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PAPER

ANTHROPOLOGY

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The Influence of Penetrative Trauma on the Rate of Decomposition*†

ABSTRACT: An understanding of the factors affecting decomposition is important for the accurate estimation of postmortem interval. An experimental study on the influence of penetrating trauma on decomposition rate was carried out using the domestic pig, *Sus scrofa.* The results of this study were: (i) Diptera were preferentially attracted to and oviposited at natural orifices. Trauma sites were not preferentially selected for oviposition; (ii) no differences between trauma and non-trauma groups were found in time to skeletonization, weight loss ($p = 0.906$), total body score ($p = 0.824$), body temperature ($p = 0.967$), or changes in soil pH ($p = 0.684$); and (iii) the effect of investigator disturbance was significant when decomposition was measured as weight loss ($p = 0.000$). This study suggests that penetrating trauma of the type used in this study cannot be considered a major factor in the rate of decomposition and time to skeletonization of a gunshot trauma victim.

KEYWORDS: forensic science, forensic anthropology, taphonomy, decomposition, trauma, arthropods

This research examines the influence of multiple gunshot injuries on soft tissue decomposition on the ground surface. A number of inter-related variables influence soft tissue decomposition rates (1). Temperature is the greatest influence on decomposition (1–5) and an increase will accelerate the rate of decomposition. Insect activity is also widely recognized as being a highly influential factor (1,6) and is heavily dependent on temperature (1,7–9), with warmer temperatures encouraging more oviposition and larval development.

Diptera (flies) are attracted to the natural orifices of the body as a result of volatile gases released in initial and ongoing postmortem processes and the fact that they provide a warm, moist, sheltered area in which to oviposit (10). Anecdotal evidence holds that insects will oviposit on open wounds as well as natural orifices (1). Coleoptera (beetles) are also important arthropods that contribute to the decomposition process. These arthropods usually appear in the later stages of decomposition and tend to prefer drier remains; however, in ideal conditions, they can appear in large numbers and cause significant tissue loss (11).

Observations from the Anthropological Research Facility (ARF) at the University of Tennessee suggested that penetrating trauma influences decomposition rates (1). This observation was clearly visually based, and indicated that a chest wound appeared to attract insect succession preferentially; the area showed extensive maggot activity and tissue destruction. Whilst the authors also state that a wounded individual decomposed more rapidly, there are no quantitative data whatsoever reported to substantiate this. It must be remembered that the sample observed consisted of a single case with a gunshot to the chest and a single case with no gunshot wounds (1). The authors clearly state that "the effect of trauma *might* (emphasis added) explain" the increased rate of decay observed (1) and no further work producing quantitative data confirming the lone observation was forthcoming. The *pattern* of decomposition may indeed differ in a wounded individual, but the *rate* of decomposition (as measured by defined variables to the point of skeletonization) may not ultimately differ. Despite the lack of quantitative data, other researchers have made reference to trauma as an influential variable. Vass et al. (12) also listed trauma as a factor that influences the onset of decay stages. Campobasso et al. (3) considered penetrating trauma as providing easy access for bacteria and Diptera, thus accelerating decomposition.

The aforementioned studies perpetuate the notion that penetrating trauma influences decomposition and arthropod succession by increasing the rates of both. More recent studies, however, seem to contradict this assumption. Whilst studying the persistence of pathological findings after burial, Breitmeier et al. (13) noted that exhumed bodies exhibiting injury did not reveal accelerated decomposition. As these bodies were buried, however, they would not be subject to maggot colonization and the subsequent tissue loss the maggot masses cause during surface decomposition. Kelly (14) studied the effect of knife trauma on decomposition rates of pigs and found no evidence of preferential oviposition by Diptera to trauma sites and no effect on decomposition rate compared with that of pigs that had not suffered trauma.

Hence, there is limited research into the effects of trauma on the rate of decomposition and the majority are based on anecdotal evidence. This study assesses the effect of multiple gunshot trauma on the surface decomposition rate in domestic pigs (*Sus scrofa).* The information gained from this research will be used to improve postmortem interval (PMI) estimation in decomposing human remains that have suffered gunshot trauma and thus aid in the death investigation.

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Methods

The study was conducted May through July 2006 on a field site (Fig. 1) owned by the University of Central Lancashire (UCLAN) at Newton Rigg (54.65°N, 2.73°W), United Kingdom. The site is 169 m above average mean sea level (AMSL). The field used in the study is fenced and bordered by pasture land and surrounded by a wooden and wire fence.[1] Earlier decomposition studies have been carried out using animals as models for human decomposition with the domestic pig as a recognized model for the human in decomposition studies (15). Thirty-four pigs were used for this study. Use of the pigs was approved by the UK Department of the Environment, Food and Rural Affairs (DEFRA).[2] The pigs were humanely dispatched by an Official Veterinary Surgeon using a captive bolt pistol to the head. Three pigs were used for the trauma experimental group and three pigs used for the non-trauma experimental group. Twenty-eight pigs were used as undisturbed controls. Previous work has suggested that investigator disturbance may affect the decomposition process by disruption of larval feeding (16). The undisturbed control group was also inflicted with trauma.

In the non-trauma experimental group, the captive bolt wound to the head was sealed using a pithing cane and plasticine to ensure that insects could not access the wound. Any blood present around the captive bolt wound was washed off prior to laying out the pigs. In the trauma experimental group and the undisturbed control group the captive bolt wound produced bleeding. Additional gunshot wounds were inflicted on the pigs using a Pietro Berreta 92F 9 mm handgun and jacketed soft point (JSP) ammunition; wounds were inflicted to each of the four limbs and to the chest 4–6 h postmortem. With the exception of some of the chest wounds, no bleeding occurred as a result of these gunshots. Fresh pigs' blood, obtained from an abattoir, was applied to each trauma site to mimic bleeding. The pigs were protected from vermin, scavengers, and birds by wire netting, which was wrapped over each pig and secured to the ground using aluminum tent pegs. Each pig was set a minimum of 50 cm apart on the ground (Fig. 2).

As temperature is the main driver of decomposition, it is more appropriate to consider the rate of decomposition in terms of accumulated degree days (ADD) (12). Data were collected at approximately 45 ADD intervals from deposition. Based on carcass weights, the estimated time to skeletonization was 642.5 ADD (12). Seventeen data collections were carried out (to a total of 765 ADD). At each ADD interval, data were collected from each of the pigs of the experimental groups. In addition, data were collected from two different undisturbed pigs of the trauma disturbance control group. Thus, one pair of trauma undisturbed pigs was observed at 45 ADD, a second pair at 90 ADD, a third pair at 135 ADD, etc. Data were collected only once from each sequential pair of undisturbed pigs; they were subsequently discarded from the data collection protocol. As a result of time to skeletonization exceeding 642.5 ADD, no pigs were available for data collection from the undisturbed trauma group for the last two data collection points (681.6 and 739.9 ADD).

At each data collection interval, the following data were recorded:

- Decomposition stages were recorded using the total body score (TBS) system presented in Megyesi et al. (2). Here, decomposition is divided into four categories: fresh, early decomposition, advanced decomposition, and skeletonization. Within each category the appearance of the head, limbs, and trunk are individually scored. The sum of these gives the TBS.
- Weight loss was measured using a hanging scale. Body temperature readings were taken from the mouth and anus.
- Chest temperature measurements were taken using the entrance made by the bullet; however, in the non-trauma group it was only taken when the integrity of the chest wall was destroyed through the decomposition process.
- Body temperature was recorded using a digital thermometer probe, and interface temperature was recorded using a digital thermometer with thermocouples. A thermocouple was placed permanently beneath the body of each pig and connected to the thermometer to obtain readings.

[1]Use of the study site for surface decomposition studies was subject to provisions set forth by the UK Environment Agency.

[2]Approved under the Animal By-Products Regulations (2005).

FIG. 1—*Study area. Map of UK with Newton Rigg located (Ordnance Survey, 2007).*

FIG. 2—*Photograph showing experimental setup.*

- Ambient temperature at the study site was recorded using a standard domestic maximum/minimum bulb thermometer. These recordings were cross-checked against the Meteorological Office data from the weather station at Shap, Cumbria, UK. This weather station is approximately 11 miles from the study site. Ambient temperature data taken on site was accurate with that from the weather station within 2°C.
- A sample of soil for pH reading, from beneath the torso of each pig, was collected and bagged. A maximum depth of approximately 3 cm was sampled.
- Rainfall data were collected from the Meteorological Office (17).

The presence of adult arthropods and the location and the extent of larval stages were recorded and photographed. Diptera larvae were collected from the carcasses and reared to adulthood. Adult and larval beetles were collected from carcasses. These were killed by freezing and held for later identification. Adult Diptera and Coleoptera were identified using a Leica L2 dissecting microscope and insect identification guides (18,19).

After data collection was completed, the skeletonized remains were disposed of in accordance with the Animal By-Product Regulations (2005).

Results

Table 1 indicates the points at which data were collected (ADD) and the measurements of cumulative rainfall and TBS at each interval.

Blowfly attraction occurred preferentially to the natural orifices of the head in both trauma and non-trauma groups. Gunshot trauma sites were not selected preferentially to the cranial orifices in any of the carcasses. By 87 ADD, maggot masses were established in the mouth and eyes and in some cases the ears. In the trauma group, the exposed captive bolt wound also had maggot masses within it. In the non-trauma group this sealing of the captive bolt wound was successful and did not attract insects. At 87 ADD oviposition had also occurred in areas where natural skin creases form, such as the forelegs and between the hind legs, and in areas where these creases were adjacent to the ground (Fig. 3). This oviposition occurred simultaneously with, and in some cases in preference to, that of the trauma sites.

In both experimental groups and the undisturbed control group the head was the first area to reach advanced decomposition (Figs. 4 and 5). At 129 ADD maggot activity was extensive.

Subsequent to the head, maggot masses generally appeared in the chest region, which incorporated the forelegs, by 173 ADD. This was followed by maggot masses forming after 173 ADD in between the hind legs and anus, extending toward the abdomen. These maggot masses became large and created extensive foaming and purging of decomposition fluids by 219 ADD (Figs. 6 and 7). This is consistent with observations by Anderson and Cervenka (20).

Rapid tissue loss in undisturbed control pigs was observed from around 219 ADD, as with the trauma experimental group (disturbed). However, tissue loss was more rapid in the undisturbed control pigs at 265 ADD than in the trauma pigs (Figs. 8 and 9). The period after 310 ADD saw the formation of adipocere on many of the pigs. This was seen in the areas of subcutaneous fat where it remained in contact with the ground. The area of adipocere formation generally extended from the neck to the pelvic area (Fig. 10). This correlated with the unusually heavy and virtually continuous rainfall experienced at the field site (Table 1). Average monthly rainfall for June and July is usually in the region of 50–60 mm (17).

Decomposition Score (TBS)

Between 87 and 310 ADD the difference between trauma (disturbed) and undisturbed control appear greater than the difference for trauma and non-trauma (both disturbed), but after 310 ADD the plots become less distinguishable from each other (Fig. 11). A *t*-test of the mean values of TBS of trauma and non-trauma groups at the final data point, reflecting the whole data collection period, indicated there was no significant difference between the two groups ($p = 0.824$). Although Fig. 11 appears to indicate that the three groups can be distinguished by TBS prior to ADD 310, *t*-tests at this point reveal that there was also no statistically significant difference ($p = 0.563$) among them. A *t*-test comparing the disturbed and undisturbed trauma groups indicated there was no

TABLE 1—*Data collection point, ADD, accumulated rainfall, and mean TBS.*

				Mean TBS		
Data Point	ADD Interval	ADD Accrued	Accumulated Rainfall (mm)	Trauma Disturbed	Non-Trauma Disturbed	Trauma Undisturbed
19-May (At death)	0	0.0	0			
20-May (At deposition)	19	19.0	0			
22-May	26.6	45.6	30.8	7	5.6	6
26-May	41.2	86.8	33	11.33	10.67	13
30-May	42.0	128.8	54.2	12	10.83	16
03-Jun	44.3	173.1	63.4	13.66	12.33	20.5
06-Jun	46.4	219.5	74.2	16.83	13	21
10-Jun	45.2	264.7	74.4	20.5	16.5	22.5
13-Jun	45.3	310.0	128.3	24	19.83	20.5
16-Jun	47.0	357.0	230.3	23.66	21.5	25
20-Jun	45.5	402.5	267.3	24	24	23.5
23-Jun	46.5	449.0	308.9	25.16	26.83	25.25
26-Jun	48.8	497.8	422.4	25.33	26.66	26
30-Jun	47.0	544.8	477.6	24.33	26	23.5
04-Jul	44.8	589.6	540.7	28	29.33	27.75
07-Jul	50.0	639.6	660.3	29.33	29.66	26.75
10-Jul	42.0	681.6	696.5	30.33	31	No data
15-Jul	53.3	734.9	737.4	31.66	30.66	No data
Average ADD interval	43.2					

FIG. 3—*Pig 11 (trauma) showing (a) 9 mm gunshot wound to inner hind-legs with no oviposition, (b) oviposition at skin crease of hind leg.*

FIG. 4—*Pig 16 (non-trauma) at 129 ADD showing extensive maggot activity in the head.*

FIG. 5—*Pig 33 (trauma) at 129 ADD showing extensive maggot activity in the head.*

significant difference, neither at the final data point ($p = 0.918$) nor in the period up to 310 ADD ($p = 0.254$). These results are summarized in Table 2.

Temperature

t-test analyses of interface and internal body temperature measurements between trauma and non-trauma groups showed no significant differences (Table 3).

FIG. 6—*Pig 33 (trauma) at 219 ADD showing foaming maggot masses at the chest.*

FIG. 7—*Pig 33 (trauma) at 219 ADD showing foaming maggot masses at the anus.*

FIG. 8—*Pig 7 (trauma) at 265 ADD.*

Weight Loss

Mean weight loss values are plotted against ADD in Fig. 11. The graph shows weight loss was most rapid in the undisturbed control group. This was followed by the trauma group, with the slowest loss exhibited by the non-trauma group. The graph of weight loss values shows that the undisturbed control group loses weight more quickly up to ca. 250 ADD but vacillates thereafter. This corresponds to the beginning of a period of heavy rainfall on the site which caused some of the pigs to become waterlogged (thus increasing their weight at random intervals) given their slightly more exposed location relative to the trauma and non-trauma groups. A *t*-test of mean body weight

FIG. 9—*Pig 35 (disturbance control) at 265 ADD.*

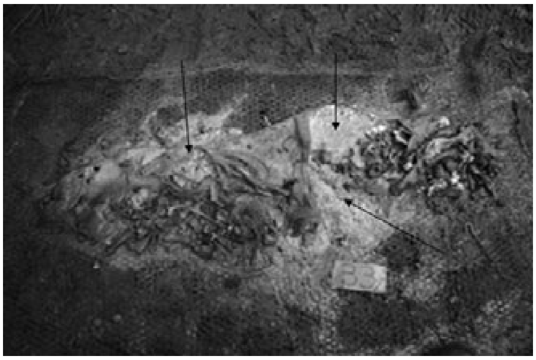

FIG. 10—*Pig 33 (trauma) at 544 ADD with arrows indicating areas of adipocere formation.*

TABLE 2—*t*-test significance of TBS and weight loss comparison.

	ADD Interval	*t*-test Significance (*p*-value)
TBS		
Trauma: non-trauma (both groups disturbed)	0–310	0.563
	0–735	0.824
Trauma (disturbed): undisturbed	0–310	0.254
	0–735	0.918
Weight loss		
Trauma: non-trauma (both groups disturbed)	0–310	0.902
	0–735	0.906
Trauma (disturbed): undisturbed	0–735	0.000

TABLE 3—*t*-test significance of temperature and soil pH comparison.

Variable	*t*-test Significance (*p*-value)
Interface temperature	
Trauma: non-trauma	0.945
Disturbed: undisturbed	0.127
Internal temperature	
Trauma: non-trauma	0.967
Disturbed: undisturbed	0.575
pH	
Trauma: non-trauma	0.684
Disturbed: undisturbed	0.966

remaining in trauma and non-trauma groups indicated no significant difference ($p = 0.906$), even in the 0–310 ADD period ($p = 0.902$). However, the comparison of trauma (disturbed) and undisturbed

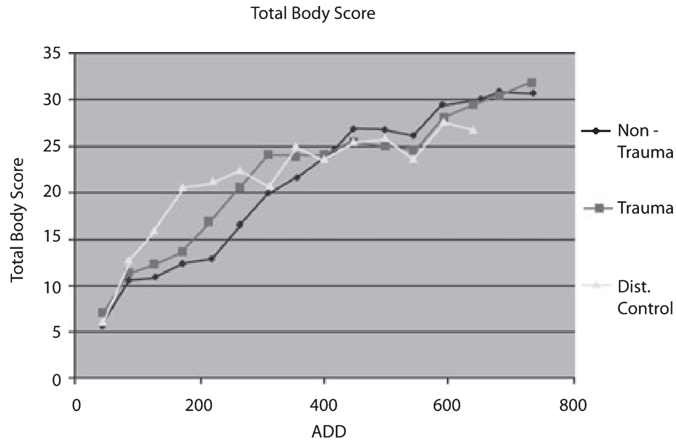

FIG. 11—*Graph showing relationship between total body score and ADD.*

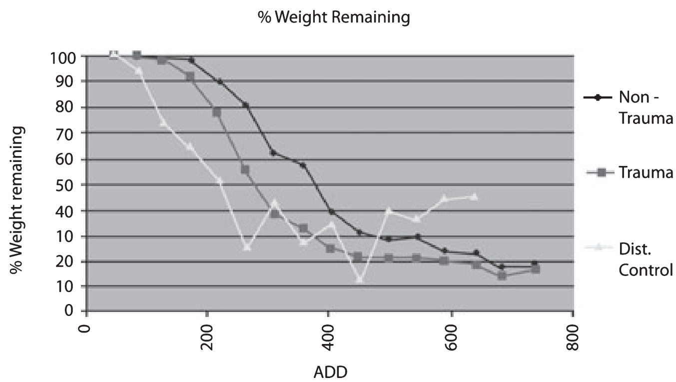

FIG. 12—*Graph showing relationship of weight loss and ADD.*

control groups indicated there was a highly significant difference ($p = 0.000$). The undisturbed carcasses lost weight significantly faster than both other groups. These results are summarized in Table 2.

Soil pH

Soil pH peaked at similar levels at 128 ADD in all groups reaching a mean pH of 8.58. After 128 ADD, soil pH declined at similar rates until 219 ADD after which levels fluctuated around pH 8.3 for the remainder of the experiment. A *t*-test of mean soil pH levels of trauma and non-trauma groups for the duration of the experiment indicated there was no significant difference ($p = 0.684$), and also between the trauma (disturbed) and undisturbed control groups ($p = 0.966$). These results are summarized in Table 3.

Discussion

Blowflies were preferentially attracted to the natural orifices of the head in all three groups. There were no differences in oviposition timing to the head in the two experimental groups (trauma and non-trauma disturbed). Sulphurous compounds produced by bacteria within the alimentary canal can easily escape from the mouth. Although these compounds are also produced by soft tissue decomposition and thus may emanate from trauma sites, it can be expected that the abundant volatiles will come from the head initially. In addition to flies being preferentially attracted to the head, these orifices were also sites of preferential oviposition. This suggests that oviposition will occur at the sites where abundant volatiles are present. Although an open wound presents easy access (3), if it lacks the compounds to which are flies are predominantly attracted, preferential oviposition does not occur.

Secondary to head orifices, oviposition occurred at other locations on the carcass. These were in areas of creased skin such as under the forelegs or between the hind legs. It should be noted that oviposition beneath the ear flaps and within the head orifices occurred simultaneously. Oviposition in these skin creases may offer protection for the ova, providing an environment that is moist and sheltered from drying by wind and direct sunlight. The fact that ear creases were selected preferentially to other skin creases suggests again that the proximity of decomposition volatiles from the alimentary tract orifices of the head is the primary factor, secondary to the nature of the site. The anus was also selected for oviposition concurrently with skin creases. It might be expected that the anus would be selected at the same time as the head, but although volatile gases would be produced in the anus, it may be that they do not escape in the same abundance or as quickly in the decomposition progression, rendering the anus less attractive to flies. In some cases trauma sites were selected at the same time as skin creases, yet in others (Fig. 3) skin creases were selected preferentially to trauma sites. In no cases were trauma sites selected preferentially to skin creases or simultaneously with the head orifices.

The appearance of maggot masses in the chest secondary only to those in the head suggests that the pig's forelegs provide better protection for ova than hind legs. The skin creases did provide easier access for oviposition. Maggot masses in the anus, hind legs, and abdomen followed.

The appearance of an earlier more rapid rate of tissue loss in the trauma pigs up to 310 ADD may suggest that, rather than providing a preferential site for oviposition, trauma sites provide larvae quicker access to underlying soft tissue. Larvae on the skin surface would take longer to reach underlying soft tissue than those accessing it via trauma sites. However, once established, maggot masses in both groups achieved similar tissue losses by 310 ADD. In this study, trauma sites were 9 mm gunshot wounds and were not large wounds exposing extensive areas of soft tissue. The similar degrees of tissue loss seen at 310 ADD may be due to the fact that the small size of the trauma sites only allowed a limited "head start" by these larvae. Larger wounds with more soft tissue exposed may result in a greater rate of tissue loss and may affect the pattern (appearance) of decomposition. This might accentuate any differences between trauma and non-trauma subjects and requires further investigation, although it is suspected that the ultimate rate of decomposition (ADD to skeletonization) will not be significantly different.

The rate of tissue loss (measured by weight loss) in undisturbed trauma control pigs was more rapid than that of the experimental (disturbed) trauma group. As both these groups had the same degree of inflicted trauma, this suggests that the slower tissue loss in the experimental disturbed trauma group may result from the disturbance of the maggot mass and an interruption of feeding activity. This supports observations by Adlam and Simmons (16). This study was unable to compare non-trauma and trauma undisturbed pigs, as there was no undisturbed non-trauma group.

The differences for TBS observed before 310 ADD would appear to suggest that there are differences in the rate of soft tissue destruction relating to both the ability of larvae to access soft tissue and the physical disturbance of the carcass. However, these differences are not statistically significant. Thus, if a carcass has been disturbed, TBS presents a better more stable method of recording decomposition than weight loss This may relate not only to the type of trauma inflicted and the degree of soft tissue exposure, but the fact that TBS is a more subjective measure. The erratic nature of the assigned body scores post 310 ADD suggests that the scoring system is suited to decomposition in drier environments and may not provide a reliable and consistent assessment of body condition in wetter circumstances such as experienced during this study.

Undisturbed control pigs show the greatest weight loss, followed by trauma (disturbed) and then non-trauma (disturbed). This supports observations made on other measured data that disturbance and the access of larvae to soft tissue via trauma sites may have an effect on soft tissue destruction. The differences between trauma and non-trauma were, however, not statistically significant, indicating the presence of trauma to be far less influential on decomposition (if at all) than disturbance.

Conclusion

This study suggests that volatile gases are released from the natural orifices of the head and are the primary attractant to Diptera in recently deceased pig remains. Trauma sites are not selected preferentially to these areas. Oviposition takes place in these head orifices and at adjacent sites. Although trauma sites are not preferential for oviposition, they do appear to provide sites of access to soft tissue by larvae.

The study has demonstrated that the rate of soft tissue destruction in pigs with 9 mm caliber gunshot wounds does not differ significantly from those of the non-trauma group as measured by the key data (e.g., TBS, weight loss). Caution is warranted regarding the use of the word *rate* when comparing decomposition in different situations, especially that of trauma and non-trauma cases. *Rate* describes the pace and progression of decomposition through the TBS stages and percent weight loss observed in the process of skeletonization, whereas *pattern* may more aptly describe differences observed in the body areas affected by tissue destruction. These are fundamentally different concepts where pattern is a qualitative observation and rate is a quantitative measure, which can be more readily statistically tested. This research has established that ADD to skeletonization in trauma and non-trauma groups is the same. The study also supports work by Adlam and Simmons (16) that suggests physical disturbance can retard the rate of decomposition by disrupting maggot masses and their feeding activity. Thus, if decomposition is measured by weight loss, then disturbance of the carcass during insect colonization is a significant factor.

This study has considered the trauma inflicted by 9 mm gunshot wounds. As results suggest that trauma sites do indeed provide access to soft tissue by insect larvae, further work is to be carried out on trauma that creates more significant degrees of soft tissue exposure, which might affect the pattern of tissue destruction. Further studies should test the effect of repeated physical disturbance on arthropod succession and importantly on the nature and stability of larval masses. This may include the size and abundance of larval masses on the carcass and the effect on the temperature within larval masses.

In conclusion, this study suggests that penetrative gunshot wound trauma of the type inflicted in this study cannot be considered as a major factor influencing the rate of decomposition. Results indicate that the influence of trauma in relation to PMI estimates may be overestimated for small caliber gunshot trauma of this degree. Heavy and prolonged rainfall, as well as disturbance, have also been shown to be significant influential factors in retarding the rate of soft tissue decomposition.

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