

News and Short Contributions

Special Study

Plow-zone Zooarchaeology: Fragmentation and Identifiability

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*Fragments of long bones of deer (*Odocoileus* sp.) and deer-sized mammals recovered from a ca. 2000-year-old site in eastern Missouri were measured to the nearest 0.5 cm. Frequency distributions of fragment size-classes are similar among five subplow-zone excavation levels, but all have more large and fewer small fragments than does the plow zone. Frequency distributions of size classes for eight identifiable skeletal elements indicate a minimum identifiable fragment size exists that creates an analytical absence of skeletal elements that have in reality been collected.*

Introduction

To date, studies of the effects of cultivation on archaeological remains have focused almost exclusively on non-faunal materials. In the only study of plow-zone zooarchaeology of which we are aware, Hesse and Wapnish (1985:26–27) assume ceramic sherds are more resistant than bone to destruction by cultivation and that low relative frequencies of identifiable faunal remains indicate heavy taphonomic attrition. They compare ratios of sherds to identifiable faunal remains within vertical excavation levels and conclude the highest ratio occurs in the plow-zone level. While Hesse and Wapnish (1985:26) admit variation in the ratios may “reflect increased rates of fragmentation of pottery” in the plow zone, that crucial variable is not studied; nor are empirically- or logically-founded warrants provided for the two key assumptions.

Here we explore one effect of cultivation on faunal remains. We test the proposition that cultivation both fractures and reduces the size of bone specimens. Our test is indirect because we did not observe the relevant bone specimens prior to cultivation. Sufficiently strong warranting arguments can, however, be mustered to prompt acceptance of the proposition. We also examine the effect of bone-fragment size on taxonomic identifiability and conclude that a significant relationship exists between those two variables.

Methods and Materials

The Burkemper site (23LN104) is located on a low terrace of the Cuivre River in east-central Missouri and overlooks the Mississippi River flood plain which lies to the east. The site has been plowed for the past 120 years or more—continuously for at least the past 50 years. An intensive surface collection was made of all cultural materials within alternate 2×2 m grid units. Surface-collected pottery from the 1525 collected grid units indicates the site was occupied between ca. 200 B.C. and A.C. 500. Subsequent excavations indicate three major stratigraphic zones: a) a 22–25-cm plow zone containing many archaeological materials; b) a 40-cm-thick black organic loam containing similar amounts of materials; and c) a compact, silty-sand loam with few cultural remains. The plow zone was removed as a distinct stratigraphic unit, and the subplow zone was excavated in five 10-cm levels until sterile deposits were reached.

Assessment of cultivation-induced damage to faunal remains involved measurement to the nearest 0.5 cm of deer (*Odocoileus* sp.) and deer-sized long-bone diaphysis (shaft) fragments. Maximum length of a fragment was taken parallel to the long axis of the complete bone represented by the fragment. Fragments from the site surface displaying old breaks (fracture surface stained the same color as the unbroken surfaces of the specimen) were distinguished from surface fragments displaying fresh breaks (fracture surface not stained and typically lighter in color than unfractured surface of specimen). No specimens with unfused epiphyses were measured. Neither did we record fracture features such as shape or type of fracture because these features are still of debatable significance for identifying fracture agents (Lyman 1987a, with references).

All deer and deer-sized long-bone fragments recovered from nine 2×2 m excavation units also were measured and vertical recovery level was noted. The nine units were chosen because plow-zone bones had been collected from screened sediment; not all plow-zone units were so collected. We employ the Kolmogorov-Smirnov two-sample test to statistically assess similarities and differences between frequency distributions of fragment assemblages; all tests are two-tailed.

Processes of Bone Fragmentation and Distribution of Bone-Fragment Size Classes

That mammal bones regularly were broken by North American Indians in order to extract marrow and grease has long been recognized (e.g., Peale 1871), and many archaeologists have discussed the processes of fragmentation and their effects on bones (e.g., Vehik 1977). Ethnoarchaeological data indicate bone fragments resulting from these processes are exceptionally small, but few metric data have been presented on the exact size (e.g., Yellen 1977).

Uerpmann (1973) suggests, and Binford's (1978) ethnoarchaeological data confirm, that many small bone fragments will remain in the marrow/grease-processing area after it is cleared of larger fragments. Bone-fragment size classes therefore may have different distributions because of human depositional processes. Another human but postdepositional process affecting the distribution of bone-size classes is trampling (Gifford-Gonzalez et al. 1985, with references), which may differentially displace smaller pieces downward and/or fracture bones. Various natural processes also result in movement and fragmentation of bones (see reviews in Lyman [1987a], and Wood and Johnson [1978]).

Experimental work performed by archaeologists interested in the effects of cultivation on archaeological materials indicates larger objects should be more frequent relative to smaller materials on the surface than in the plow zone (Ammerman 1985; Lewarch and O'Brien 1981, with references). Other studies suggest plowing homogenizes the distribution of artifact width classes within the plow zone (Frink 1984).

Modeling of particular taphonomic agents and processes that create bone assemblages has become increasingly complex as actualistic data have been generated. While reliable (replicable) analytic techniques have been developed, many are not yet generally accepted, fully perfected, or demonstrably valid (accurate) indicators of particular taphonomic agents or processes. For example, Potts (1984:149) states "methods have not yet been developed to distinguish subsets of bones in an accumulation which have had different taphonomic histories." While we find ourselves in general agreement with such a position, we also believe it is possible to identify certain taphonomic agents and processes that have left visible traces on an assemblage (Lyman 1987a, b), even though we may be unable to measure on an interval scale the magnitude of the effects of particular taphonomic agents and processes.

Our procedure follows the general analytic procedure of comparisons between assemblage attributes (Klein and

Table 1. Comparison of frequency distributions of fragment size classes from plow zone and all excavation levels.

Size Class (cm)	Plow Zone		Excavation Levels	
	n	Cumulative %	n	Cumulative %
1.0	—	—	1	.001
1.5	2	.011	11	.012
2.0	10	.069	36	.049
2.5	33	.260	83	.134
3.0	31	.439	115	.252
3.5	26	.589	136	.392
4.0	22	.716	115	.510
4.5	17	.814	88	.601
5.0	11	.878	84	.687
5.5	6	.913	66	.755
6.0	3	.930	48	.804
6.5	5	.959	43	.848
7.0	0	.959	26	.875
7.5	2	.970	35	.911
8.0	1	.976	17	.928
8.5	1	.982	17	.945
9.0	0	.982	7	.952
9.5	1	.988	8	.960
10.0	0	.988	12	.972
10.5	2	.999	4	.976
11.0	0	.999	5	.981
11.5	—	—	6	.987
12.0	—	—	1	.988
12.5	—	—	2	.990
13.0	—	—	2	.992
14.5	—	—	1	.993
16.0	—	—	1	.994
16.5	—	—	1	.995
18.0	—	—	1	.996
Total	173	.999	972	.996

$D = .213; p < .01$

Cruz-Uribe 1984); notable differences suggest different taphonomic histories. Explaining those differences, i.e., identifying and specifying differences in those histories, requires use of attributes of the bones as well as geological and contextual data (Behrensmeier and Kidwell 1985).

Fragmentation in the Plow Zone

If cultivation results in bone fragmentation, we expect fragments recovered from the plow zone to be smaller than when deposited (Hesse and Wapnish 1985). Because we do not know the size of the specimens as originally deposited, we must infer that size from other lines of evidence. We explore these below.

The frequency distribution of fragment size classes for plow-zone specimens is significantly different than the frequency distribution for all subplow-zone specimens ($D = .213; p < .01$). The greatest cumulative difference (D) occurs in the 4.0- to 4.5-cm class; 81.4% of the plow-

zone fragments are ≤ 4.5 cm long, but only 60.1% of the subplow-zone fragments are ≤ 4.5 cm (TABLE 1). The largest plow-zone fragment is 10.5 cm, and the largest subplow-zone fragment is 18 cm; 2.3% of the subplow-zone fragments are more than 10.5 cm long.

Because marked differences in sample sizes exist between the plow-zone and subplow-zone assemblages, and because average fragment size could vary vertically through the site because of factors other than cultivation, we also compared the plow-zone assemblage with each excavation-level assemblage, and each pair of excavation-level assemblages was compared. The results (TABLE 2) indicate the excavation-level assemblages are not significantly different from each other, but each is different from the plow-zone assemblage. Frequency distributions of elements derived from subplow-zone excavation levels are essentially homogeneous, and each contains more large fragments than does the plow-zone assemblage. Bone fragments in the plow-zone are smaller than those in other vertical contexts.

Assuming that vertical differences in recovery context reflect temporal differences in occupation, differences between the plow-zone assemblage and subplow-zone excavation-level assemblages may indicate more intensive fracturing of bones during the latest occupation of the site. Stability of fragment size-class frequency distributions across all deeper levels and homogeneity in artifact classes throughout the entire vertical sequence weigh against this possibility. Overburden weight apparently has not significantly reduced the size of more deeply buried fragments (Klein and Cruz-Urbe 1984).

Table 2. Comparison of plow zone to each excavation level. Size class at which D occurs is given in parentheses.

	Plow Zone ($n = 173$)	Level 1	Level 2	Level 3	Level 4
Level 1 ($n = 374$)	$D = .246$ (4.5) $p < .01$				
Level 2 ($n = 229$)	$D = .217$ (4.5) $p < .01$	$D = .029$ (4.5) $p > .05$			
Level 3 ($n = 207$)	$D = .163$ (4.5) $p < .05$	$D = .111$ (3.5) $p > .05$	$D = .093$ (3.5) $p > .05$		
Level 4 ($n = 110$)	$D = .235$ (3.5) $p < .01$	$D = .071$ (5.0) $p > .05$	$D = .07$ (5.0) $p > .05$	$D = .124$ (3.5) $p > .05$	
Level 5 ($n = 52$)	$D = .293$ (4.0) $p < .01$	$D = .067$ (4.5) $p > .05$	$D = .089$ (3.0) $p > .05$	$D = .156$ (4.0) $p > .05$	$D = .086$ (4.0) $p > .05$

It is doubtful that recycling of waste bones would create a size effect in reverse of that observed for artifacts (smaller artifacts more deeply buried than larger artifacts [Baker 1978]); no trace of such use is apparent in excavation levels 1 through 5. Trampling tends to cause smaller bone fragments to become more deeply buried and larger bone fragments to remain more shallowly buried (Gifford-Gonzalez et al. 1985; Yellen 1977). We see no evidence for such effects in excavation-level assemblages, and we see exactly the opposite in comparisons of the excavation-level assemblages with those from the plow zone. Limited data suggest smaller pieces of cultural material may "float" upward because of various perturbational processes (Villa 1982). We see no evidence for this in the excavation-level assemblages, and in fact the smallest fragments occur in those assemblages. Finally, it has been suggested that plowing tends to bring the largest pieces in the plow zone to the surface (Lewarch and O'Brien 1981). Comparison of the plow-zone assemblage to the surface assemblage suggests more small fragments were on the surface than in the plow zone ($D = .63$; $p < .001$). We suspect this phenomenon is in part the result of different analysts measuring the two assemblages.

No significant difference exists between the frequency distribution of size classes for the surface assemblage and plow-zone assemblage when only specimens identifiable to element are considered ($D = .107$; $p > .1$). A single analyst measured all those specimens; thus interobserver bias is not involved, but the minimal size of identifiable fragments is no doubt involved (see below) and may be causing the lack of difference. We therefore cannot evaluate whether larger bone fragments are differentially brought to the surface by cultivation.

Given the foregoing observations, we suggest that bone specimens recovered from the plow zone were larger and less fragmented when originally deposited than when recovered, and therefore we infer that cultivation has in fact fractured bones in the plow zone. This inference accounts for fragments in the plow zone being smaller than those in excavation levels below the plow zone. Because fragment size exerts strong control over whether or not a specimen can be identified to element and taxon, we now turn to this important topic.

Fragment Size and Identifiability

At the most general level, faunal remains can be identified as representing large, medium, or small animals. At a finer level, the analyst may be able to recognize the skeletal element, and perhaps the taxonomic order or family, represented by a fragmented specimen. At the finest level, the skeletal element and genus and species can be

identified. In order to recognize the taxon at family or finer levels, the skeletal element typically must be identifiable; often, if the analyst cannot recognize the element, then fine-scale taxonomic identifications are precluded (Lyman 1979). Therefore, factors controlling the identifiability of skeletal elements represented by fragments also control taxonomic identification. While analyzing our plow-zone data, we found fragment size to be a major factor controlling identifiability.

Fifteen years ago Watson (1972:224) wrote that there generally is a "failure to identify fragments below a certain size. The degree of difficulty of identification will depend on the proportion of diagnostic zone that a fragment possesses." Although Watson noted only that unidentifiable cattle-bone fragments would on average be larger than unidentifiable sheep-bone fragments, his observation can be expanded to include noting that unidentifiable fragments of cattle phalanges will on average be smaller than unidentifiable fragments of cattle femurs because complete specimens of the former are only 10% or less the size of complete specimens of the latter.

We compared the frequency distribution of old breaks in the combined surface and plow-zone assemblages to those of old breaks in the subplow zone for each of eight skeletal elements. Only one of the eight elements showed a significant difference (TABLE 3); 100% of the plow-zone metacarpals are ≤ 5.0 cm, while only 43.7% of those from the subplow zone are ≤ 5.0 cm. These results suggest some factor other than *cultivation* is controlling the frequency distributions of size classes of the eight elements. We then compared the frequency distribution of size classes for old-break fragments of the summed eight identified elements from the plow zone and subplow zone with the frequency distribution of size classes for all unidentifiable diaphysis fragments from the plow zone and

subplow zone. These two distributions are significantly different ($D = .186$; $p < .01$). The greatest cumulative difference (D) occurs at size class 5.0–5.5 cm; 67.5% of the identifiable specimens ($n = 567$) are ≤ 5.5 cm, while 86.1% of the nonidentifiable fragments ($n = 705$) are ≤ 5.5 cm. This indicates that the identifiable fragments tend to be larger than the unidentifiable fragments.

This conclusion has important implications. Of primary concern here, it supports Hesse and Wapnish's (1985) assumption that low relative frequencies of identifiable faunal remains indicate taphonomic attrition. If reduced beyond the minimal identifiable size, then the proportion of identifiable fragments will be decreased. At a more general level, an entire skeleton might be recovered, but if the bones of that skeleton are extensively and intensively fragmented, few bones may be identifiable to skeletal element and even fewer to genus or species. This *analytic absence* of elements (and perhaps taxa) has significance for analytic techniques that interpret frequencies of elements and element parts in terms of differential transport and/or destruction (Lyman 1985, with references). Such techniques must include consideration of whether rare elements are rare because of their analytic absence or because of their prehistoric absence in the systemic context (resulting from transport and/or destruction by consumption or fragmentation). Because all these factors result in decreased abundances, interpretations of those abundances must take into account the equifinality involved.

Shipman (1981) suggests comparisons between sizes of nonidentifiable and identifiable specimens could have taphonomic significance. On one hand, she suggests that if the two categories consist of similarly sized specimens, then the taphonomic histories of each category are similar. On the other hand, if the two categories consist of specimens of different sizes, then each category experienced a unique taphonomic history. Further, she suggests if specimens in the nonidentifiable category are smaller than identifiable specimens, then intensive fracture of the former is probable. And, if the nonidentifiable specimens are larger than the identifiable specimens, Shipman (1981: 129) suggests this indicates the latter were "protected from the forces that damaged the indeterminates." The only possible way we can conceive of nonidentifiable specimens being, on average, the same size or larger than the identifiable specimens is when multiple taxa of various sizes are represented. Although our data indicate Shipman is correct in suggesting that when nonidentifiable specimens are smaller than identifiable specimens the former were subjected to intensive fragmentation, this correlation should be found only when taxonomic variation in bone sizes has been controlled. Clearly, then, the other sugges-

Table 3. Comparison of identifiable fragments displaying old breaks from the surface and subsurface plow zone to identifiable fragments from excavation levels.

Element	PZN*	EXL†	D statistic	p
Humerus	19	58	.188	> .05
Radius	16	46	.179	> .05
Metacarpal	14	32	.563	< .01
Femur	11	23	.330	> .05
Tibia	23	42	.325	> .05
Metatarsal	46	89	.234	> .05
Metapodial	25	31	.283	> .05
First phalanx	19	63	.168	> .05

*Sample size from plow zone.
†Sample size from excavation levels.

tions Shipman offers only can be considered if taxonomic variation in bone size has been controlled.

Summary and Conclusions

Diaphysis fragments from the plow zone tend to be smaller than those from excavation levels beneath the plow zone. Consideration of available geological, contextual, and ethnoarchaeological data suggests that cultivation activity has resulted in fragmentation of bone specimens in the plow zone. Our analyses suggest that there is a minimum identifiable size of diaphysis fragment. This minimum identifiable size will vary from taxon to taxon and from skeletal element to skeletal element within a skeleton. Analysts who interpret element frequencies of a single taxon must now be cognizant of the possibility that some elements may be analytically absent despite their actual presence in a collection.

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