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PAPER

ANTHROPOLOGY

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A Study of the Human Decomposition Sequence in Central Texas*

ABSTRACT: Decomposition studies utilizing nonhuman subjects as human analogues are well established, but fewer studies utilizing intact human remains exist. This study provides data from a controlled decomposition study involving human remains in Central Texas. A 63.5-kg unmodified cadaver was placed in an open-air site and observed over a 10-week period from April 11 through June 19, 2008. A wire enclosure restricted scavenger access. State of decomposition and environmental conditions were recorded daily for the first 36 days and then every 2 weeks thereafter. Results indicated a high degree of correlation with other decomposition studies originating in the southwestern United States, although slight deviations for the average duration of early events were noted. The data were also utilized to test a quantitative method for estimating the postmortem interval. Results indicated preliminary support for a quantitative approach. Additional research is encouraged to further establish the human decomposition data set for Central Texas.

KEYWORDS: forensic science, forensic anthropology, decomposition, postmortem interval, accumulated degree-days, time since death, Texas

The outdoor decomposition of human remains involves a suite of complex, highly variable processes. Early processes, such as autolysis, putrefaction, and insect activity, are dependent on environmental conditions, particularly temperature and humidity (1–6). Other decomposition processes, such as animal scavenging, are also specific to the local environment and its faunal constituency (7). Because of such dependencies, a "one size fits all" decomposition model is unrealistic. It is imperative that ecologically distinct regions establish specific benchmarks by conducting controlled analyses that consider local conditions (1,8,9). Although retrospective and experimental human decomposition studies have been conducted to establish decay rates for specific eco-locations, such studies have been limited and primarily confined to the southeastern and southwestern United States (1,2,4,5,8,10). In Central Texas, similar studies have been performed using pigs (*Sus scrofa*) and other nonhuman substitutes (11,12); however, no study to date has utilized intact human remains. This report provides summarized data from the first controlled field study involving human remains at the Forensic Anthropology Research Facility, Texas State University-San Marcos.

Study Location

The research facility is a secured, open-air laboratory of five acres of grassland and woods located near the main campus of Texas State on university-owned property known as Freeman Ranch. Elevations on the ranch range from 670 to 940 ft. Dominant vegetation includes live oak, Ashe juniper, and prickly pear cactus. Documented weather conditions at the Ranch for 2007 include low and high temperatures of −10°C (14°F) in February and 36°C (97°F) in August, a mean humidity of 77%, 1595 mL of precipitation, and an average wind speed of 3.6 mph—spring being a particularly breezy time of the year. Soil in the region is considered slightly acidic (pH 6.3) and is classified as the Rumple series, a cherty clay loam with a surface layer comprised of 20% chert and limestone fragments and gravel. Wildlife includes turkeys, vultures, white-tailed deer, gray foxes, coyotes, bobcats, raccoons, ringtail, skunks, armadillos, bats, rodents, and numerous species of amphibians and reptiles (13–16). Although the facility is located within the boundaries of a 3500-acre working ranch, no ranch activities occur inside the research area. The facility is bounded by an 8′ high, 6″ stay wire fence—preventing access to large, terrestrial scavengers—and is secured with multiple gate-lock combinations known only to researchers. Individuals not directly involved in research activities are not permitted access to the facility.

Materials and Methods

One unembalmed, nonautopsied donated human cadaver was used in this pilot field study. The cadaver, hereafter referred to as the "subject," was an 81-year-old adult male weighing 63.5 kg (140 lbs) and standing approximately 169 cm (5′5″) at the time of death. The Medical Examiner documented the death as natural and occurring on April 5, 2008. The subject was stored in a refrigerated environment (3.3–4.4°C/38–40°F) for 6 days prior to delivery to the research facility. On April 11, 2008 at 12:50 PM CDT, the subject was delivered and placed at the research facility. Placement was in a tree-surrounded clearing that received full sun for approximately 11 h each day. The length of sun exposure remained consistent because of the mature trees surrounding the placement site. The subject was placed unclothed in a supine, extended northeast to southwest position, arms to the sides, legs slightly apart, and in

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direct contact with the ground. No major injuries or open wounds were observed. After examination and documentation, the subject was covered with a 6 ft long, 3 ft wide, 2 ft high enclosure constructed of heavy-duty one-gauge welded wire rod with $2'' \times 4''$ openings.

Environmental data were collected from a permanent weather station located <1 aerial mile west of the research facility. Collected weather data consisted of visually assessed sky conditions, ambient air temperature, relative humidity, wind speed, precipitation, accumulated degree-days (ADD), and weather events, e.g., rain. The weather station utilizes Vaisala instrumentation (San Jose, CA) to measure and log air temperature, humidity, and wind speed. A standard tipping rain gauge collects and logs precipitation. Measurements were recorded every 30 min, 24 h a day, at 5 ft above ground level. Following Megyesi et al. (17) and Micozzi (18), ADD were calculated using temperature thresholds of 0 and 37°C (32 and 98.6°F). Sky conditions were categorized as clear, overcast, or partly cloudy.

Photographic and visual documentation assessing the state of decomposition, insect activity, and environmental conditions was performed daily between the hours of 11:00 AM and 4:00 PM CDT for the first 36 days (April 11–May 17, 2008). Observations and collections were conducted approximately every 2 weeks thereafter (May 18–June 19, 2008). Decomposition observations and duration of each stage and/or event were assessed following Galloway's (2) decomposition stages, descriptions, and durations (Table 1).

Utilizing the scoring system of Megyesi et al. (17), a total body score (TBS) was associated with each stage and event in this study (Table 1) and was used to comparatively test the postmortem interval (PMI) formulae developed by the authors.

Results

The decomposition data, environmental conditions, and insect observations presented in this paper were collected between April 11 and June 19, 2008, ending when decompositional changes at the visual level ceased occurring. Assessments, calculations, and correlations are thus based on the above mentioned 10-week period.

Table 1 represents a comparison between Galloway's (2) decomposition stages and those documented in this study. Results indicate a high degree of correlation with those reported by Galloway. Bolded figures in Table 1 indicate stages in this study that fall outside the average durations reported by Galloway. Application of Megyesi et al.'s (17) quantitative method to the decomposition stages completed in this study was also similarly correlated (Table 1). Following is a detailed account for each of the decomposition stages completed or in progress at the end of the data collection period.

Fresh Stage

The duration of the fresh stage in this study was 3 days. The subject exhibited a normal skin tone, lividity was present and fixed,

TABLE 1—*Stages and events of decomposition.*

	Other Southwestern United States Studies*			This Study				
	Typical Onset	Average Duration	Min-Max Duration	Onset	Total Length of Stage or Event	TBS†	Predicted PMI in ADD†‡§	Actual PMI in ADD‡§
Stages								
Fresh	Day 0–2	0–2 days	0–7 days	Day 0 1PM CDT	**3 days**¶	3	67 ± 1 SD	57 ± 1 SD
Early decomposition	Day 1–5	4–5 days	3 days–2 months	Day 3	**8 days**	16	210 ± 1 SD	208 ± 1 SD
Advanced decomposition (postbloat)	Day 4–10	3–6 days	3 days–2 months	— see Mummification —				
Mummification (<half skeleton exposure)	Day 10–1 month	2–6 months	3 days–9 months	Day 12	In progress			
Skeletonization (>half skeleton exposure)	Month 2–9	6–18 months	7 days–2 years	Pending	Pending			
Skeletal bleaching	Month 6	6 months	2 months-not documented	Pending	Pending			
Skeletal exfoliation	Month 12–18	Not documented	4 months-complete decay	Pending	Pending			
Events							Event Begin/End ADD	
Bloat	Day 2	5 days	2–13 days	**Day 3**	**8 days**		57–208 ± 1 SD	
Marbling	Not documented	Not documented	Not documented	Day 3	4 days		57–125 ± 1 SD	
Bulla formation	Not documented	Not documented	Not documented	Day 3	3 days		57–110 ± 1 SD	
Rectal purge	Not documented	Not documented	Not documented	Day 3	1 day		57 ± 1 SD	
Skin slippage	Not documented	Not documented	Not documented	Day 4	3 days		71–125 ± 1 SD	
Initial carnivore activity	Not documented	Not documented	Not documented	Day 4	In progress		71 ± 1 SD	
Facial purge	Not documented	Not documented	Not documented	Day 5	1 day		89 ± 1 SD	
Darkening	Day 9	9–21 days	3 days–2 months	**Day 6**	In progress		110 ± 1 SD	
Abdominal rupture/ Gas release	Day 9	n/a	n/a	**Day 11****	n/a		208 ± 1 SD	

*After Galloway (2) and Sledzik (19).
†Following Megyesi et al. (17). TBS and PMI apply to this study only. No correlation made to other studies.
‡ADD applies to this study only and is calculated through completion of stage/event. No correlation made to Galloway's study.
§For stages/events completed at the end of data collection.
¶Cadaver refrigerated 6 days prior to delivery.
**Premature deflation may have been caused by observer handling.
ADD, accumulated degree-days; PMI, postmortem interval; TBS, total body score.
Bolded figures indicate stages that fall outside the average durations reported by Galloway.

and insect activity commenced within 20 min of placement. Differential rigor mortis and lack of odor were also observed. The duration of the fresh stage in this study was lengthier, yet consistent with the maximum fresh stage duration (0–7 days) reported by Galloway (2). As noted previously, the subject had been housed in a refrigerated environment for 6 days prior to delivery, and this may have lengthened the fresh stage by an estimated 24–48 h.

Early Decomposition Stage

The duration of the early decomposition stage in this study was 8 days. During early decomposition, the subject exhibited skin color that progressed from a pink-white, to gray, to green, and finally to a dark brown leathery appearance. Bloat commencement and completion (3 and 11 days, respectively), skin slippage, hair loss, strong odor, and moderate maggot activity were also present. Bullae formation on the upper arms, trunk, and thighs (day 3–5), rectal purge (day 3), initial carnivore activity (day 4), purge from the mouth and nasal region (day 5), and noncarnivore-based bone exposure (day 11) were also observed during this stage. Although the duration of this stage in this study (8 days) falls outside the average duration reported by Galloway (4–5 days), it is consistent with the indicated maximum duration of 2 months (2).

Advanced Decomposition–Mummification Stage

At the completion of data collection, the advance decomposition–mummification stage was ongoing. The subject exhibited sagging flesh, extreme maggot activity, moist decomposition, the presence of a thick, black liquid, and bone exposure. Onset of mummification occurred on approximately day 12, after which the subject presented a hard, leathery outer shell with moist decomposition continuing internally and on the underlying surfaces. As of writing, all internal organs had decomposed, and the subject exhibited mummification of outer tissues, with <10% of the body demonstrating skeletal exposure. Maggot activity was markedly decreased, while beetle activity appeared heavier. With the exception of the appearance of mold, all of the characteristics exhibited were consistent with Galloway's (2) description and possible sequence alternatives for this stage.

Quantitative Method

Using the scoring strategy and formulae reported by Megyesi et al. (17), a TBS and PMI were calculated for the decomposition stages and/or events completed at the completion of data collection. Individual PMI event values were also calculated for completeness. PMI values are given as the ADD necessary to arrive at the TBS assigned to a stage or an event. Table 1 represents a comparison of the predicted PMI-ADD based on the Megyesi formulae and the actual PMI-ADD calculated for this study. For table simplicity, the listed values do not include the standard deviation of 388.16.

PMI-ADD estimates for the completed decomposition stages and events in this study were found to be consistent with those produced using the Megyesi formulae. Although this study is ongoing, these preliminary findings support Megyesi et al.'s (17) contention that PMIs can be accurately modeled using quantitative methods and observations.

Accumulated Degree-Days and Weather Conditions

Weather conditions for the 10-week study were initially moderate but increasingly warmed after the fifth week (Table 2). Ambient temperature reached a high of 37.9°C (100°F, June 19) and a low of −1.8°C (29°F, April 14). Mean temperature and humidity were 24°C (75°F) and 63.9%, respectively. Precipitation totaled 69.4 mL, with the heaviest precipitation occurring the first and second weeks (April 11–25), totaling 54.8 mL. Wind speeds averaged near 5.6 mph, and ADD totaled 1692.1 (*c.* 71 degree-days given the mean temperature reported above).

Discussion

The data documented in this study indicate a high degree of correlation with other decomposition studies originating in the southwestern United States (2,10). The results show deviation from such studies primarily in (i) the average duration of the fresh stage (3 days instead of 0–2 days), and (ii) the average duration of the bloat event (accidental truncation at 8 days instead of the expected 4–5 days). Both results are, however, only minimally outside the data of the aforementioned studies.

Two unexpected events occurred in the present study. The first, as noted above, was the duration of the fresh stage (3 days). The subject was placed in a location receiving direct sunlight approximately 11 h each day, with clear, sunny skies for the 3 days of the fresh stage, and a mean temperature for the duration of this stage of 25°C (77°F). Given the placement and warm temperature, a shorter duration for the fresh stage was expected. Two possible explanations are offered. One is the 6-day preplacement cooling of the subject. Galloway's (2) study was retrospective, and all subjects were assumed to have been deposited in a noncooled state. Therefore, the fresh stage for a cooled body may extend beyond Galloway's reported 0–2 days duration. Another possible explanation for the extended fresh stage is the nighttime temperatures, with cool temperatures ranging from 0.34 to 7°C (33 to 45°F) recorded for the first three nights—temperatures possibly causing re-cooling and the delay of early decomposition.

The second unexpected event was the early onset of mummification (day 12). For the first 12 days of placement, the mean temperature and humidity were 18°C (64°F) and 63%, respectively. Given

TABLE 2—*Summarized weather data for 10-week reporting period.*

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Weeks 1–10
Daily maximum temperature mean (°C)	24.83	28.14	26.56	28.93	28.01	33.34	33.98	34.90	35.56	36.30	31.06
Daily minimum temperature mean (°C)	4.98	15.26	10.81	13.99	17.17	16.31	21.24	23.29	23.83	20.64	16.75
Temperature mean (°C)	15.61	21.96	19.23	21.84	22.78	25.15	27.33	28.16	28.61	28.83	23.95
Daily maximum humidity mean (%)	92.76	94.69	93.86	93.01	90.93	93.40	91.51	86.44	87.40	89.59	91.36
Daily minimum humidity mean (%)	26.21	50.84	39.14	39.90	44.76	29.36	35.45	33.59	31.10	26.66	35.70
Humidity mean (%)	56.18	74.31	67.23	67.49	66.95	61.84	65.01	62.47	61.92	55.62	63.90
Total precipitation (mL)	29.56	25.20	1.24	1.87	11.51	0.00	0.00	0.00	0.00	0.00	69.38
Mean wind speed (Km/h)	8.64	7.70	8.10	7.38	8.57	7.52	8.68	13.50	12.31	6.73	8.91
Accumulated degree-days	124.90	278.60	413.22	566.13	725.57	901.60	1092.92	1290.05	1490.33	1692.14	1692.14

the moderate temperature and humidity, the rapid onset of mummification in lieu of moist decomposition was unexpected, and two possible explanations may account for this occurrence. As detailed above, the placement location in direct sunlight likely contributed to the rapid mummification. Clear skies dominated the first 12 days, and recorded body surface temperatures were consistently over 40°C (104°F), with several days more than 50°C (122°F). Wind may be another possible explanation for the accelerated drying. Wind speeds during the 10-week study averaged 5.6 mph and were constant. Constant winds coupled with over 11 h of direct sunlight each day may explain the deviation toward mummification instead of moist advanced decomposition.

Conclusion

The purpose of this study was to establish a preliminary decomposition baseline for human remains in Central Texas and regions of similar climate and geography. This study provides the foundation for a new and original data set—one tailored to specific environmental conditions and compared against previously published descriptive and quantitative studies. Further research is imperative for the continued refinement of this initial study, and future studies should include observations in different seasons and varying depositional and burial contexts.

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