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ABSTRACT

Cutmarks observed in archaeofaunal assemblages are an important source of evidence in the reconstruction of prehistoric butchery strategies. Inherent in these reconstructions is the assumed covariance of the intensity of butchery activities and the resulting cutmarks. This study proposes a simple measure of processing (butchery) intensity—the number of tool strokes amassed during defleshing activities—in an attempt to test this assumption. Data on this measure of processing intensity were collected during the experimental butchery of 16 appendicular carcass segments from large ungulates. Based on the measure of processing intensity utilized here, there seems to be no clear-cut relationship between the number of tool strokes and the resulting frequency of cutmarks or the frequency with which specific bone specimen classes are cutmarked. The results presented here have substantial implications for the interpretation of cutmarks and concomitant assessments of prehistoric human diet and subsistence behavior.

Keywords: cutmarks, butchery, experimental archaeology, processing intensity, zooarchaeology

The concept of processing intensity as it relates to carcass butchery behavior plays an integral role in zooarchaeological inferences of prehistoric human diet and subsistence. Inferring variation in the intensity of processing between or within units of analysis (e.g., skeletal elements, prey body size, sex, age classes, etc.) is important because this variation presumably reflects different trajectories of carcass utilization (e.g., Rapson 1990). Zooarchaeologists commonly use data on bone surface modifications (cutmarks, percussion marks) to ascertain the nature of inferred differences in processing intensity. Variation in the intensity of processing behavior has been considered in relation to several interrelated contingencies, including prey body size (Lyman 1987, 1992; Marshall 1986), postmortem carcass condition (Binford 1981, 1988; Lupo 1994), carcass acquisition strategies (Bunn and Kroll 1986; Lupo and O'Connell 2002; Marean 1998; Marean et al. 2000; Milo 1998; Monahan 1996; Shipman 1986), and variation in specific butchery procedures (Fisher 1984; Frison 1970, 1971; Guilday et al. 1962; Parmalee 1965; Todd et al. 1997; Wheat 1972, 1979). However, all analyses attempting to distill evidence of differential processing intensity from bone surface modification data are subject to a critical assumption: the intensity of butchery activities is directly related to the frequency occurrence of bone damage resulting from those activities. This assumption has been explicitly supported several times (e.g., Abe et al. 2002:657; Binford 1988:127; Milo 1998:104; Parmalee 1965:9) and its implications discussed in depth (Lyman 1992, 1994 for cutmarks, 1995 for cutmarks and percussion marks). As Lyman (1992, 1995) points out, this assumption must be recognized and accounted for in order to conduct any meaningful pattern recognition study of prehistoric manifestations of butchery.

The present study provides an initial test of this assumption through the analysis of cutmarks resulting from the experimental butchery of large ungulate carcass units. First, archaeological definitions and measurements of processing intensity will be examined. Second, an investigation of the

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quantitative relationship between processing intensity (as measured experimentally) and cutmark frequency will be conducted. Finally, several factors contributing to differential processing intensity and variation in cutmark frequency will be considered.

DEFINING AND MEASURING CARCASS PROCESSING INTENSITY ARCHAEOLOGICALLY

An examination of how different workers envision carcass processing intensity and its relation to cutmark creation helps to develop a working definition of the concept and how to measure it. For example, Milo (1998:104) argues that "other things being equal, the frequency with which bones are marked is related primarily to the butchering effort exerted, and, by extension, to the relative difficulty of disarticulating and filleting a carcass." Similarly, Abe et al. (2002:657) state "[a] key assumption that all zooarchaeologists make in this type of analysis is that more intensive cutting (more cutting actions) results in higher frequencies of cutmarks on the bone surface." Finally, Binford (1988:127) suggests that "the number of cut marks, exclusive of dismemberment marks, is a function of differential investment in meat or tissue removal." The theme propounded here is that if a butcher works harder, more bone specimens will be cut and more individual cutmarks will be created on each specimen. However, what constitutes "working harder"? The above quotations suggest that a butcher works harder when more time and more cutting actions are invested in completing a particular activity.

Archaeologically, processing intensity is commonly measured in two ways: (1) by counting the number of specimens that exhibit one or more cutmark; and (2) by counting the frequency of individual cutmarks on each specimen (for useful reviews of cutmark quantification procedures see Abe et al. 2002; Bartram 1993; Lyman 1992, 1994:303-306). Based on the traditional assumption under scrutiny here, the number of specimens displaying at least one cutmark is expected to be proportional to the frequency with which specimens of that type (e.g., skeletal element, skeletal element portion, etc.) were butchered (Lyman 1992, 1995). These measures are referred to here as butchered specimen counts. Similarly, higher frequencies of individual striations on a specific specimen presumably reflect or are proportional to the number of tool strokes amassed in butchering the skeletal element or skeletal element portion represented by that specimen. These measures are referred to as cutmark frequency counts. The experimental data presented here will be used to investigate the effectiveness of these measures for estimating the intensity of processing behavior empirically.

MATERIALS AND METHODS

Over a period of two years (4 November 1999 to 18 October 2001), a total of 22 experimental butchery events (referred to as BE-1 through BE-22) were conducted by the author and colleagues at the Laboratory of Public Archaeology (LOPA), Colorado State University, Ft. Collins, Colorado. Because of limited sample sizes for other taxa, only those butcheries involving domestic horse (*Equus caballus*) and domestic cattle (*Bos taurus*) are considered (n=16) (Table 1). Butcheries were carried out on supple fore- and hindlimb units, with one exception involving a frozen horse hindlimb. "Supple" refers to any carcass unit with skin and meat packages that are still fresh and easily manipulated. Supple carcasses may, however, have stiff joints due to rigor mortis. The delayed butchery of fresh but rigored carcasses as a result of hunting tactics and logistical contingencies appears to be fairly common among ethnographically documented hunter-gatherers (e.g., Binford 1981; Lupo 1994).

The present analysis is restricted to cutmarks produced by the defleshing of appendicular meat-bearing skeletal elements only (forelimb: scapula, humerus, radius/ulna; hindlimb: femur, tibia). Because all skeletal elements from a specific limb unit were exposed to various processing activities (skinning, disarticulation, tendon removal, etc.), it was necessary to carefully record where on a skeletal element each of these non-defleshing activities was initiated in order to eliminate cutmarks resulting from these procedures from the present analysis. This was fairly straightforward in all cases as skinning and tendon removal impacted metapodials, carpals and tarsals and disarticulation was conducted in only one instance.

All tools were manufactured by the butchers and consisted of unmodified obsidian or chert

Table 1. Description of butchery episodes

Butchery no	Taxon	Unit	Completeness	Condition
BE-1	Cattle	Hindlimb	Complete	Supple
BE-2	Horse	Forelimb	Complete	Supple
BE-3	Horse	Hindlimb	Minus Femur	Supple
BE-4	Horse	Hindlimb	Minus Femur	Supple
BE-5	Horse	Hindlimb	Minus Femur	Supple
BE-6	Horse	Hindlimb	Minus Femur and Proximal Tibia	Supple
BE-7	Horse	Hindlimb	Complete	Supple
BE-8	Horse	Hindlimb	Complete	Supple
BE-11	Cattle	Hindlimb	Complete	Supple
BE-12	Cattle	Forelimb	Complete	Supple
BE-13	Horse	Forelimb	Complete	Supple
BE-14	Horse	Forelimb	Complete	Frozen
BE-15	Cattle	Forelimb	Complete	Supple
BE-19	Cattle	Forelimb	Complete	Supple, immature
BE-21	Cattle	Forelimb	Complete	Supple
BE-22	Cattle	Forelimb	Complete	Supple

flakes (i.e., expediently manufactured flake tools: Figure 1). No attempt was made to resharpen any tools during the butchery process. When butchery became exceedingly difficult with a particular tool, it was replaced immediately and butchery resumed. Following butchery, the elements comprising each unit were boiled in tap water until the remaining tissues could be easily removed. Cutmarks were tallied individually (i.e., each discernable striation) under a strong oblique light source with the aid of a 10x hand lens using established identification criteria (see Blumenschine et al. 1996; Bunn 1981, 1982).

Tool strokes were counted as an estimate of carcass processing intensity. "Tool strokes" denotes the total number of discrete motions required to completely deflesh an entire limb unit or individual skeletal element. Thus, a higher tool stroke count

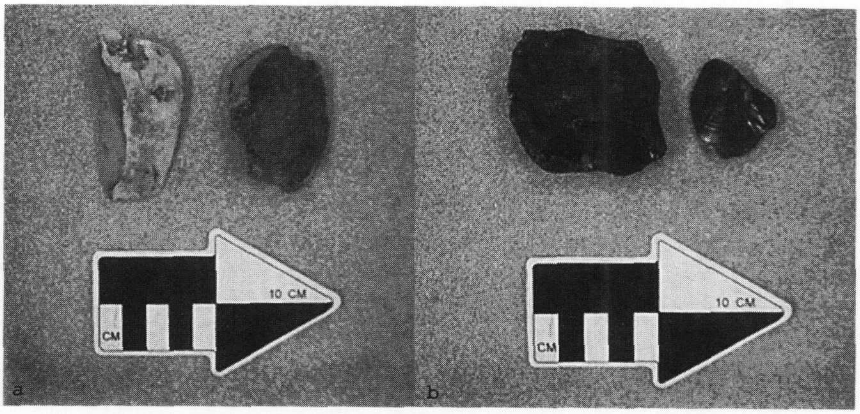

Figure 1. Examples of tools used during experimental butchery: (a) Chert; (b) Obsidian.

Table 2. Locational descriptions of anatomical zones for appendicular meat-bearing skeletal elements (as defined by Hill 2001: Table 2.1)

Element	Anatomical Zone	Description
Scapula		
	Proximal	distal acromion toward proximal, including spine
	Distal	distal acromion toward glenoid cavity
Humerus		
	Proximal	proximal of proximal deltoid tuberosity
	Shaft	proximal deltoid tuberosity to proximal olecranon fossa
	Distal	distal of proximal olecranon fossa
Radius/Ulna		
	Proximal	proximal of proximal radial tuberosity
	Shaft	proximal radial tuberosity to distal fusion line
	Distal	distal of distal fusion line
Femur		
	Proximal	proximal of proximal minor trochanter
	Shaft	proximal minor trochanter to distal supracondyloid fossa
	Distal	distal of distal supracondyloid fossa
Tibia		
	Proximal	proximal of proximal fusion line
	Shaft	proximal fusion line to distal fusion line
	Distal	distal of distal fusion line

is equivalent to a higher processing intensity. Although elapsed time is a common measure of differential investment in an activity (and was recorded in these experiments), tool strokes were chosen because they can establish an empirical link with cutmark frequencies. In other words, a unit of time cannot, under normal circumstances, "become" a cutmark. A tool stroke, on the other hand, has the potential to inflict bone surface damage and become a visible cutmark such that each tool stroke, when in contact with the bone surface, can produce a corresponding striation. Because we cannot observe archaeologically either the tool strokes or the time spent in a prehistoric butchery episode, we need to examine how, if at all, the frequencies of *observable* cutmarks relate to processing intensity.

Because archaeofaunal assemblages are invariably fragmented to some degree, an identified specimen is commonly attributed to a portion of

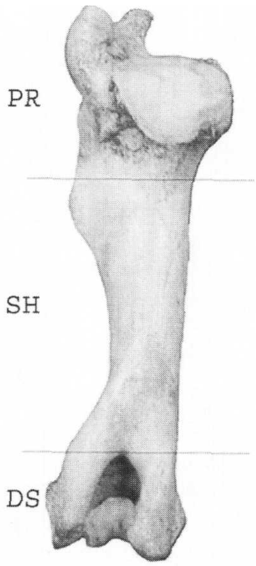

Figure 2. Anatomical zones for the humerus. PR-proximal zone; SH-shaft zone; DS-distal zone (adapted from Hill 2001: Figure 2.1).

the skeletal element from which it derives. This results in butchered specimen and cutmark frequency counts that are tallied by skeletal portion (e.g., proximal, shaft, and distal for long bones). In order to evaluate the applicability of butchered specimen counts as reliable indicators of processing intensity, each appendicular element was divided into anatomical zones, which are based on easily identified landmarks (Bunn 2001; Hill 2001). Table 2 summarizes the descriptive information for these anatomical zones for meat-bearing appendicular skeletal elements. Although the approach is obviously biased against some zones of particular elements (the proximal and distal zones of the tibia, the distal zone of the radius/ulna) in terms of surface area represented, it has the advantage of being analytically comparable across assemblages. In addition, the method assumes no *a priori* functional relationship with cutmark location; indeed, aspect data (i.e., lateral, medial, cranial, caudal, etc.) are probably necessary for real functional interpretations of cutmark location (Egeland and Byerly unpublished experimental data). Figure 2 displays the anatomical zones of the humerus as an example. These divisions allow for a test of whether or not all parts of a skeletal element will equally reflect the intensity of butchery.

Meat weights were taken for each skeletal element to the nearest tenth of a kilogram. The meat allocated to each skeletal element was determined by straight cuts along the articular planes of adjoining elements (Figure 3).

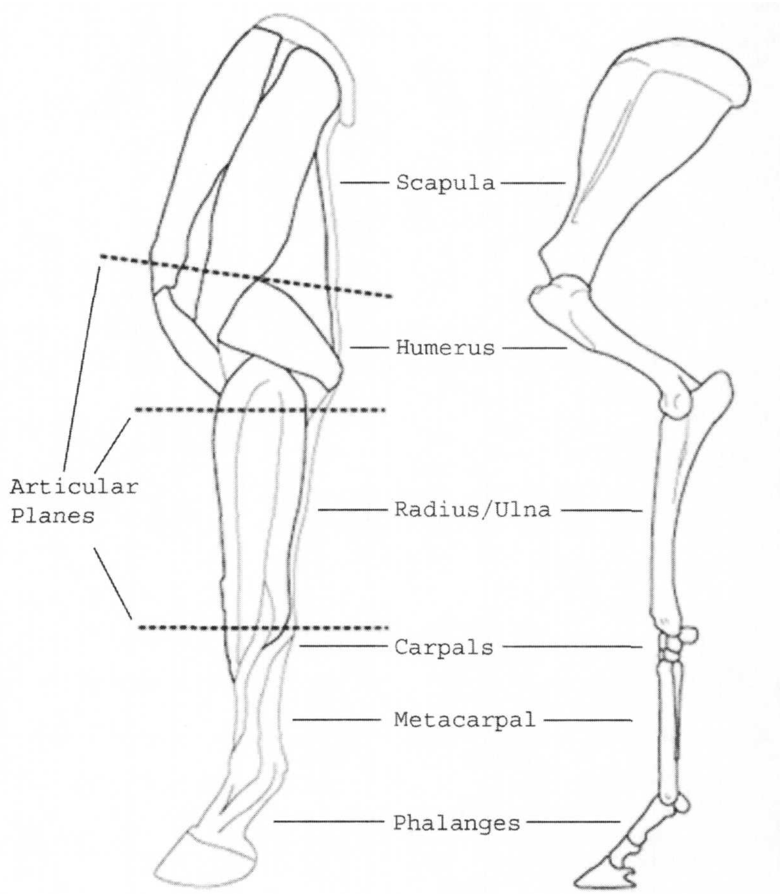

Figure 3. Schematic representation of a forelimb unit showing how muscle packets were allocated for meat weight measurements.

RESULTS

Carcass Processing Intensity and Cutmark Frequency Counts

Table 3 summarizes the total tool strokes and the total number of observed cutmarks on each appendicular unit for each butchery episode. Figure 4 displays the data graphically in a bivariate scatterplot. A Pearson's correlation coefficient shows that these two variables are not significantly correlated ($r=0.02$, $P=0.94$). Omitting the frozen carcass unit (BE-14) results in an insignificant correlation as well ($r=-0.04$, $P=0.89$).

Subdividing the data by taxon also produces insignificant relationships (horse: $r=0.59$, $P=0.13$; cattle: $r=-0.46$, $P=0.30$). These data are presented graphically in Figure 5. Although the relationships

Table 3. Raw data for each butchery episode

Butchery no	Taxon	Unit	StrokesDF[a]	Cuts[b]	%[c]
BE-1[d]	Cattle	Hindlimb	3747	11	0.29
BE-2	Horse	Forelimb	1937	59	3.05
BE-3	Horse	Hindlimb	577	8	1.39
BE-4	Horse	Hindlimb	582	14	2.41
BE-5	Horse	Hindlimb	594	1	0.17
BE-6	Horse	Hindlimb	202	1	0.50
BE-7	Horse	Hindlimb	2575	32	1.24
BE-8	Horse	Hindlimb	2407	2	0.08
BE-11	Cattle	Hindlimb	1402	53	3.78
BE-12	Cattle	Forelimb	1128	20	1.77
BE-13	Horse	Forelimb	2449	39	1.59
BE-14	Horse	Forelimb	9742	39	0.40
BE-15	Cattle	Forelimb	2469	0	0.00
BE-19[e]	Cattle	Forelimb	326	53	16.26
BE-21[e]	Cattle	Forelimb	1291	62	4.80
BE-22[e]	Cattle	Forelimb	1379	136	9.86

[a]Total tool strokes required to deflesh all skeletal elements.
[b]Total observed cutmarks on all defleshed skeletal elements for each event.
[c]Percentage of defleshing tool strokes that become manifest as visible cutmarks (Cuts/StrokesDF) * 100.
[d]Tool strokes were not counted for each individual skeletal element during this episode; thus, data will not be included in skeletal element comparisons.
[e]Humerus not defleshed.

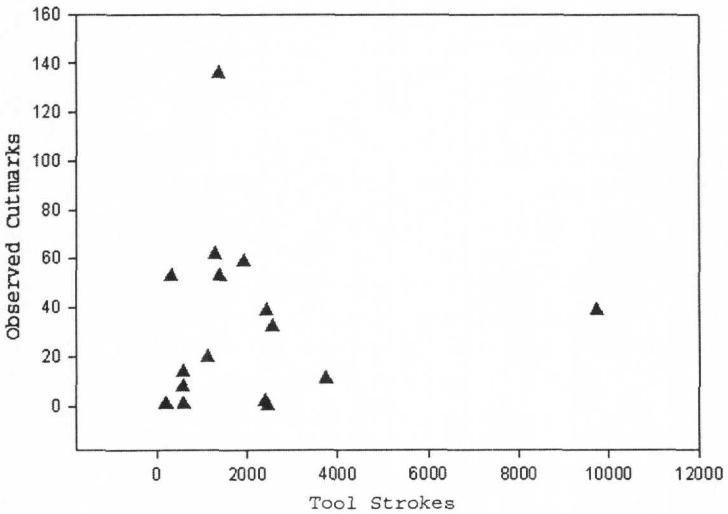

Figure 4. Bivariate scatterplot showing the relationship between processing intensity (tool strokes) and observed cutmark frequency for complete appendicular units from all experimental episodes.

between tool strokes and cutmark frequencies are statistically insignificant, it is interesting to note that each taxon displays opposite relationships; i.e., horse units show a positive relationship while cattle units display a negative relationship. This suggests that increased numbers of tool strokes during cattle butchery actually generated *decreased* cutmark frequencies on this taxon (Figure 5).

Table 4 summarizes the tool stroke and cutmark data for each individual skeletal element from each butchery episode. Table 5 presents

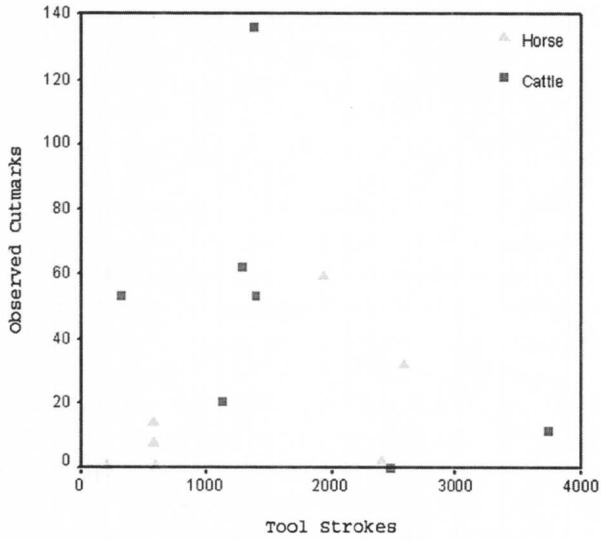

Figure 5. Bivariate scatterplot showing the relationship between processing intensity (tool strokes) and observed cutmark frequency for complete appendicular units from horse (triangles) and cattle (squares).

Pearson's correlations for the relationship between tool strokes and cutmark frequencies for each skeletal element. No skeletal element displays a statistically significant relationship between the two variables.

Carcass Processing Intensity and Butchered Specimen Counts

Because all observed cutmarks were inflicted during defleshing and each anatomical zone was butchered with equal frequency, the experimental data can be examined to evaluate if all anatomical zones preserve evidence of this activity in equal proportions. Because of the nature of butchered specimen counts (see above), the only requirement that need be met is

Table 4. Tool stroke and cutmark data for individual skeletal elements.

		Scapula			Humerus			Radius/Ulna		
		DFStrokes[a]	Cuts[a]	%[a]	DFStrokes	Cuts	%	DFStrokes	Cuts	%
BE-2	Horse	535	8	1.5	877	7	0.8	525	44	8.38
BE-12	Cattle	395	5	1.27	371	7	1.89	362	8	2.21
BE-13	Horse	739	26	3.52	1124	9	0.8	586	4	0.68
BE-14	Horse	5397	13	0.24	2265	17	0.75	2080	9	0.43
BE-15	Cattle	986	0	0	532	0	0	951	0	0
BE-19	Cattle	148	20	13.51	—	—	—	178	33	18.54
BE-21	Cattle	596	31	5.20	—	—	—	695	31	4.46
BE-22	Cattle	502	107	21.31	—	—	—	877	29	3.31
Averages		1162.3	26.3	5.82	1035.8	8	0.85	781.8	19.8	4.75

		Femur			Tibia		
		DFStrokes	Cuts	%	DFStrokes	Cuts	%
BE-3	Horse	—	—	—	577	8	1.39
BE-4	Horse	—	—	—	582	14	2.41
BE-5	Horse	—	—	—	594	1	0.17
BE-6	Horse	—	—	—	202	1	0.5
BE-7	Horse	2155	3	0.14	420	29	6.9
BE-8	Horse	1757	0	0	650	2	0.31
BE-11	Cattle	687	31	4.51	715	22	3.08
Averages		1533	11.3	1.55	534.3	11	2.11

[a]See Table 3 for definitions.

Table 5. Pearson's correlation coefficients for the relationship between observed cutmarks and tool strokes for each skeletal element

Element	r-value	P-value
Scapula (n=7)[a]	-0.16	0.73
Humerus (n=4)[a]	0.54	0.46
Radius/Ulna (n=7)[a]	-0.62	0.14
Femur (n=3)	-0.94	0.23
Tibia (n=7)	0.14	0.76

[a]Frozen horse forelimb not included.

that each anatomical zone display at least one cutmark.

If all specimens were recovered as complete or nearly complete skeletal elements, the frequency with which each skeletal element was butchered could be reliably reconstructed, as 87% of the butchered elements retain at least one cutmark. This is, however, rarely the case because of the fragmentary nature of most archaeofaunal assemblages. When divided into anatomical zones, the cutmark data present a significantly less accurate reflection of butchery behavior (Table 6). Cutmarks not only appear unequally across anatomical zones, but also are entirely absent from some zones. Nevertheless, several patterns emerge. First, distal anatomical zones from radio/ulnae, femora, and tibiae display no cutmarks from any butchery episode. Butchered specimen counts based on these zones are not an accurate reflection of the frequency with which these skeletal elements were in fact butchered. Second, proximal anatomical zones from tibiae also display no cutmarks, which means that only shaft zones from tibiae ever preserve evidence of experimental defleshing. Third, although not all anatomical zones for the humerus display cutmarks in every instance, each zone was cut with the same *proportion* (three out of five). Thus, archaeologically (assuming low levels of differential destruction, complete recovery techniques, a comprehensive analysis of all fragments, etc.) one would accurately conclude that all zones were butchered with the same frequency. Inter-element variability in the proportion of cutmarked zones is more problematic. For example, even to arrive at broadly equivalent proportions of butchery across all elements, which is indeed the case (all zones of all elements were subjected to butchery), one would need to have compared either the proximal, shaft, or distal anatomical zone of the humerus (60%), the proximal zone of the scapula (75%), the proximal zone of the radius/ulna (62.5%), the shaft zone of the femur (66.7%), and the shaft zone of the

Table 6. Number and percentage of each anatomical zone displaying at least one cutmark

Scapula				Humerus				Radius/Ulna			
Zone	Butchered	Cut	%	Zone	Butchered	Cut	%	Zone	Butchered	Cut	%
PR	8	6	75.0	PR[a]	5	3	60.0	PR	8	5	62.5
SH[d]	–	–	–	SH[b]	5	3	60.0	SH	8	7	87.5
DS	8	3	37.5	DS[c]	5	3	60.0	DS	8	0	0.0
All	8	7	87.5	All	5	4	80.0	All	8	7	87.5

Femur				Tibia			
Zone	Butchered	Cut	%	Zone	Butchered	Cut	%
PR	3	0	0.0	PR	7	0	0.0
SH	3	2	66.7	SH	7	7	100.0
DS	3	0	0.0	DS	7	0	0.0
All	3	2	66.7	All	7	7	100.0

[a]Proximal anatomical zone (see Hill 2001: Table 2.1).
[b]Shaft anatomical zone.
[c]Distal anatomical zone.
[d]Scapulae have no "shaft" anatomical zone.

tibia (100%).

VARIABLES INFLUENCING CARCASS PROCESSING INTENSITY AND CUTMARK CREATION

Experimental data indicate that there is no consistent relationship between increased frequencies of cutmarks and more intensive processing activities. Thus, the question remains: Why are some bones cutmarked with higher frequencies than others? From the viewpoint of inter-element variation, differential cutmark frequencies may be conditioned by the amount of meat on a particular skeletal element. This assertion assumes that the amount of meat attached to a particular element makes it more/less likely that a stone tool will inflict bone surface damage (Bunn 2001; Bunn and Kroll 1986, 1988; Gifford-Gonzalez 1989). Table 7 presents meat weights for each skeletal element from each butchery episode. Correlation analysis indicates no significant relationship with cutmark frequency ($r=-0.08$, $P=0.67$), suggesting that the amount of meat attached to a particular skeletal element has little direct influence on cutmark frequency.

Binford (1981, 1984, 1988) has argued that postmortem carcass condition may significantly affect cutmark frequencies. Although his discussions were limited almost exclusively to disarticulation activities, the implications can be tested using the experimental defleshing data set. Binford posited that because some postmortem conditions, specifically frozen or dessicated, would render carcasses stiff, more effort would be required to butcher them. He predicted this increase in effort would result in diagnostic cutmark placement and increased cutmark frequencies. The experimentally butchered frozen horse forelimb (BE-14) presents an opportunity to examine specifically this hypothesis concerning stiff carcass butchery. Figure 6 displays the disparity in processing intensities between the frozen horse forelimb and the supple horse forelimbs and compares these to the observed cutmark frequencies. For two of the three meat-bearing appendicular skeletal elements (scapula and radius/ulna), increased processing intensities are *not* accompanied by an increase in cutmark frequencies for the frozen horse forelimb. This situation is best explained by the fact that even though

Table 7. Meat weights associated with each skeletal element

Taxon (Butchery #)	Weight (kg)
Scapula	
EQ(2)	8.60
EQ(13)	3.10
EQ(14)	8.40
BO(12)	6.10
BO(15)	3.00
BO(19)	1.10
BO(21)	5.20
BO(22)	5.80
Humerus	
EQ(2)	7.10
EQ(13)	4.40
EQ(14)	5.50
BO(12)	4.80
BO(15)	6.30
Radius/Ulna	
EQ(2)	2.80
EQ(13)	2.10
EQ(14)	2.40
BO(12)	1.90
BO(15)	2.30
BO(19)	0.70
BO(21)	2.40
BO(22)	2.30
Femur	
EQ(7)	25.70
EQ(8)	17.50
BO(11)	17.40
Tibia	
EQ(3)	3.40
EQ(4)	2.50
EQ(5)	3.80
EQ(6)	0.50
EQ(7)	4.50
EQ(8)	2.90
BO(11)	4.10

Codes: BO-*Bos taurus;* EQ-*Equus caballus*

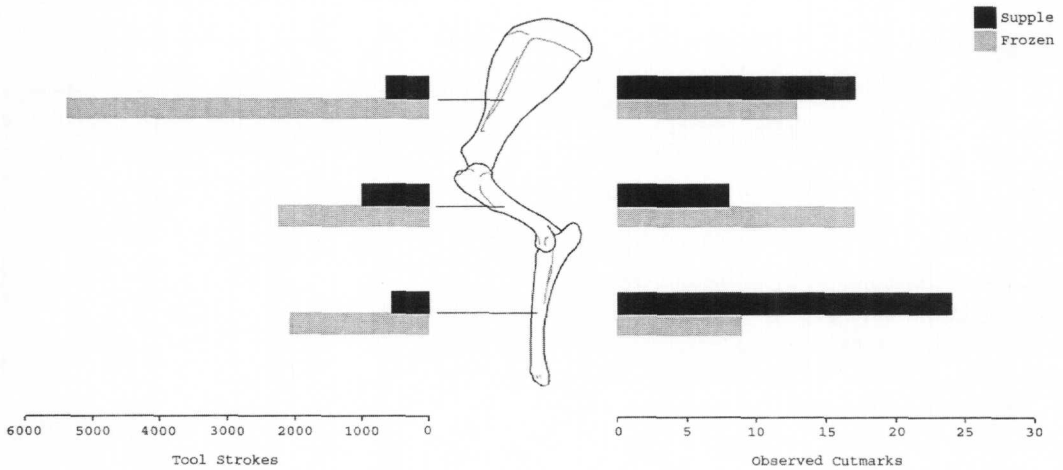

Figure 6. Comparison of total tool strokes and observed cutmarks for the frozen horse forelimb and supple horse forelimbs. Data for supple horse forelimbs are averages (n=2).

the topmost layers of flesh on the frozen limb allowed a stone tool to cut through them, the bottom layers remained in a condition such that the tool edges had almost no chance of coming into contact with the bone surface.

Finally, the unique position of the meat in relation to the bone that is characteristic of each skeletal element may have a significant impact on cutmark frequency. This implies that some skeletal elements are potentially more conducive to cutmarking, irrespective of processing intensity (as suggested by Binford [1988:128] for the scapula). To test this hypothesis, a single-factor ANOVA test was run on the mean number of observed cutmarks on each skeletal element. Results of this test indicate that the differences in mean cutmark frequencies between skeletal elements are not statistically significant (F=0.84, P=0.51). However, small sample size precludes a confident interpretation of this result. Further experimental work may in fact indicate that each skeletal element varies predictably in its conduciveness to cutmarking. There are several other possibilities that merit further investigation. For example, broad differences in prey body size may have a significant affect on cutmark frequency. Further experimental data (Egeland and Byerly in preparation) tentatively suggest that smaller animals display more cutmarks as suggested by others researchers (e.g., Gifford-Gonzalez 1989).

SUMMARY AND CONCLUSIONS

Cutmark analysis of 16 experimental episodes of large ungulate butchery indicates that, contrary to traditional assumptions, no clear-cut relationship exists between the intensity of processing activities and the resulting frequency of butchery damage. This is especially evident for cutmark frequency counts. Processing intensity, as measured by the number of tool strokes, has little direct influence on the resulting frequencies of cutmarks. Although not perfect reflections of butchery behavior either, butchered specimen counts are, as measures of the frequency with which particular skeletal elements or portions of skeletal elements were butchered, more accurate estimates of processing intensity. Thus, using butchered specimen counts to estimate the frequency with which particular specimen classes were butchered are at this point more useful measures of processing intensity than utilizing cutmark frequency counts to estimate the effort exerted in butchering individual specimens. Variation in both cutmark frequency and butchered specimen counts for the experimental sample also caution against assuming that different skeletal elements and different taxa preserve evidence of butchery in equal, or roughly equal, proportions.

Meat weight, as an estimate of the relative "insulation" provided bone surfaces against cutmark damage, does not show a significant relationship with cutmark frequencies, at least within the context of inter-element variation. As suggested above, broad dissimilarities in body size (and by extension in meat weight and "insulation") both within and between taxa may exhibit a different pattern. Although substantial differences in processing intensity are apparent between butcheries conducted on a frozen horse forelimb and supple horse forelimbs, cutmark frequencies are in fact *higher* for two of the three supple appendicular meat-bearing bones, which required less intensive processing to deflesh.

In light of these results, cutmark frequencies may be conditioned by the inherent morphological attributes of each skeletal element and their associated meat masses. This implies that each skeletal element has a different potential to receive cutmark damage, independent of the intensity of butchery. It is hoped that further experimental and ethnoarchaeological work will test this suggestion and help to formulate predictive models of how particular skeletal elements preserve evidence of butchery in various situations.

The results and discussion provided above are especially significant considering the design of this experiment provides estimates of carcass processing intensity under conditions of *complete meat removal*. This is an important point because the cutmark frequencies derived here represent a "best case scenario" for the zooarchaeologist, in which relatively inexperienced butchers were working towards the goal of removing all of the adhering meat on each bone. *Defleshing activities conducted by experienced butchers under various conditions are expected to reflect much less of the costs of meat removal*. For example, Bunn and Kroll (1988) report that Hadza butchers are able to remove substantial quantities of meat from large mammal carcasses without inflicting any bone surface damage at all. Crader (1983) also made this same suggestion for elephant butcheries conducted by the Bisa. In addition, the taphonomic processes that compromise bone surface preservation certainly affect the survivability of cutmarks in an archaeological situation.

There are several aspects of this study that require further consideration. First and most obvious, the sample size must be increased. Including complete carcasses of various ages, carcass conditions, and body sizes is a logical next step. Second, episodes focusing on incomplete meat removal in different combinations must be included. Complete meat removal was not the sole motive behind prehistoric butchery. Third, the butchery strategies employed in this experiment, because the measurement of meat weights required cutting along articular planes, may be unrealistic proxies of the actual complexities involved in removing a packet of meat. Most muscle attachments are not relegated to individual bones, but are located at various locations on articulating bones. This may have an impact on the frequencies of some cutmarks. These results should not frustrate future attempts to glean behavioral information through the study of cutmarks. It should, however, demonstrate the limits to which cutmark data are presently informative of butchery activities. We are now better equipped to understand the interplay between one aspect of the butchery process and its archaeological manifestations.

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