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The Application of Geographic Information Systems and Spatial Analysis to Assess Dumped and Subsequently Scattered Human Remains*

ABSTRACT: This study utilizes geographic information systems (GIS) and spatial analysis (SA) technology to address the problems associated with prediction of location and effective recovery of dumped and scattered human remains in Louisiana. The goals are to determine if a selective bias exists in Louisiana as to where and when human remains are dumped and to assess whether or not geographically specific patterns exist in the dispersal of human remains. We hypothesized that a positive relationship exists between postmortem interval (PMI) and dispersal distance, and that there are negative relationships between PMI and dispersal direction and between dispersal direction and distance. Our results indicate that, in Louisiana, remains are more often dumped in rural areas away from a structure, and are found within $\frac{1}{4}$ mile of the nearest road. For Louisiana, no seasonal bias was found in the analysis of when remains are dumped. Furthermore, with the exception of the relationship between PMI and the shortest distance remains were dispersed, no geographically specific patterns were detected in the analyses of dispersal distance, dispersal direction, and PMI.

KEYWORDS: forensic science, forensic anthropology, dumped bodies, scattered remains, geographic information systems, spatial analysis

Past studies in forensic taphonomy have considered the myriad of factors that influence the discovery and condition of human remains in contemporary death assemblages. Such anthropological studies have investigated decomposition rates, scavenging patterns, and recovery of remains, while strategies for locating bodies have focused mainly on cadaver dog assistance, informant details, or accidental discoveries (1,2). Today, geographic information systems (GIS) and spatial analysis (SA), technology more often associated with geography than with anthropology, have the potential to help us understand the dispersal of human remains across the landscape as well as locations chosen by perpetrators for deposition of bodies.

The research and application of GIS and SA are relatively new to the field of forensic taphonomy, and their use could be termed "spatial forensic taphonomy" or "geo-forensic taphonomy." However, the term "geo-forensic" is, itself, not new and the utility of SA as a tool for tracking certain types of criminal behavior was suggested as early as the end of the 1970s. For example, the application of SA and mapping to develop a decision support tool used by law enforcement to make estimates about the likely location of a serial offender's haven (mostly his/her residence) was introduced by several authors in the late 1970s and throughout the 1980s (3–6). These early decision support tools have developed into modern and more complex "criminal geographic profiling" models utilized by law enforcement to maximize limited resources (7). A second important application of SA has been used in forensic analyses to identify and map the location of crime hot spots (8).

Two researchers have studied patterns of dumped bodies in Louisiana (9,10). Fowler examined dump sites of homicide victims in Jefferson Parish, a large urban parish contiguous with the city of New Orleans in south Louisiana (9). He found that females comprise a significantly higher number of dumped victims than males, and that death by assault in dump victims is more frequent than death by firearm. He also noted that the majority of dumped bodies are found within 12 h of the victim's death, and that most dump sites are within 9 km of the victim's home and/or the place the victim was last seen alive (9). Mirtipati examined the relationship between homicides and dump sites in Baton Rouge, Louisiana, from 1991 to 1997 (10). Her results were consistent with Fowler's: victims left at dump sites were more likely to have been killed with nongunshot injuries.

The present study applies GIS and SA to the problem of locating and maximizing the recovery of dumped and/or scattered human remains in Louisiana. The goals were (1) to determine if a selective bias exists in Louisiana in where and when human remains are dumped and (2) to assess whether or not geographically specific patterns exist in the dispersal of human remains. With regard to the latter goal, we hypothesized that a positive relationship exists between postmortem interval (PMI) and dispersal distance (the longer the PMI, the greater the distances between the skeletal elements and the original deposition site (ODS)). We also hypothesized that there are negative relationships between PMI and dispersal direction (the longer the PMI, the less likely there will be a directional bias in element dispersal) and between dispersal direction and distance (the greater the distance, the lower the directional bias). Finally, we considered the impact that other variables might have on element dispersal in Louisiana: the season in which the remains were dumped, the location of the dump site, and the proximity of the dump site to the nearest road or waterway.

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TABLE 1—*Summary of variables, conditions, and definitions used in the analysis of body deposition by location (n = 175).*

Variable	Conditions	Definitions
General location	Urban	Within a metropolitan area
	Rural	Outside of a metropolitan area
Specific location	Near structure	Within sight of buildings, houses, or bridges
	Within structure	Inside a building, house, or bridge
	Away from structure	Out of sight of buildings, houses, or bridges
Ground cover	Wooded	Moderate to heavy tree cover
	Open	Sporadic tree cover to open fields or grasslands
	Water	Floater in a river or lake, or on a riverbank

Materials and Methods

Data were selected from cases analyzed by anthropologists at the Louisiana State University Forensic Anthropology and Computer Enhancement Services Laboratory from 1984 to 2005. All cases included in this study came from Louisiana, the majority from the southern parishes. Body disturbance in these cases ranged from little or no movement of the body from the ODS to skeletal elements dispersed over great distances.

A total of 175 cases were used in the analyses of the selective bias of dump sites. Table 1 lists and defines the variables assessed. Frequency distributions, cross tabulations, and χ^2 analyses were generated for these data using SPSS® 11.0 for Windows (11).

Geographically specific patterns in element dispersal were assessed for a subset of 36 cases, which were extracted from the 175. These cases were selected for the subset because they have original site maps that were drawn during field recovery. The site maps pinpointed the location of skeletal elements that had been dispersed from the original deposition site (ODS). All maps contained descriptions of elements that were found and a scale for reference. Figure 1*a* is an example of an original site map created in the field. Because maps were drawn at different times by multiple individuals, all data were standardized into a common coordinate system.

We chose a Cartesian coordinate system for our frame of reference, in which the coordinate origin (i.e., $x = 0$, $y = 0$) was designated as the ODS. From this reference point, dispersed skeletal elements and other artifacts (e.g., clothing) were recorded as x- and y-coordinate pairs. All distances were measured and standardized using scales present on each map and were recorded in meters. In cases where the remains had been dispersed over great distances, the ODS was determined based on body stain or clustering of elements.

The coordinates of the ODS and of all skeletal elements were entered into ESRI® ArcView® GIS 3.3 (12) for further analysis and mapping. Figure 1*b* displays an example of a map in the ArcView® program. In the figure, several windows are opened to show the different types of information that can be stored and displayed in the program: "view 1" and "view 2" present the site map featured in Fig. 1*a* using two different scales. The window with the heading "Attributes of…" exhibits the coordinate data for the skeletal elements in a single case, as well as attribute information such as element side and PMI estimates.

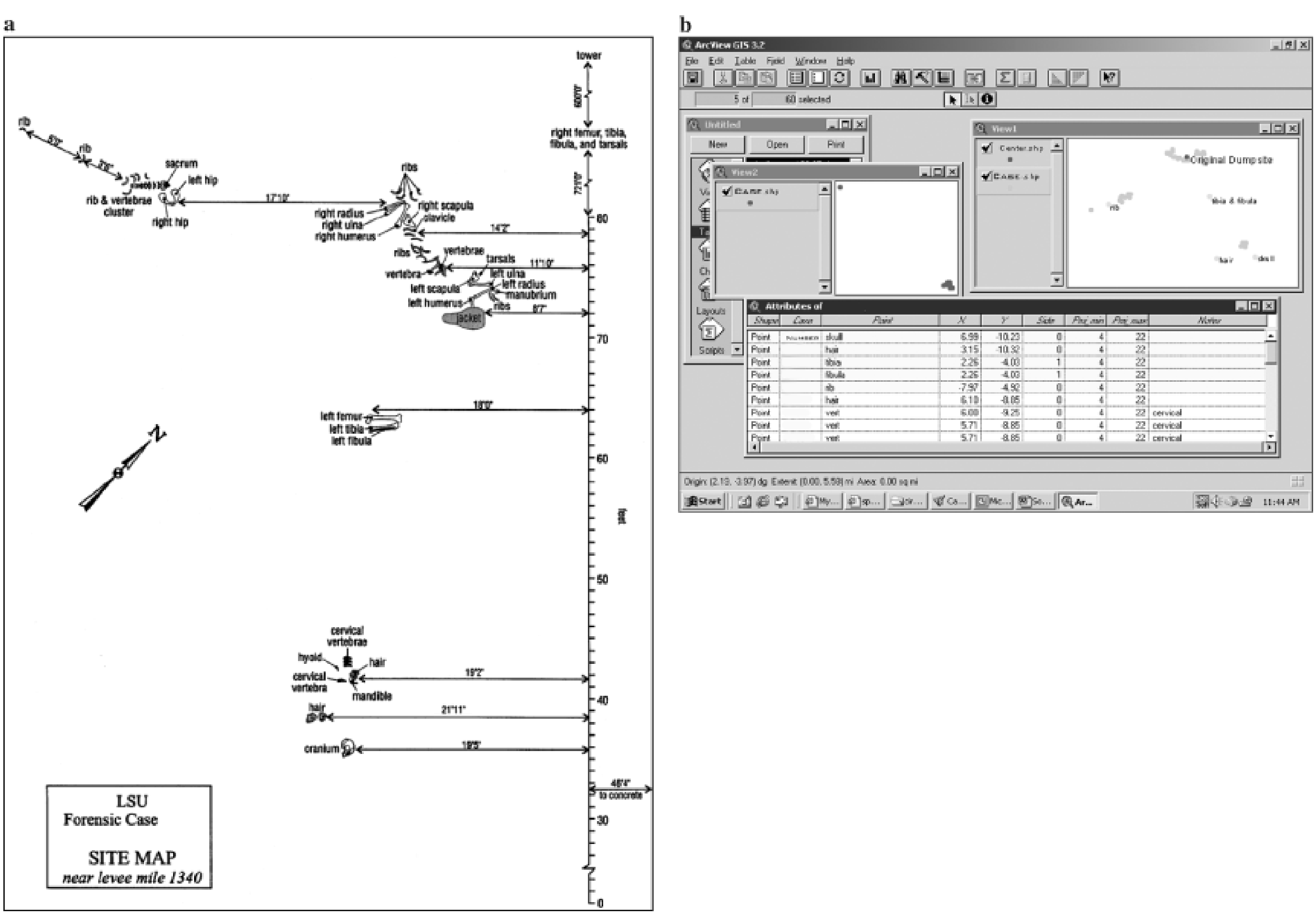

FIG. 1—*(a) Example of original site map. (b) Sample of site map data in ArcView® Program.*

TABLE 2—*Summary of variables, conditions, and definitions used in the analysis of the sample subset (n = 36).*

Variable	Conditions	Definitions
Season of deposition	Season minimum	Season of the year based on minimum estimated PMI
	Season maximum	Season of the year based on maximum estimated PMI
	Mean season	Season based on mean estimated PMI
Distance from road	Within $\frac{1}{4}$ mile	Remains were located within $\frac{1}{4}$ mile of the nearest road
	$\frac{1}{4}\frac{1}{2}$ mile	Remains were located between $\frac{1}{4}$ and $\frac{1}{2}$ mile of the nearest road
	$\frac{1}{2}$1 mile	Remains were located between $\frac{1}{2}$ and 1 mile of the nearest road
	>1 mile	Remains were located over 1 mile from the nearest road
Distance from waterway	Within $\frac{1}{4}$ mile	Remains were located within $\frac{1}{4}$ mile of the nearest waterway
	$\frac{1}{4}\frac{1}{2}$ mile	Remains were located between $\frac{1}{4}$ and $\frac{1}{2}$ mile of the nearest waterway
	$\frac{1}{2}$1 mile	Remains were located between $\frac{1}{4}$ and 1 mile of the nearest waterway
	>1 mile	Remains were located over 1 mile from the nearest waterway
Postmortem interval	Estimated PMI minimum	Minimum estimate of PMI
	Estimated PMI maximum	Maximum estimate of PMI
	Mean estimated PMI	Mean PMI estimate

PMI, postmortem interval.

Dispersal patterns were assessed using CrimeStat® III (13). Variables used in these analyses include dispersal distance, dispersal direction, and PMI. The relationships between dispersal distance, dispersal direction, and PMI were assessed using Pearson's correlation coefficient.

Dispersal direction first was analyzed graphically using standard deviational ellipses (14) and circular histograms (15). A standard deviational ellipse is a measure of the dispersion of incidents (here, skeletal elements) in two directions (i.e., major and minor axes of the ellipse). This reflects the anisotropic conditions of most spatial distributions. Circular histograms, also commonly called "rose diagrams," are based on the mean angle, which was calculated for each case in the subset of 36. The mean angle is categorized as one of 16 classes of compass directions and, thus, displays the mean direction in which remains are dispersed from around the ODS.

Two different circular histograms were created using weighted and nonweighted data from the sample subset of 36 cases. For the nonweighted data, every distance between the ODS and each skeletal element for which the mean angle was calculated was assigned the same length (i.e., a unit length of one). For the weighted data, the actual distances were used in the calculation of the mean angle. Therefore, greater distances have more impact (weight) on the resulting mean angle than shorter distances.

Next, the circular variance, which is a statistical indicator of dispersal direction, was calculated for those cases in which remains had been dispersed. This included 27 of our subset of 36 cases. Similar to the mean angle, we included both weighted and nonweighted data in our analyses. For the nonweighted data, each distance was measured with a unit vector; for the weighted data, the actual distances between the ODS and each skeletal element were used. Circular variance then was utilized as a measure of dispersal direction in analyses assessing the relationship between direction, dispersal distance, and PMI. Pearson's correlation coefficients were calculated to assess these relationships for all elements in each case collectively, as well as for individual elements such as the skull, os coxae and femora.

Finally, the sample subset of 36 cases was used to assess patterns for the season in which remains were dumped and the distance from the dump site to the nearest road or waterway. Table 2 lists and defines the variables used in these analyses. Summary statistics and χ^2 values were calculated using SPSS® 11.0 for Windows (11).

Results

Table 3 displays the cross-tabulations and χ^2 values for the analysis of body deposition by location for the entire sample. Approximately three quarters ($n = 130$) of all cases were dumped in a rural area. Among these cases, a significant relationship exists between specific location and ground cover ($p < 0.01$); for example, 116 (89%) were dumped away from a structure and approximately half (49%) were dumped in a wooded environment. Among those cases dumped in an urban area ($n = 45$), a significant relationship exists between specific location and ground cover ($p < 0.05$). The majority of the urban cases were dumped in an open environment ($n = 35$, or 78%), nearly half of which were dumped within sight of a structure ($n = 15$). The rest of these cases were approximately equally distributed between inside a structure (24%) and out of sight of a structure (20%). When the entire sample of 175 was considered collectively, very few dumped bodies were found in water (11/175, or 6%) or inside a structure (16/175, or 9%). Finally, summary statistics for the analyses of body deposition by location for the subset basically mirror the results obtained for the total sample.

Table 4 presents the results from the Pearson's analysis of dispersal distance and PMI for the subset of 36 cases. A significant positive correlation ($p < 0.05$) exists between the estimated minimum and average PMI and the shortest distance an element was dispersed. This indicates that the more time that had passed since

TABLE 3—*Cross-tabulations and χ^2 values for the analysis of body deposition and location (n = 175).*

	Urban				Rural			
	Specific Location				Specific Location			
Ground Cover	Near Structure	Inside Structure	Away from Structure	Total	Near Structure	Inside Structure	Away from Structure	Total
Wooded	1 (2%)	1 (2%)	7 (16%)	9 (20%)	0 (0%)	1 (1%)	63 (48%)	64 (49%)
Open	15 (33%)	11 (24%)	9 (20%)	35 (78%)	10 (8%)	3 (2%)	43 (33%)	56 (43%)
Water	0 (0%)	0 (0%)	1 (2%)	1 (2%)	0 (0%)	0 (0%)	10 (8%)	10 (8%)
Total	16 (35%)	12 (27%)	17 (38%)	45 (100%)	10 (8%)	4 (3%)	116 (89%)	130 (100%)
χ^2		$\chi^2 = 9.959$				$\chi^2 = 16.655$		
p value		($p = 0.041$)				($p = 0.002$)		

TABLE 4—*Pearson's analysis of dispersal distance and postmortem interval (PMI) for sample subset (n = 36).*

	Shortest Distance*		Greatest Distance†		Average Distance‡	
	R Value	*p* Value	*R* Value	*p* Value	*R* Value	*p* Value
Estimated minimum PMI	0.447	(0.006)	− 0.167	(0.330)	− 0.070	(0.684)
Estimated maximum PMI	0.308	(0.068)	− 0.232	(0.172)	− 0.134	(0.436)
Estimated average PMI	0.342	(0.041)	− 0.223	(0.192)	− 0.123	(0.476)

*Denotes the straight-line distance between the original deposition site (ODS) and the skeletal element closest to it.
†Denotes the straight-line distance between the ODS and the skeletal element farthest away from it.
‡Denotes the average straight-line distance between the ODS and all skeletal elements.

the remains were deposited, the greater the distances between the ODS and the skeletal element closest to it. However, no significant relationships exist between PMI and either the greatest or average distances that remains were dispersed away from the ODS.

Results for the analyses involving dispersal direction are displayed in Figs. 2*a–d* and Tables 5 and 6. Figures 2*a* and *b* display the standard deviational ellipses, showing the dispersion of all skeletal elements for each case around the ODS in two dimensions. Figures 2*c* and *d* depict the weighted and nonweighted circular histograms displaying the directional means for cases in which skeletal elements had been dispersed. Most of the standard deviational ellipses are long and narrow, indicating a dominant dispersal direction for each case (Fig. 2*a* and *b*). However, when considering the mean dispersal directions of all cases simultaneously, no dominant direction is observed (Fig. 2*c* and *d*). As these graphs illustrate, no directional bias exists in the dispersal of skeletal elements around the ODS.

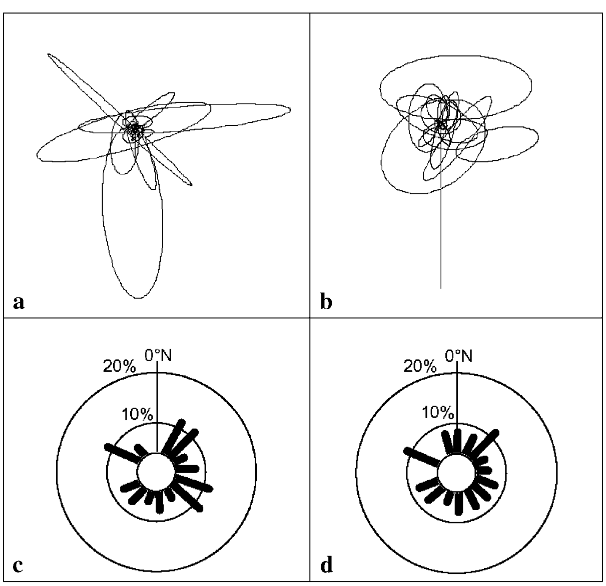

FIG. 2—*Standard deviational ellipses and circular histograms depicting directional scatter of elements around the ODS (n = 27). (a) Standard deviational ellipses for all cases, except those with bodies intact; (b) standard deviational ellipses as in Fig. 2a, with the removal of cases with the largest dispersal distances; (c) circular histogram based on nonweighted data; (d) circular histogram based on weighted data.*

Tables 5 and 6 display the results for the Pearson's analyses of dispersal distance and dispersal direction, and for PMI and dispersal direction, respectively. No significant relationships exist among any of these variables.

With the sample subset, we also wished to examine whether geographically specific patterns exist in the dispersal of specific skeletal elements such as the skull, os coxae, and femora. We selected these three elements for analysis because they often provide crucial profile information. The analyses we ran included only cases for which these elements were present and separated from the entire body. Moreover, if the skull, os coxae, or femora fragments from the same case were scattered separately, they were recorded as separate elements. For this reason, the sample size for each element varies. Table 7 presents summary statistics for dispersal distance of the skull, os coxae, and femora. In our dataset, the greatest distance any of these elements moved was 291 meters.

Additionally, we wished to analyze the relationships among PMI, dispersal distance, and dispersal direction for the skull, os coxae, and femora using Pearson's Correlation Coefficient. Table 8 displays the results of the analysis of PMI and dispersal distance for all three elements. No significant relationship exists between these two variables for any of the skeletal elements.

For analyses that involved dispersal direction, we were only able to assess the femora and os coxae. The reason for this is that circular variance can only be calculated in instances where at least two elements of the same kind (e.g., two or more femora or femoral fragments from the same case) have been dispersed from the ODS. Cases in which the femora and os coxae were separated from each other and the ODS provided the data needed to calculate the statistic. Tables 9 and 10 display the results of the analyses between dispersal direction and distance and between dispersal direction and PMI, respectively, for the femora and os coxae. In Louisiana, no significant relationship exists among any of the variables for either element.

Table 11 presents the summary statistics and the results from the analysis of the relationship between body deposition and season. No significant relationships exist between body deposition and season in this area.

TABLE 5—*Pearson's analysis of dispersal distance and dispersal directions (n = 27).*

	Shortest Distance*		Greatest Distance†		Average Distance‡	
	R Value	*p* Value	*R* Value	*p* Value	*R* Value	*p* Value
Circular variance (nonweighted)	0.045	(0.823)	0.319	(0.105)	0.170	(0.396)
Circular variance (weighted)	0.125	(0.535)	− 0.042	(0.835)	− 0.303	(0.125)

*Denotes the straight-line distance between the original deposition site (ODS) and the skeletal element closest to it.
†Denotes the straight-line distance between the ODS and the skeletal element farthest away from it.
‡Denotes the average straight-line distances between the ODS and all skeletal elements.

TABLE 6—*Pearson's analysis of postmortem interval (PMI) and dispersal direction ($n = 27$).*

	Estimated Minimum PMI					
	R Value	*p* Value	*R* Value	*p* Value	*R* Value	*p* Value
Circular variance (nonweighted)	– 0.277	(0.162)	– 0.253	(0.204)	– 0.261	(0.188)
Circular variance (weighted)	– 0.109	(0.587)	– 0.008	(0.968)	– 0.030	(0.880)

TABLE 7—*Dispersal distances of the skull, os coxae, and femora.*

Element	Number of Skeletal Elements	Shortest Distance*,†	Greatest Distance*‡	Average Distance*§
Skull	20	0	202.12	24.44
Os coxae	38	0.12	230.89	27.60
Femur	31	0.22	291.01	40.57

*All distances recorded in meters.
†Denotes the straight-line distance between the original deposition site (ODS) and the skeletal element closest to it.
‡Denotes the straight-line distance between the ODS and the skeletal element farthest away from it.
§Denotes the average straight-line distance between the ODS and all skeletal elements.

TABLE 8—*Pearson's correlation coefficient for dispersal distance and estimated postmortem interval (PMI).*

	Average Distance*					
	Skull ($n = 20$)		Os Coxae ($n = 21$)		Femora ($n = 20$)	
	R Value	*p* Value	*R* Value	*p* Value	*R* Value	*p* Value
Estimated minimum PMI	– 0.242	(0.305)	– 0.244	(0.286)	– 0.208	(0.279)
Estimated maximum PMI	– 0.289	(0.217)	– 0.249	(0.276)	– 0.323	(0.165)
Estimated average PMI	– 0.280	(0.231)	– 0.253	(0.269)	– 0.302	(0.196)

*Denotes the average straight-line distance between the ODS and all skeletal elements

TABLE 9—*Pearson's analysis for dispersal distance and dispersal direction (circular variance) for the os coxae and the femora.*

	Average Distance*			
	Os Coxae ($n = 16$)		Femora ($n = 11$)	
Dispersal Direction	*R* Value	*p* Value	*R* Value	*p* Value
Circular variance (nonweighted)	– 0.207	(0.441)	– 0.324	(0.332)
Circular variance (weighted)	– 0.168	(0.534)	– 0.341	(0.305)

*Denotes the average straight-line distance between the ODS and all skeletal elements.

TABLE 10—*Pearson's analysis of dispersal direction (circular variance) and estimated postmortem interval (PMI) for the os coxae and femora.*

	Os Coxae ($n = 16$)				Femora ($n = 11$)			
	Circular Variance Nonweighted		Circular Variance Weighted		Circular Variance Nonweighted		Circular Variance Weighted	
	R Value	*p* Value	*R* Value	*p* Value	*R* Value	*p* Value	*R* Value	*p* Value
Estimated minimum PMI	0.068	(0.803)	– 0.101	(0.710)	– 0.184	(0.589)	– 0.115	(0.736)
Estimated maximum PMI	0.037	(0.892)	– 0.096	(0.723)	0.094	(0.784)	0.201	(0.554)
Estimated average PMI	0.043	(0.875)	– 0.099	(0.714)	0.056	(0.871)	0.160	(0.639)

Results from the analysis of the distance of the dump site to the nearest road or waterway are presented in Table 12. A significant number of dump sites were located within $\frac{1}{4}$th mile of the nearest road ($p < 0.001$). Also, a significant number of dump sites were found farther than 1 mile from the nearest waterway ($p < 0.05$).

Discussion

Several factors need to be considered when examining data for universal or geographically specific patterns in dump sites, not only where the dump site is located but also how much time has passed since the body was deposited. Although our results for Louisiana indicate a clear preference for rural dump sites, our data sample is inherently biased toward bodies that have been missing for some time. Unlike Fowler, whose data are strictly urban Louisiana and indicate that dumped bodies are generally found within 12 h of being reported missing (9), the average estimated PMI for our subsample of 36 cases is 77 weeks (the minimum estimate is 25 weeks; the maximum estimate is 128 weeks). Therefore, our results are most applicable in situations where a missing person has not been found within the first 12 h since he or she went missing.

TABLE 11—*Summary statistics and χ^2 values for the analysis of body deposition by season (n = 36).*

	Number of Cases Based on Estimated Minimum PMI	Number of Cases Based on Estimated Maximum PMI	Number of Cases Based on Estimated Average PMI
Spring	7	13	10
Summer	10	7	7
Fall	7	7	12
Winter	12	9	7
Total	36	36	36
χ^2 value	2.000	2.667	2.000
p value	(0.572)	(0.446)	(0.572)

PMI, postmortem interval.

Additionally, our results do not indicate a directional bias in where remains are dispersed; however, our results must be interpreted with caution for several reasons. First, the nature of our data set is such that not every element was recovered in each case; we base the results on what we found (which, in some cases, was only a small percentage of the skeleton). If all elements in every case had been recovered, our results might have been slightly different. Secondly, though we examined the proximity of the dump sites to the nearest road and found that a significant number were dumped within a $\frac{1}{4}$ mile, we did not assess the influence that the road had on the direction in which elements were dispersed. Because the road or waterway presents a natural or man-made boundary, we hypothesize that the remains would be dispersed in directions parallel to the road or water. Although several of our cases followed this trend, we were unable to test this hypothesis using statistics because of our small sample size.

Finally, our analyses of the three specific skeletal elements (skull, os coxae, and femora) revealed that no pattern exists among dispersal distance and PMI for these elements. Additionally, we found that no relationship exists between dispersal direction and distance or between dispersal direction and PMI for the femora and os coxae. However, for all of these analyses, our sample size is small and, thus, should be interpreted with caution.

Conclusion

The results obtained in this study from Louisiana indicate that remains that have not been recovered within the first 12 h after being reported missing are more likely to have been dumped in a rural area. These dump sites tend to be within $\frac{1}{4}$ mile of a road, are found away from any type of structure, and are more likely to be found in wooded environments.

We did not find a geographically specific pattern in how remains are dispersed; however, if the dump site is near a road or waterway, the remains may parallel the boundary created by the road or water. Also, we hypothesized that a positive relationship exists between PMI and dispersal distance. Our results indicate there is a significant relationship ($p < 0.01$) between the shortest distance remains had been scattered and PMI; however, no relationship existed between PMI and the greatest or average distances.

TABLE 12—*Summary statistics and χ^2 analyses for the distance of the dump site to the nearest road or waterway (n = 36).*

Distance	To Nearest Road		To Nearest Waterway	
0.00–0.25 mile	30	(83.33%)	11	(30.56%)
>0.25–0.50 mile	4	(11.11%)	0	(0%)
>0.50–1 mile	2	(5.56%)	0	(0%)
>1 mile	0	(0%)	25	(69.44%)
Total	36	(100%)	36	(100%)
χ^2 value	40.66		5.44	
p value	(0.000)		(0.020)	

Additionally, we hypothesized that a negative relationship may exist between PMI and dispersal direction, and between dispersal direction and distance. Our data do not support any such relationships. Finally, in our dataset from Louisiana, we found no relationship between dispersal distance and the season in which the remains were dumped.

No geographically specific patterns of element dispersal were found among the variables assessed in this study of human remains dispersal in Louisiana. However, other factors that were not considered may contribute to where bodies are dumped and to how, where, and when remains are dispersed. Such variables would include the different kinds of animals typical of a specific area and their various scavenging behaviors, geographic factors such as vegetation, elevation, and natural rises or depressions, human infrastructure such as roads, or the tendency for the dump site to be inundated with water. Future directions for this research would include addressing the variables listed above, conducting similar studies in different geographic regions, and using satellite images to assess relationships among dump site selection, element dispersal, and geographical terrain on a larger and more representative database of dumped bodies.

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