Measuring Skeletal Part Representation in Archaeological Faunas

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Most analyses of relative skeletal abundances in archaeological contexts are based on units derived, in one way or another, from the number of identified specimens (NISP): the minimum number of elements (MNE), the "minimal animal unit" (MAU), and the skeletal-element based minimum number of individuals (MNI). MNE values can be interpreted as if they were the results of a sampling exercise, telling us the chances that specimens drawn from a population of NISP values match in some specified way. Since this is the case, MNE values should scale to the NISPs for the body part involved. Since MAUs are generally calculated by standardizing MNE values by the number of times the part occurs in the skeleton, and MNIs by a combination of this and both age- and side-matching, there should be a very predictable relationship between the values of NISP, MNE, MAU, and MNI within any given assemblage. Using a series of assemblages from South Africa, Iran, and France, we show that this is, in fact, the case.

Introduction

Most zooarchaeological research is targeted at the quantitative analysis of the abundances of objects that have been identified within two biological classificatory systems—one taxonomic, the other anatomic. Indeed, the remarkable successes of zooarchaeology, and the rapid rise in importance of zooarchaeology as a subdiscipline, are closely tied to the fact that the physical objects we study are biological in origin and that the biological meaning of these objects, once properly identified, are never in doubt. Zooarchaeologists might argue about whether a particular object is a fragmentary shaft of a reindeer femur or of a red deer humerus, but the classes that underly such an argument—reindeer versus red deer, humerus versus femur—are not up for debate.

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A vast literature exists that examines changing relative abundances of taxa through time and across space, with those abundances now most often quantified in terms of numbers of identified specimens (NISP). A smaller but ever-growing and equally important literature is focused on the analysis of the relative abundances of anatomical—skeletal—parts both within and among taxa in archaeological contexts. Although some of these latter analyses are NISP-based, most are based on units derived, in one way or another, from identified specimens. These are 1) the minimum number of elements (MNE), or "the minimum number of skeletal portions necessary to account for the specimens representing that portion" (Lyman, 1994:102); 2) the "minimal animal unit" (MAU; Binford, 1984:50), or the MNE standardized by the number of times the skeletal portion involved occurs in a complete skeleton of the same animal; and 3) the skeletal-element based minimum number of individuals (MNI), conceptually similar to the MAU but generally calculated by also taking specimen age and side into account (Klein & Cruz-Uribe, 1984).

Lyman (1994) provides an insightful discussion of all of these counting units. Here, we assume that the reader is familiar with the issues he examines, and ask a series of questions that recall earlier discussions of the relationship between NISP and MNI within the context of quantifying taxonomic abundances (Grayson, 1984).

What, we ask, is the relationship between NISP, MNE, MAU, and element MNIs within single faunal assemblages? Can the derived values be predicted from the NISP-values from which they are derived and, if so, how closely can they be predicted? Can one replicate the results of MNE, MAU, and MNI-based skeletal part abundance analyses using NISP values alone?

We conducted the analyses reported here because we had reasons to expect that NISP-based analyses of skeletal part abundance should, in general, mirror the results provided by these other units. MNE values can be interpreted as if they were a result of a sampling exercise. We begin with a population of specimens of particular skeletal parts from a given taxon within an assemblage, expressed as NISPs. MNE values derived from those NISPs tell us the chances that specimens drawn from that population matched one another anatomically. As a result, MNE values should scale to the NISPs for the body part involved. Since MAUs are generally calculated by standardizing MNE values by the number of times the part occurs in the skeleton, and MNIs by a combination of this and both age- and side-matching (see the discussion in Lyman, 1994), there should be a very predictable relationship between the values of NISP, MNE, MAU, and MNI within any given assemblage.

We explore whether or not this is the case, using three faunal assemblages analyzed by zooarchaeologists working in very different parts of the world and in very different time periods: the Middle Pleistocene South African Elandsfontein assemblage (Klein & Cruz-Uribe, 1991), the Mousterian Kobeh Cave assemblage from the Zagros Mountains (Marean & Kim, 1998), and the Late Pleistocene (Magdalenian) stratum F2 assemblage from Rond-du-Barry, France (Costamagno, 1999). We chose these three examples

because they are well-reported and the methods used clearly stated. As a result, they provide the information we need to conduct our own analyses. Our purpose is not to support or refute the arguments made by these authors, but to examine the degree to which we can replicate the results of their analyses using NISP values alone. We proceed from the oldest assemblage (Elandsfontein) to the youngest (Rond-du-Barry).

Elandsfontein

Elandsfontein is an Acheulean open site in Western Cape Province, South Africa. Dated to between 400,000 and 700,000 years ago, this site provided some 7300 bones and teeth from 18 species of bovids. While Klein & Cruz-Uribe (1991) identified a subset of this material to at least the genus level, their analysis of skeletal part representation was based on the distribution of specimens into five body-size classes: small (e.g., Cape grysbok, *Raphicerus melanotis*), small-medium (e.g., southern reedbuck, *Redunca arundinum*), large-medium (e.g., greater kudu, *Tragelaphus strepsiceros*), large (e.g., eland, *Taurotragus oryx*), and very large (the extinct long-horned buffalo *Pelorovis antiquus*).

To compare relative skeletal abundances across these five bovid size classes, Klein & Cruz-Uribe (1991) first calculated skeletal part MNIs using the procedures detailed in Klein & Cruz-Uribe (1984). As has now become standard, they set the highest MNI within a given size class to 100%, and scaled the other values accordingly (see Klein & Cruz-Uribe, 1991,
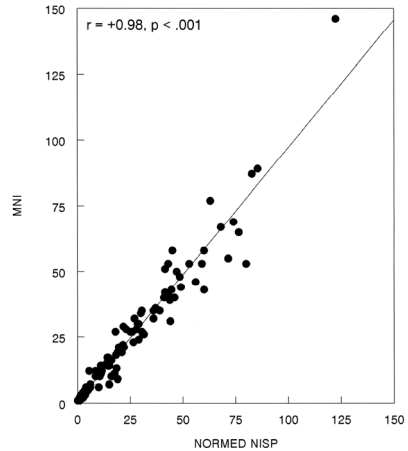

Figure 1. The relationship between single-element MNI and normed NISP (NNISP) values for the Elandsfontein bovids.

Table 4 for NISP and MNI values). By proceeding in this fashion, they found that the two smallest bovid size classes at Elandsfontein are dominated by skulls and mandibles, and that larger size classes show a far greater representation of limbs and tarsals. We now ask whether we can replicate this result using NISP values alone.

Klein & Cruz-Uribe (1991) do not provide MNE values since they were not analytically relevant to their approach. As a result, we cannot examine the relationship between NISP and MNE in this context. In all cases, however, their MNIs are derived by taking into account the number of times a given element occurs in the bovid skeleton, either by including element side in the determination, or by dividing what is essentially the minimum number of elements by the number of times that

Table 1. *Elandsfontein small bovids: Number of Identifiable Specimens (NISP),* *normed NISP values (NNISP), and Minimum Number of Individuals (MNI) per skeletal part (raw data from Klein & Cruz –Uribe, 1991, Table 4)*

	NISP	NNISP	%NNISP	MNI	%MNI
Frontlet	61	30.50	73.49	35	68.63
Maxilla (teeth)	83	20.75	50.00	20	39.22
Mandible (teeth)	166	41.50	100.00	51	100.00
Atlas	4	4.00	9.64	4	7.84
Axis	2	2.00	4.82	2	3.92
Cervicals 3-7	12	2.40	5.78	3	5.88
Thoracics	13	0.93	2.24	1	1.96
Lumbars	2	0.33	0.80	1	1.96
Sacrum	2	0.40	0.96	1	1.96
Caudal	-	-	-	-	-
Ribs	7	0.25	0.60	1	1.96
Scapula	4	2.00	4.82	3	5.88
Distal Humerus	2	1.00	2.41	1	1.96
Proximal Radius	2	1.00	2.41	1	1.96
Distal Radius	1	0.50	1.20	1	1.96
Proximal Ulna	1	0.50	1.20	1	1.96
Carpals	3	0.50	1.20	1	1.96
Proximal Metacarpal	3	1.50	3.61	2	3.92
Distal Metacarpal	4	2.00	4.82	2	3.92
First Phalanges	20	2.50	6.02	4	7.84
Second Phalanges	8	1.00	2.41	2	3.92
Third Phalanges	8	1.00	2.41	2	3.92
Pelvis	7	3.50	8.43	3	5.88
Proximal Femur	3	1.50	3.61	2	3.92
Distal Femur	3	1.50	3.61	2	3.92
Patella	1	0.50	1.20	1	1.96
Proximal Tibia	8	4.00	9.64	5	9.80
Distal Tibia	8	4.00	9.64	5	9.80
Lateral Malleolus	1	0.50	1.20	1	1.96
Calcaneus	9	4.50	10.84	5	9.80
Astragalus	10	5.00	12.05	5	9.80
Naviculocuboid	3	1.50	3.61	2	3.92
Cuneiform Tarsals	1	0.50	1.20	1	1.96
Proximal Metatarsal	4	2.00	4.82	2	3.92
Distal Metatarsal	3	1.50	3.61	2	3.92
Proximal Sesamoids	1	0.06	0.14	1	1.96

element occurs in the bovid skeleton (see Klein & Cruz-Uribe, 1984: Table 6.1). Any NISP-based attempt to replicate Klein & Cruz-Uribe's MNI-based skeletal part analysis must, as a result, take a comparable step. Throughout this paper, we refer to the resultant NISP values as "Normed NISPs", abbreviated NNISP. These simply represent the skeletal part NISP values divided by the number of times the relevant part occurs in the skeleton of the animal involved. Unless otherwise noted, the divisors we have used to calculate these values are those used by the authors themselves. As Figure 1 shows, the magnitudes of the Elandsfontein MNI and NNISP values are tightly correlated ($r = +0.98$, $p < .001$). That is, the Elandsfontein bovid MNI values can be closely predicted from the corresponding NNISP values.

As we have mentioned, Klein & Cruz-Uribe (1991) did not use their raw MNI values directly. Instead, for any given size class, they set the highest MNI value to 100% and scaled the rest of the values within that size class accordingly. We have taken the same approach with our NNISP values: the highest NNISP in a given size class was set to 100% and the rest of the NNISP values within that class scaled to that figure. To make this process clear, Table 1 presents the relevant data for the Elandsfontein small bovids.

Figure 2 provides the relationship between the MNI percentage (MNI%) and NNISP percentage (NNISP%) figures. Again, the former can be tightly predicted from the latter ($r = +0.98$, $p < .001$).

Given these results, it will be no surprise to learn that the NNISP% values replicate the MNI-based results obtained by Klein & Cruz-Uribe (1991). Four of the five appropriate comparisons are presented
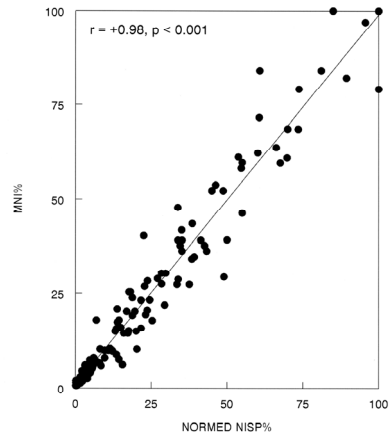

Figure 2. The relationship between scaled single-element MNI (MNI%) and scaled NNISP (NNISP%) values for the Elandsfontein bovids.

in Figures 3 and 4 (see Table 2 for skeletal element abbreviations used in all figures). Our NISP-based analysis provide the same results as Klein & Cruz-Uribe's (1991) MNI-based analyses: the small and small-medium ungulates at Elandsfontein are dominated by mandible and skull elements, while post-cranial portions of the skeleton are much better represented among the larger bovid size classes.

As these histograms also make clear, the matches between the MNI-based and NISP-based percentage values are not perfect, as an analysis of regression residuals, not presented here, also shows. Nor, of course, would we expect the matches to be perfect. For instance, unlike our NISP-based approach, the Klein & Cruz-Uribe MNI values were derived in part by taking age- and side-differences into account. In addition, differential fragmentation may also play a role in driving these mismatches, with greater

Table 2. Skeletal element abbreviations used in the figures

|			
AST	Astragalus	NC	Naviculocuboid
AT	Atlas	PAT	Patella
AX	Axis	PELV	Pelvis (Innominate)
CALC	Calcaneus	PF	Proximal Femur
CARP	Carpals	PH	Proximal Humerus
CAU	Caudal Vertebrae	PHAL	Phalanges
CERV	Cervical Vertebrae	PH1	First Phalanx
DF	Distal Femur	PH2	Second Phalanx
DH	Distal Humerus	PH3	Third Phalanx
DMC	Distal Metacarpal	PMC	Proximal Metacarpal
DMT	Distal Metatarsal	PMT	Proximal Metatarsal
DR	Distal Radius	PR	Proximal Radius
DSES	Distal Sesamoids	PSES	Proximal Sesamoids
DT	Distal Tibia	PT	Proximal Tibia
FEM	Femur	PU	Proximal Ulna
FRONT	Frontlet	RAD	Radius
HUM	Humerus	SAC	Sacrum/Sacral Vertebrae
LUMB	Lumbar Vertebrae	SCAP	Scapula
MAL	Malleolus (Fibula)	SES	Sesamoids
MAND	Mandible	SK	Skull
MAX	Maxilla	TARS	Tarsals
MC	Metacarpals	TTH	Teeth
MT	Metatarsals	THOR	Thoracic Vertebrae
		TIB	Tibia
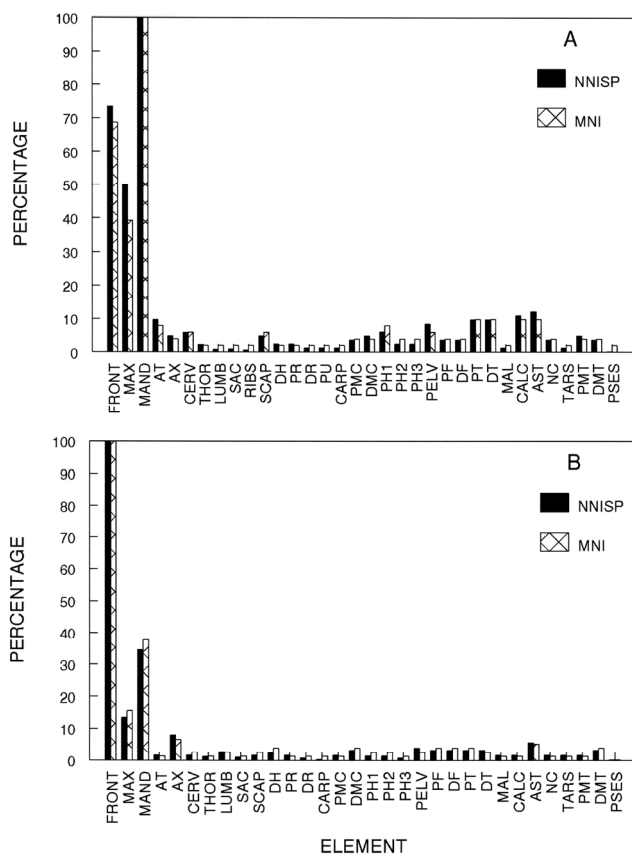
Figure 3. Relative skeletal abundances of the Elandsfontein small (Figure 3A) and small-medium (Figure 3B) bovids, as measured by scaled single element MNI and scaled NNISP values.

fragmentation both increasing NISP values and decreasing the chances of obtaining a body part match. One could legitimately argue whether it is the MNI-based or the NISP-based approach that provides the better assessment of body-part representation here, but such an argument would hardly be worthwhile. Both MNI-based and NISP-based analyses document the same pattern of skeletal element abundances across bovid size classes at Elandsfontein.

Kobeh Cave

Located in the Zagros Mountains of Iran, Kobeh Cave provided an ungulate assemblage of some 4000 specimens
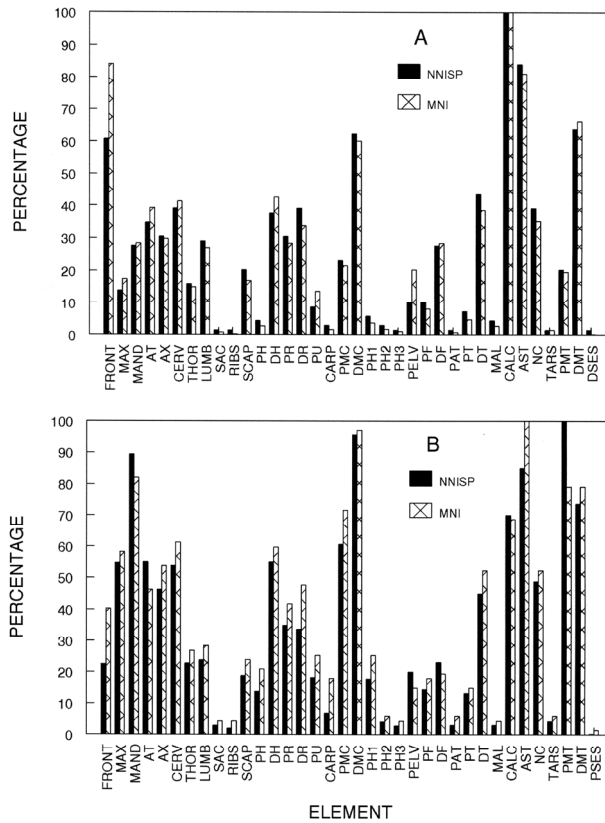
Figure 4. Relative skeletal abundances of the Elandsfontein large (Figure 4A) and very large (Figure 4B) bovids, as measured by scaled single element MNI and scaled NNISP values.

representing at least eight species of equids, bovids, and cervids, all associated with a Mousterian lithic assemblage of unknown absolute age. While Marean and his colleagues have discussed the Kobeh Cave material in a number of places (e.g., Marean, 1998; Marean & Assefa, 1999; Marean & Frey, 1997), the analyses we present here are based on the detailed

discussion provided by Marean & Kim (1998).

The analysis of the Kobeh Cave material by Marean and his colleagues was similar to that provided by Klein & Cruz-Uribe (1991) for Elandsfontein in that the ungulate fraction of the assemblage was divided into size categories to incorporate material that could not be identified to at
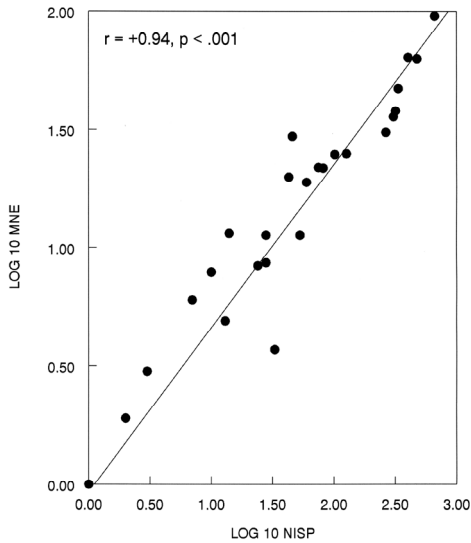
Figure 5. The relationship between MNE and NISP values for the size class 2 bovids and cervids at Kobeh Cave.

long bones are extremely well-represented compared to cranial and mandibular elements within the Kobeh ungulate assemblage. Here, we ask whether we can replicate their MAU-based results using NISP values.

The raw data for our analyses are presented in Table 3. Figure 5 provides the best-fit relationship between NISP and MNE values for the size class 2 bovids and cervids, and shows that the latter values can be tightly predicted from the former (r = +0.94, p < .001). It follows from this that once normed and translated into percentages, NISP values can also predict the Kobeh Cave size class 2 MAU% values. Figure 6 shows that this is, in fact, the case (r = +0.95, p < .001). There is only a single

least the genus level. For several reasons (Marean & Kim, 1998:S83), the Kobeh faunal analyses have focused primarily on bovid and cervid remains that fall into size class 2 (*sensu* Brain, 1981), in this case most likely representing wild goats (*Capra aegagrus* [=*hirca*]) and sheep (*Ovis orientalis* [=*aries*]). As with Klein & Cruz-Uribe (1991), Marean & Kim (1998) were interested in examining the differential representation of ungulate body parts. In addition, they explored the possible impact of including or excluding long bone shaft fragments on the resultant body part patterning. To address these issues, they used standard MNE values converted to MAUs by taking into account the number of times each body part occurs in the skeleton. Their analyses demonstrated that
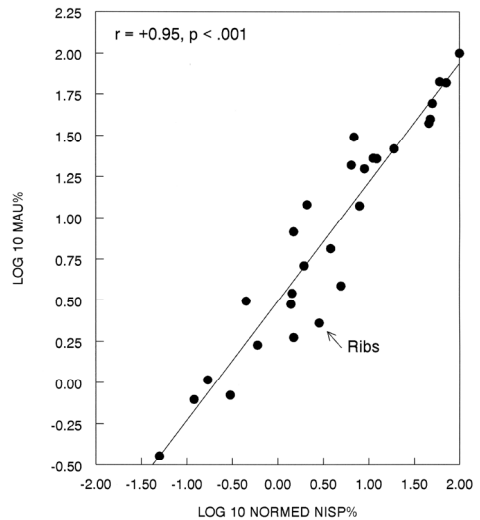

Figure 6. The relationship between scaled MAU and scaled NNISP values for the size class 2 bovids and cervids at Kobeh Cave.

Table 3. Kobeh Cave bovid/cervid size class 2 data (from Marean & Kim. 1998, Table 6)

|	NISP	MNE	MAU	NNISP	NNISP%	MAU%
Horn	43	20.00	10.00	21.50	6.47	20.90
Skull Bone	60	19.00	9.50	30.00	9.02	19.85
Mandible Bone	75	22.00	11.00	37.50	11.28	22.99
Skull Teeth	46	29.60	14.80	23.00	6.92	30.93
Mandible Teeth	82	21.86	10.93	41.00	12.33	22.84
Atlas	5	0.90	0.90	5.00	1.50	1.88
Axis	1	0.40	0.40	1.00	0.30	0.84
Cervical Vert.	24	8.35	1.67	4.80	1.44	3.49
Thoracic Vert.	28	11.30	0.81	2.00	0.60	1.69
Lumbar Vert.	28	8.60	1.43	4.66	1.40	2.99
Sacral Vert.	2	1.90	0.38	0.40	0.12	0.79
Caudal Vert.	1	1.00	0.17	0.17	0.05	0.36
Scapula	33	3.70	1.85	16.50	4.96	3.87
Ribs	266	30.80	1.10	9.50	2.86	2.30
Humerus	404	63.80	31.90	202.0	60.75	66.67
Radius	336	47.25	23.63	168.0	50.53	49.38
Ulna	127	25.10	12.55	63.50	19.10	26.23
Carpals	14	11.50	5.75	7.00	2.11	12.02
Metacarpals	319	37.95	18.98	159.5	47.97	39.67
Pelvis	53	11.30	5.65	26.50	7.97	11.81
Femur	478	62.90	31.45	239.0	71.88	65.73
Tibia	665	95.70	47.85	332.5	100.0	100.0
Astragalus	3	3.00	1.50	1.50	0.45	3.13
Calcaneus	13	4.90	2.45	6.50	1.95	5.12
Metatarsals	307	35.85	17.93	153.5	46.17	37.47
Tarsals	10	7.85	3.93	5.00	1.50	8.21
Phalanges	102	24.90	3.11	12.73	3.83	6.50
Sesamoids	7	6.00	0.50	0.58	0.17	1.04
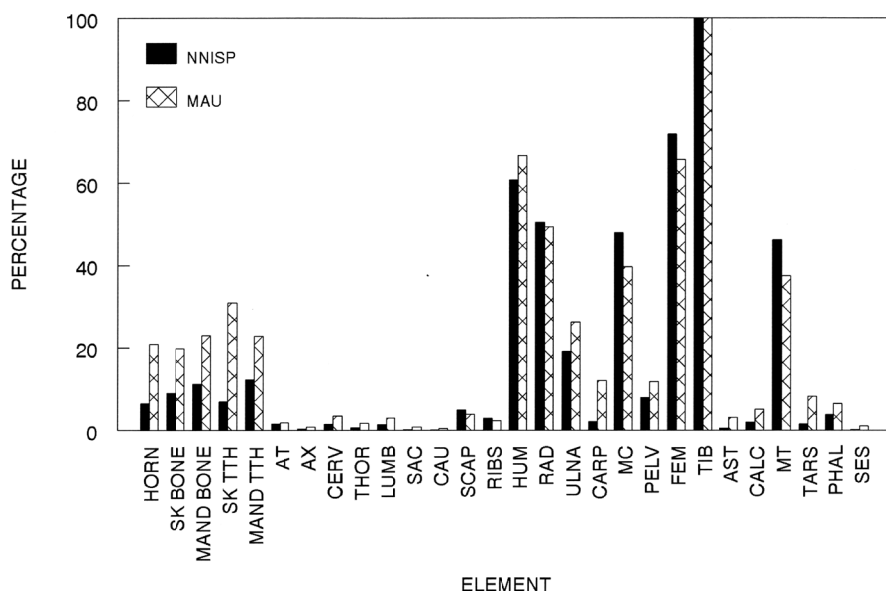
Figure 7. Relative skeletal abundances of the Kobeh Cave size class 2 bovids and cervids, as measured by scaled MAU and scaled NNISP values.

two standard deviation outlier in this relationship: ribs have a predicted MAU% of 6.59, compared to an observed value of 2.30. This, in turn, is likely a function of the fact that ribs are easily fragmented into multiple identifiable specimens which rarely retain landmarks that can be used to determine MAU values.

Finally, Figure 7 compares our normed NISP% values to the MAU% values calculated by Marean & Kim (1998). Although there are certainly differences in the details of the results of the two approaches, the NNISP% values closely replicate the results obtained by Marean & Kim (1998).

Rond-du-Barry

A Magdalenian site in south-central France, Rond-du-Barry was the focus of a remarkably detailed analysis by Costamagno (1999). Here, we revisit her examination of two species—horse (*Equus caballus*, NISP = 1556), and ibex (*Capra hircus ibex*, NISP = 709) from Stratum 2, which dates to ca 17,000 ^{14}C yr B.P.

Costamagno's methods were generally similar to those used by Marean & Kim (1998). To determine body part representation, she calculated MNE values and, from these values, derived MAU figures by standard skeletal part division (Costamagno, 1999: Table 10-6;
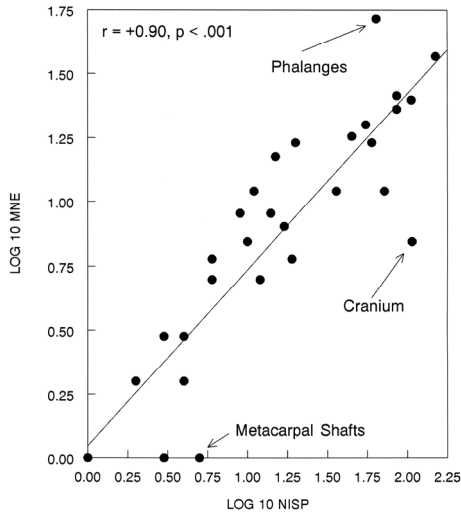
Figure 8. The relationship between MNE and NISP values for the Rond-du-Barry Stratum F2 horse assemblage.

Costamagno used a divisor of 1 for the skull, but, since the cranial elements generally used to determine MNE are paired, we have used a divisor of 2). She graphed her body part data by raw MAU values, but calculated and presented MAU% values as well. In the most general terms, these analyses led her to conclude that for horse and ibex, long bones were the best-represented part of the skeleton in Stratum F2.

Figure 8 shows the best-fit relationship between NISP and MNE for the Stratum F2 horses. Again, MNE values can be tightly predicted by NISP ($r = +0.90$, $p < .001$). However, there are two significant (>2 standard deviation) outliers in this relationship, and a third that is nearly so (at +1.91 standard deviations). Since

two of these outliers are informative, we discuss them here.

Metacarpal shafts provide the uninformative outlier, since this skeletal part is represented by only 5 specimens (with an MNE of 1 compared to a predicted MNE of 3.4, a -2.37 standard deviation difference). The informative outliers are provided by cranial specimens and phalanges.

Phalanges are represented by an NISP of 64 and an MNE of 52, compared to a predicted MNE of 19.48 (+1.91 standard deviations). This difference is due to the fact that Costamagno (1999) calculated MNE values for the phalanges by phalanx type, but provides NISP values for the phalanges as a whole. This is obviously no criticism of Costamagno (1999), who
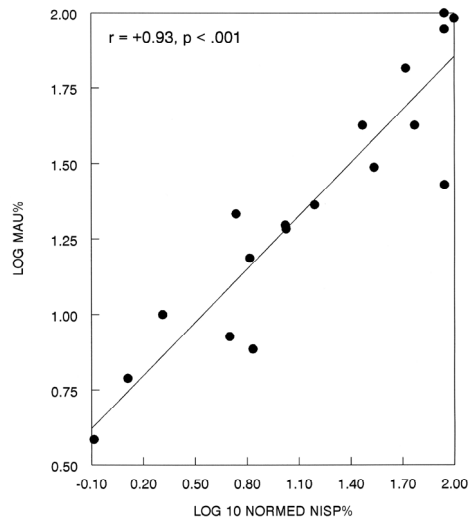

Figure 9. The relationship between scaled MAU and scaled NNISP values for the Rond-du-Barry Stratum F2 horse assemblage.

provided exactly those data she needed for her analyses. However, these are the values we have compared, and it is this comparison that has produced the overprediction. Because of this, we do not include phalanges in the analyses that follow.

Cranial fragments are represented by an NISP of 107 and an MNE of 7, compared to a predicted MNE of 27.7 (-2.68 standard deviations). As was the case with the Kobeh Cave ribs, we suspect that this difference reflects the low probability of finding matching landmarks in highly fragmented material.

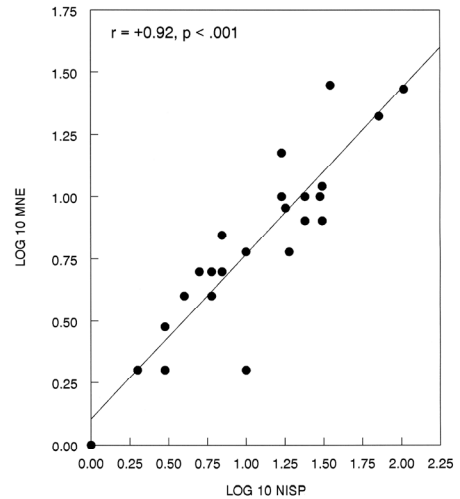Costamagno's examination of skeletal part representation proceeded in

Figure 11. The relationship between MNE and NISP values for the Rond-du-Barry Stratum F2 ibex assemblage.

terms of whole bones (for instance, the humerus and femur) and groups of whole bones (for instance, her body part category V, which includes the humerus, radioulna, femur, and tibia: Costamagno, 1999, Table 10-6). Accordingly, Figure 9 compares MAU% with normed NISP% for these whole elements. The tight relationship between the two is evident (r = +0.93, p < .001). Finally, Figure 10 presents these results in the form of a histogram. Again, and excluding the skull, our NISP-based analysis replicates the general pattern uncovered by Costamagno (1999) using MAU data.

Figure 11 presents the best-fit relationship between NISP and MNE for the Stratum F2 ibex. Crania and ribs emerge as two standard-deviation outliers

Figure 10. Relative skeletal abundances of the Rond-du-Barry Stratum F2 horse assemblage, as measured by scaled MAU and scaled NNISP values.
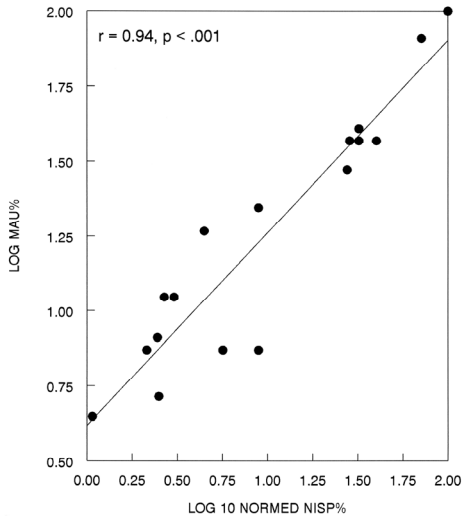
Figure 12. The relationship between scaled MAU and scaled NNISP values for the Rond-du-Barry Stratum F2 ibex assemblage.

in the set but, as Figure 11 shows, MNE values can be tightly predicted from NISP values for this taxon (r = +0.92, p < .001). Figure 12 provides the relationship between MAU% and normed NISP% for Costamagno's whole-bone data set and makes the tight relationship between these variables clear (r = +0.94, p < .001). Figure 13 presents these results in the form of a histogram.

We have also analyzed other taxa from Rond-du-Barry in the same way. Because the results are, in all cases, similar to the ones we have discussed here, we do not present the results of those other analyses.

Conclusions

Our goals in this paper have been simple. Given the nature of the relationships among the four counting units we have considered here—NISP, MNE, MAU, and single-element MNI values—it was our expectation that NISP-based body-part analyses could replicate the results of those based on counting units derived from NISP. The case studies we have presented meet those expectations. We conclude that NISP-based body-part analyses can and do replicate the results of such analyses based on MNE, MAU, and single-element MNI values.

We do not maintain that they must always do so, although other analyses that we have conducted but do not present here have provided results very similar to those we have presented, including analyses of the very large samples available from Equus Cave (Klein, Cruz-Uribe, & Beaumont, 1991). As has long been recognized, the principle advantages of NISP over MNI and similar measures, including MNE, relate to the relative simplicity and replicability of NISP calculations and to the fact that this measure is not subject to aggregation effects (Grayson, 1984).

On the other hand, it is also well-recognized that NISP is strongly affected by fragmentation. There is no question that differences in the degree of fragmentation across strata and across taxa can impact the results of relative skeletal abundance analyses, just as it can impact the results of analyses of taxonomic abundances (e.g., Grayson & Delpech, 2001). The results we have presented, for ribs at Kobeh Cave and for crania at Rond-du-Barry, show this
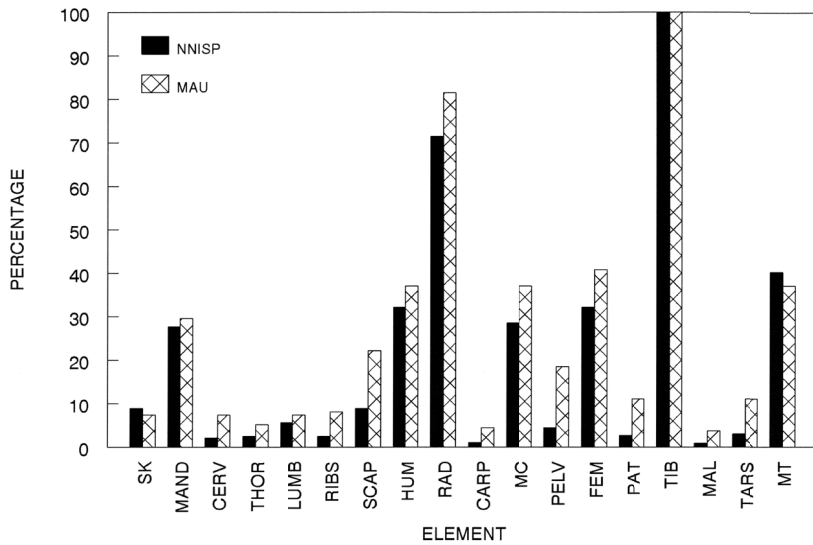
Figure 13. Relative skeletal abundances of the Rond-du-Barry Stratum F2 ibex assemblage, as measured by scaled MAU and scaled NNISP values.

process in action. However, when fragmentation causes mismatches between NISP and MNE values, it will not be clear which statistic is providing the more accurate measure of relative skeletal abundance.

We also maintain that there are strong probabilistic reasons to expect that the results of these different approaches will normally be consistent with one another. In addition, we have shown that statistical analysis can identify the kinds of cases in which the results obtained from these measurement units are not likely to coincide (as with the Kobeh Cave ribs and the Rond-du-Barry phalanges and crania), allowing researchers to consider the relative advantages and disadvantages of each in any given context. We are certainly not suggesting that MNE, MAU, and single-element MNI based analyses be abandoned in favor of NISP-based ones, and would welcome further explorations of the issues we have raised here.

Acknowledgements

References

Binford, L. R. (1984). *Faunal remains from Klasies River Mouth*. Academic Press, New York,

Brain, C. K. (1981). *The Hunters or the hunted? An introduction to African cave taphonomy*. University of Chicago Press, Chicago.

Costamagno, S. (1999). Stratégies de chasse et fonction des sites au Magdalénien dans le sud de la France. Thèse de l'Université Bordeaux I, No. 2134, Talence, France.

Grayson, D. K. (1984). *Quantitative zooarchaeology*. Academic Press, New York.

Grayson, D. K. & Delpech, F. (2001). The Upper Paleolithic at Grotte XVI (Dordogne, France): richness, evenness, and cave bears. In (Hays, M. A. & Thacker, P., eds.) *Questioning the answers: resolving fundamental problems of the early Upper Paleolithic*. Oxford: *British Archaeological Reports* 1005, pp. 187-197.

Klein, R. G. & Cruz-Uribe, K. (1984). *The analysis of animal bones from archaeological sites*. University of Chicago Press, Chicago.

Klein, R. G. & Cruz-Uribe, K. (1991). The bovids from Elandsfontein, South Africa, and their implications for the age, palaeoenvironment, and origins of the site. *The African Archaeological Review*, 9: 21-79.

Klein, R. G., Cruz-Uribe, K. & Beaumont, P. B. (1991). Environmental, ecological, and paleoanthropological implications of the Late Pleistocene mammalian fauna from Equus Cave, northern Cape Province, South Africa. *Quaternary Research*, 36: 94-119.

Lyman, R. L. (1994). *Vertebrate taphonomy*. Cambridge University Press, Cambridge.

Marean, C. W. (1998). A critique of the evidence for scavenging by Neandertals and early modern humans: New data from Kobeh Cave (Zagros Mountains, Iran) and Die Kelders Cave 1 Layer 10 (South Africa). *Journal of Human Evolution*, 35: 111-136.

Marean, C. W. & Assefa, Z. (1999). Zooarchaeological evidence for the faunal exploitation behavior of Neandertals and early modern humans. *Evolutionary Anthropology*, 8: 22-37.

Marean, C. W. & Frey, C. J. (1997). Animal bones from caves to cities: Reverse utility curves as methodological artifacts. *American Antiquity*, 62: 698-716.

Marean, C. W. & Kim, S. Y. (1998). Mousterian large-mammal remains from Kobeh Cave: behavioral implications for Neanderthals and early modern humans. *Current Anthropology*, 39: S79-S113.