deposition point (2004).

	Cranium (I)	Ribs/Vert. (II)	U. Limbs (III)	L. Limbs (IV)
Non-random sites				
Bloating				
Location/Pig B	0	0	0	0
Location/Pig C	0	X	X	X
Location/Pig D	0	0	0	0
Location/Pig H	0	X	0	0
Location/Pig M	0	X	X	X
Deflation				
Location/Pig K	0	X	0	0
Active decay				
Location/Pig E	0	X	X	X
Location/Pig F	0	X	X	X
Location/Pig G	0	X	0	X
Location/Pig J	0	X	X	0
Location/Pig L	X	0	X	0
Advanced decay/skeletonized				
Location/Pig A	X	X	X	X

X = bone element of category found; 0 = no bone element of category found. *Note*: Decomposition stages as cited in Anderson and VanLaerhoven [5] are used as a general guideline.

in close proximity to the original placement point regardless of movement type (2002: 11 of 12; 2004: 9 of 12). The decomposition stage at the time of scavenging activity onset seemed to correlate with the number of bone element categories discovered close to the original placement point. Fewer bone elements were found close to the original placement point when a carcass was in an earlier decomposition stage; more were found when a carcass was in a later stage. For example, when scavenging activity onset occurred while a carcass was in a later stage of decomposition, 4 bone element categories were usually found, but 2 or less were represented when scavenging activity onset occurred while the carcass was in an earlier stage.

Figs. 2 and 3 compare scavenging activity onset to the environmental context and clothing, respectively. In 2002, there did not seem to be a scavenger preference between wooded and open contexts (wooded mean = 42.3, open mean = 43.3 days since death), but this was not seen in the 2004, when open contexts exhibited scavenger activity sooner than wooded ones (open mean = 42.8; wooded mean = 61.2 days since death). In 2002, unclothed carcasses exhibited scavenging activity sooner (mean = 32.3 days since death) than clothed carcasses (mean = 53.3 days since death). This was also exhibited in 2004 (unclothed mean = 44.3 days since death, clothed mean = 59.7 days since death).

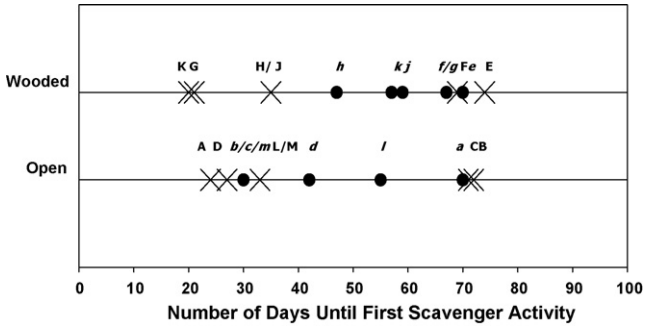

Fig. 2. Scavenging activity onset compared to environmental context. Upper case letters are pig identifiers from 2002, lower case for 2004. X = 2002, ● = 2004. 2002 wooded statistics: max. = 74, min. = 21, mean = 42.3, n = 6. 2002 open statistics: max. = 72, min. = 24, mean = 43.3, n = 6. 2004 wooded statistics: max. = 70, min. = 47, mean = 61.2, n = 6. 2004 open statistics: max. = 70, min. = 30, mean = 42.8, n = 6.

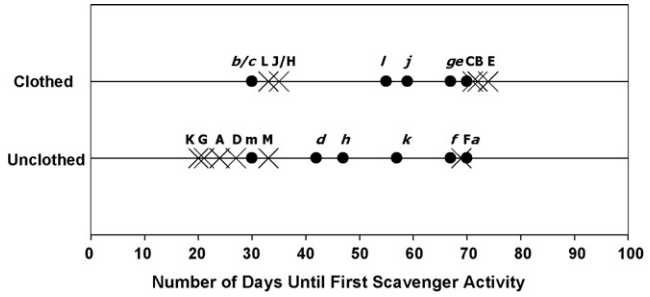

Fig. 3. Scavenging activity onset compared to clothing context. Upper case letters are pig identifiers from 2002, lower case for 2004. X = 2002, ● = 2004. 2002 clothed statistics: max. = 74, min. = 33, mean = 53.3, n = 6. 2002 unclothed statistics: max. = 69, min. = 21, mean = 32.3, n = 6. 2004 clothed statistics: max. = 70, min. = 30, mean = 59.7, n = 6. 2004 unclothed statistics: max. = 70, min. = 30, mean = 44.3, n = 6.

4. Discussion

Little has been reported on the patterns in the scattering of remains associated with scavenger activity. Research has been conducted by Morton & Lord [9–11] and Crader [16], who attempted to document the process of scavenging on animal carcasses; however, these studies relied on sample sizes considered to be too small to reveal the presence of predictable patterns.

The data gathered in this study support most of the evidence presented by cross-sectional studies and studies reliant on small sample sizes. Haglund [17] presents evidence that ribs and vertebrae are likely to remain closest to the original placement point. The results of this study support this evidence. As it was found that the disarticulation sequences of the pigs were similar to those for other mammalian quadrupeds and humans, additional support is provided for the use of pigs as a viable human analogue in both decomposition and scattering studies. This study also suggests that if a carcass is in a later stage of decomposition and is moved in a non-random manner, more bone element categories will be located close to the original placement point. If the carcass is in an earlier stage of decomposition prior to movement, fewer bone element categories will be located close to the original placement point. These data would suggest that the decomposition stage correlates with disarticulation sequence: as the decomposition stage increases so does the likelihood that the skeletal elements will be individually disarticulated rather than as a group. If the carcass is scavenged before a later stage of decomposition has been reached, the skeletal elements will still be sufficiently held together by intact muscles, tendons, and ligaments that they will be pulled from the carcass as a disarticulation group and transported away from the original placement point. It has been suspected that specific joints and the decay of the surrounding tissues contribute to the rate of disarticulation of individual joints [12,13]. For the purposes of recovering skeletal remains, the correlation between degree of decomposition and disarticulation sequence can be used as an indication of the original placement by the identification of the found skeletal element groups.

Haglund's [17] and Haglund's et al. [18] evidence also suggests that game trails are places of high potential in a search for remains, stating that drag marks may lead back to the carcass's original position. This study supports the search of game trails for possible scattered remains and, further, the search for newer paths made by scavengers dragging the carcass and its remains. Wiley and Snyder [19] suggest that it is difficult to correlate scavenging activity with the post-mortem interval and, therefore, cannot be used as an indicator of time since death. This study found no correlation between scavenging activity and TSD. On the other hand, though

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Manheim [5,20] provides evidence suggesting that there is no directional component to remains scattered by scavenging activity, our studies demonstrate that the movement of a carcass and its parts typically occurs in directions leading away from human activity. While no coyote dens were found, this observed directional movement of each carcass in both years of the study may be explained by coyote behaviour.

A component of this study not found in the literature concerns scavenger preference for clothed or unclothed carcasses and those in wooded or open situations. It was clear that scavengers preferred unclothed carcasses in open environmental contexts. The carcasses in these situations tended to exhibit scavenging activity before others in clothed and wooded situations. The stage of decomposition might account for this bias in scavenging preference, but there is no pattern in the results that supports this interpretation. In 2002, the carcasses in the open contexts reached later stages of decomposition and exhibited scavenging activity later than some clothed and wooded carcasses. In contrast, in 2004, one-half of the open situated carcasses exhibited scavenging activity sooner than the ones in wooded contexts and were in an earlier stage of decomposition.

It might have been implied that since most of the carcasses on the south end of the study were in open contexts they would have been scavenged first, as suggested by Fig. 3. If the scavengers came from the South (as the directional movement of each carcass illustrates), then this would be a possible explanation. But this was not the case. Carcasses at locations C and B in 2002 and A in 2004 were among the last to exhibit initial scavenging activity. It is possible that the decomposition of the southern most carcasses alerted the scavengers to the area even though they may not have fed upon them; however, there were many carcasses between the Southern most locations A–C and the carcass at location K, nearly 1 km to the North. In both 2002 and 2004, the carcasses at location K exhibited scavenging activity earlier than most other carcasses in wooded situations to the South.

5. Conclusion

Overall, this study provides evidence that patterns exist in the way surface deposited remains are scattered due to scavenger activity. Also, evidence is provided that time since death is not a good indicator for time of scavenging activity onset or vice versa, though the decomposition stage could be the key to how and where surface deposited remains may be located. Our findings also provide support for a number of earlier cross-sectional and small sample size studies. While the results discussed here may be study-specific, the consistency of the 2002 and 2004 data provides support for the conclusions that the effect scavengers have on surface deposited carcasses can be predicted, and a knowledge of how scavengers scatter remains non-randomly can lead to a more confident search and recovery plan in real cases.

Acknowledgement

Support for this research was provided in part through a grant from the Natural Sciences and Engineering Research Council of Canada.

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