

QUANTIFYING ANIMAL FOOD DIET: A COMPARISON OF FOUR APPROACHES USING BONES FROM A PREHISTORIC IROQUOIAN VILLAGE

Suzanne Needs-Howarth

During an analysis and quantification of faunal material from a Late Prehistoric Iroquoian village, I obtained differing faunal abundance estimates using four distinct quantification methods. In this paper I outline briefly the methods and the results. I discuss how and why the results differ, and what implications this has for the interpretation of relative dietary contribution.

INTRODUCTION

The analysis and quantification of faunal remains from the Coleman site (AiHd-7), was part of a larger project, in which plant and animal food data from the site were integrated to quantify diet (Needs-Howarth 1992). An estimation of diet should include not only an identification of the animal and plant foods which were eaten, but also an assessment of the proportion, in terms of weight or energy, that each food contributes to the diet. Caloric value is a common denominator which allows a comparison of the energy provided by different kinds of foods in past diet.

I first discuss different kinds of faunal quantification methods, emphasizing those that involve the estimation of animal food soft tissue biomass and caloric content. I then apply the methods to the Coleman site faunal remains and highlight differences in results.

This paper is a methodological exercise, intended to further the debate on faunal quantification and interpretation. It is not intended as an in-depth critique of dietary quantification, but rather as an overview of some of the problems involved.

THE SAMPLE

The Coleman site is a permanently occupied

longhouse village, located west of New Dundee in the Regional Municipality of Waterloo, Ontario (Figure 1). It was partly excavated by Robert MacDonald in 1983 and 1984, and probably dates to the late fifteenth or early sixteenth century (MacDonald 1986:70).

Up to one half of the fill of large features and all the fill of small features was floated; the remainder was screened through .56 cm mesh (MacDonald 1986:27). Screened and floated faunal remains were not bagged separately. Hence I cannot add to recent findings (Lennox et al. 1986, Stewart 1991) on the relationship between faunal abundance and recovery techniques. Rosemary Prevec (1985) identified 669 specimens from midden Feature 2 to family or lower taxonomic level. I identified 134 additional specimens from internal and external pits, internal hearths, and semi-subterranean features (Needs-Howarth 1992).

QUANTIFICATION METHODS

Abundance Measures

Several commonly used faunal methods can quantify which taxa were present at a site. The simplest of these methods involves counting bones identified below a certain taxonomic level, usually referred to as Number of Identified Specimens (NISP). NISP is highly dependent on fragmentation rates. Because it estimates taxonomic abundance, it is not an appropriate measure of the relative potential dietary importance of animal taxa.

Prehistoric butchering techniques frequently resulted in differential deposition of body parts on sites (White 1952, 1953a). In addition, interspecies differences in body size, number of elements, and element identifiability, ensure that each species did not contribute equally to

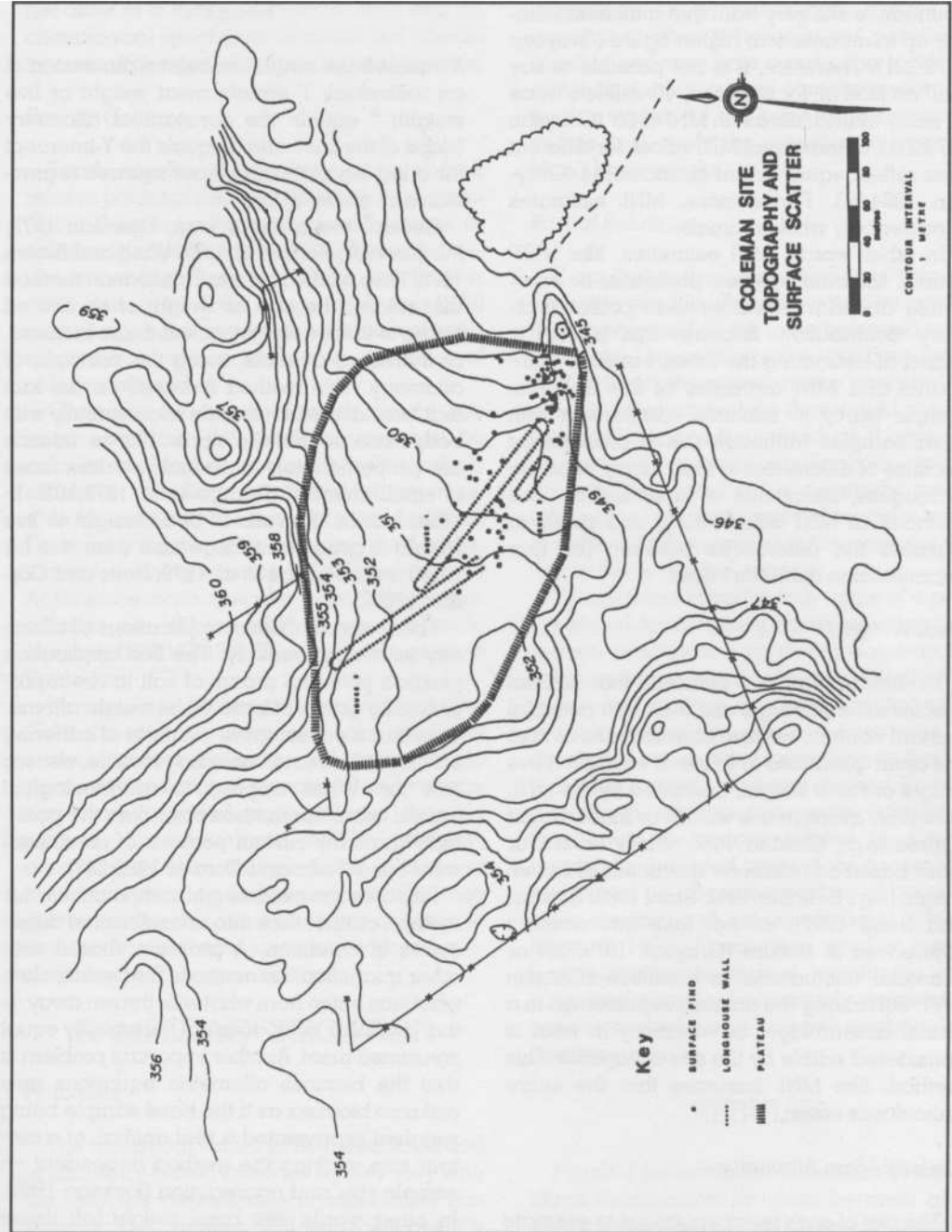


Figure 1. Settlement Patterns at the Coleman site (MacDonald 1986: Figure 2).

a past diet. For this reason, White (1953b) employed a different faunal abundance estimator: Minimum Number of Individuals (MNI), in which a combination of element duplication, side and age are used to estimate how many individual animals would accommodate the bones recovered.

Since this method should only be applied to species-level identification, the data potential of non-specific identifications is reduced. The main problem, however, is that MNI means exactly that: the minimum number of individual animals needed to account for the faunal material in an aggregation unit. The actual

abundance will *vary* from that minimum number up to an unknown higher figure (Grayson 1979:221). Therefore, it is not possible to say that "an MNI of, for instance, 40, reflects twice as many individuals as an MNI of 20" (Grayson 1979:221), or that equal MNI values for different taxa reflect equal actual abundances (Grayson 1984:94). Furthermore, MNI estimates consider only whole animals.

In other words, MNI estimates, like NISP counts, indicate species presence, or *taxonomic* abundance, rather than potential *dietary* contribution. Because this project is aimed at estimating the latter, I include NISP counts and MNI estimates of the Coleman sample partly to facilitate comparison with other samples (although this is problematic because of differences in taphonomy, recovery techniques, definitions of identifiability, and methods of MNI calculation), and partly to illustrate the differences between the four quantification methods I used.

Meat Weight

To circumvent the problem that animal species differ in weight and therefore potential nutrient content, relative contributions of taxa are often quantified in terms of estimated live weight or meat weight, multiplied by the MNI. However, average live weight or meat weight figures (e.g., Cleland 1966; White 1953b), or those based on reference specimens of known weight (e.g., Schaffer 1992; Stahl 1982; Stewart and Stahl 1977), do not take into account differences in stature (Grayson 1979:226) or seasonal fluctuations in condition (Chaplin 1971: 68) among the animals represented in a faunal assemblage, or variability in what is considered edible by the site occupants. This method, like MNI, assumes that the entire animal was eaten.

Skeletal Mass Allometry

The use of such linear equations to estimate meat weight is problematic because the relationship between bone dimension or weight and meat weight in individual animals is actually curvilinear, or exponential (Casteel 1974, 1978; Reitz and Cordier 1983:238; Reitz et al. 1987:305). The following equation describes this relationship:

$$Y = aX^b$$

X equals bone weight or skeletal dimension of an individual; Y equals meat weight or live weight; *b* equals the constant of allometry (slope of the line); and *a* equals the Y-intercept for a log-log plot using least squares regression and a best-fit line.

Several researchers (e.g., Emerson 1978; Purdue 1987; Reitz et al. 1987; Wing and Brown 1979) have worked on a quantification method that relates the size or weight of excavated bones to the live weight, or soft-tissue biomass, of individual animals, using the principle of allometry. This method is based on the fact that "animal skeletons scale allometrically with body mass, so that skeletons of large animals are proportionately more massive than those of small animals" (Prange et al. 1979:103). In other words, the ratio of bone weight to live weight is greater for large taxa than it is for small ones (Prange et al. 1979; Reitz and Cordier 1983).

There are two distinct applications of allometry in zooarchaeology. The first application predicts potential grams of soft tissue represented by grams of bone. Bone weight allometry is thus a conservative estimate of adhering soft tissue biomass, including muscle, viscera and fat. When applied to archaeological animal bone, this method considers the possibility that only certain portions of an animal were used (Reitz and Cordier 1983:247).

Like average meat weight computations, this method cannot take into consideration differences in condition. A problem shared with other quantification methods that extrapolate what was eaten from what was thrown away, is that available meat does not necessarily equal consumed meat. Another important problem is that the biomass allometric equations only estimate biomass as if the bone sample being weighed represented a real animal, of a certain size, making the method dependent on sample size and aggregation (Jackson 1989). In other words, the bone weight:soft tissue weight equation estimates the *average* weight of adhering soft tissue biomass for a specific bone weight, and not necessarily the *actual* biomass that once adhered to the element or elements being weighed.

The second application, dimensional allometry, uses linear measurements of articular facets to predict the live weight of the animal.

Because of a lack of empirical data and archaeological specimens, dimensional allometry cannot be applied to the Coleman sample.

Energy Content

Foods can be compared in terms of their relative potential dietary contribution by quantifying them as either soft-tissue biomass or calories (Needs-Howarth 1992). By using calories rather than "biomass" (Reitz and Cordier 1983; Reitz et al. 1987; Wing and Brown 1979) as the unit of comparison, the problem of interspecies variation in kinds and quantities of calories is avoided.

Once the soft-tissue biomass weight has been estimated, its caloric content can be calculated. Modern species-specific caloric estimates, including viscera and fat, are available for only a few of the wild taxa identified. To quantify a prehistoric Iroquoian diet I had to improvise, using existing U.S. Department of Agriculture data (usually provided as kilocalories per 100 gm edible portion) (Needs-Howarth 1992:177-178). The results are given in Table 1.

Mammal and bird meat contributions to the Coleman diet, in particular, are probably underestimated because prehistoric "edible portions", consisting of muscle, fat and viscera, may have provided more calories than do modern Euro-American "edible portions", consisting of lean muscle tissue. Obtaining nutritional data on indigenous species may partly resolve this issue. Another concern is that this method also does not address seasonal fluctuations in condition.

SAMPLE AGGREGATION

Problems

The numerical values of MNI estimates and of allometry-based biomass figures vary with the way the assemblage is subdivided into clusters. The smallest MNI value will result if the entire collection is treated as one cluster (Grayson 1984:29).

Bone weight allometry is also dependent on sample size and aggregation, because the regression equations are derived from the bone weight of real, individual animals (Jack-son 1989:605, 607). The equations must, therefore, only be applied to the bones of individual

animals in the archaeological sample. Because it is often practically not possible or feasible and very time consuming to identify real individuals in a bone sample, researchers tend to weigh all the bone of one taxon together and apply the equation to this combined bone weight.

Partial Solutions

If applied to the bone weight per taxon for the entire site, the allometric equation predicts the biomass as if all the bone belonged to one individual. Depending on the total bone weight for that taxon, the equation may thus predict a greater biomass weight than could ever be accommodated in a live individual. If applied to subsamples, each with smaller bone weights, the equation predicts a relatively greater biomass weight; the combined biomass weight of the subdivided samples is thus greater than that of the undivided sample.

This problem is particularly acute at a partly excavated, permanently occupied village with several structures, such as the Coleman site, because the occupants discarded their refuse in several locations. Ethnohistoric and ethnographic information on how carcasses are distributed across sites may alleviate this flaw of the bone weight allometry method. To avoid applying the equation to a greater bone weight than could be accommodated in a single animal, I subdivided parts of the faunal sample, based on an understanding of Iroquoian food sharing and refuse disposal (Needs-Howarth 1992). I quantified smaller taxa by feature, and larger, shared, taxa for the entire combined sample. I separately weighed the bone from each taxon for each analytical unit (feature or site).

RESULTS

Figure 2 indicates the difference in assemblage composition by class between abundance based on NISP, MNI, and bone weight allometry and calories. The contribution of fish and amphibians decreases dramatically for this sample when caloric estimates are used, while that of mammals increases.

The results of the Coleman quantification are presented in Table 1. The most interesting difference between methods is that 194 fish bones, constituting 24 percent of the site NISP,

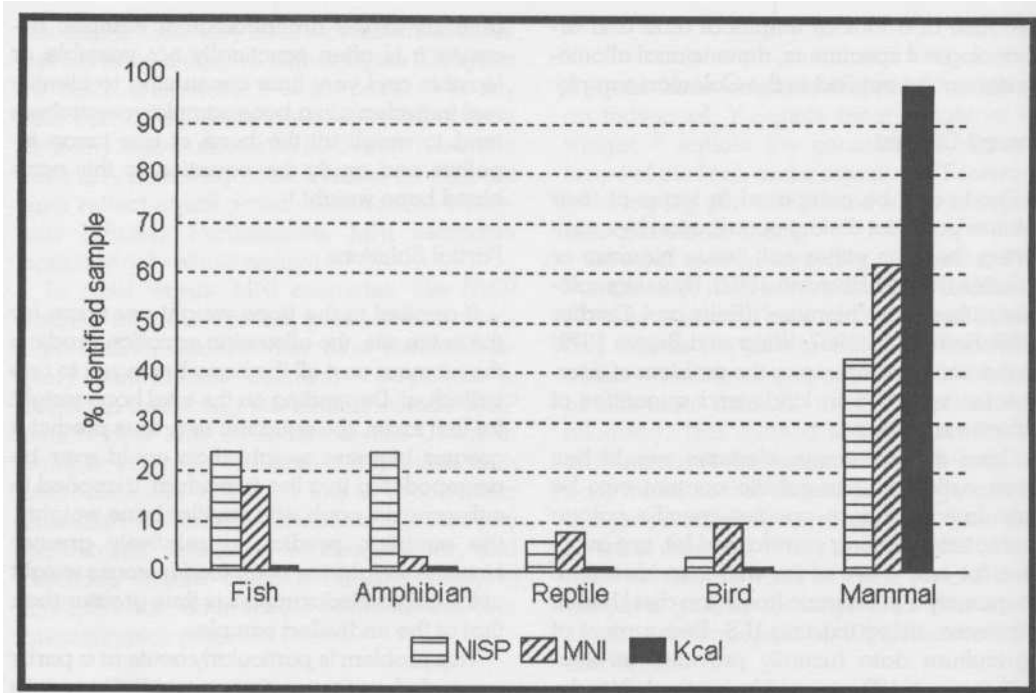


Figure 2. Percentage of NISP, MNI, and Kilocalories Contributed by Each Class to the Identified Sample.

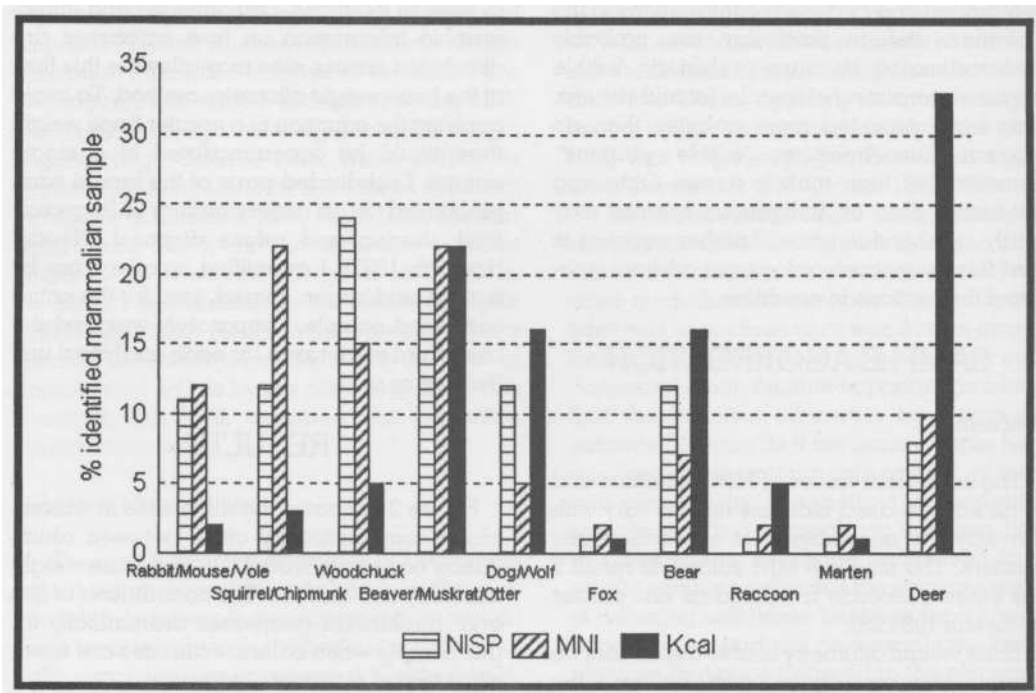


Figure 3. Percentage NISP, MNI and Kilocalories Contributed by Mammalian Taxa to the Identified Mammalian Sample.

contribute less than 1 percent of the kilocalories of the identified sample. Dog and bear each contribute the same number of bone fragments and calories, yet the bear bone weight is 50 percent greater. Woodchuck constitutes the largest mammal NISP and MNI (27 and 6, respectively), yet the caloric contribution is only 5 percent. In contrast, 27 beaver bones contribute 16 percent of the calories. The same number of deer bones contribute 33 percent of the calories.

The contribution of birds is minimal, regardless of the quantification method used. However, the contribution of medium- and large-sized mammals to the total identified sample is increased by two thirds when bone weight allometry and calories are used, rather than NISP.

To illustrate this point further, I provide the relative abundance measures for mammals identified below class, as a percentage of the identified mammal sample (Figure 3). For the sake of clarity I have grouped taxa with similar habitats. The only taxa for which the three abundance measures produce similar results are marten, fox, and the group comprised of muskrat, beaver, and otter. The calorie-based contribution of bear, and especially of raccoon and deer, is much greater than the NISP-based abundance. In contrast, the calorie-based contribution of small rodents and rabbit is substantially lower than the NISP- or MNI-based abundance.

EVALUATION OF DIET

The reconstructed animal food diet represented by the Coleman faunal remains consists mainly of medium- and large-sized mammals. Recovery of fragile bones (e.g., fish, amphibians, small birds) was enhanced through intensive floatation, but many may have been destroyed by taphonomic agents prior to excavation. The analysed sample probably does not reflect accurately the assemblage of the entire site; however, as a result of the recovery methods used, the Coleman faunal assemblage resembles closely what was present in the ground immediately prior to excavation in that section of the site.

The bone weight allometry and calorie quantification method I present here is clearly not without problems. The results from the application of allometric equations to archaeo-

logical samples are dependent on sample size and aggregation (Barrett 1993; Jackson 1989). The caloric estimates are based on Euro-American foods and "edible portions". Moreover, my reconstruction represents a relative, average diet, and cannot account for difference in the diets of men, who were probably often away from the village, and women and children, who may have spent more time at the village.

A more accurate and comprehensive practical application of this quantification method requires more empirical data, such as bone weight and dimensional allometry formulae, including those which predict adhering soft tissue biomass of body portions/butchering units, and caloric estimates, including fat and viscera, for indigenous animal species.

It can be argued that the permutations necessary to derive caloric estimates have no more basis in reality than the simpler abundance measures (Edwin Jackson, personal communication 1993). Despite methodological flaws, soft tissue biomass estimates, insofar as these are accurate for archaeological material, provide a more biologically justifiable estimate of potential food intake represented by excavated bone, than do NISP or MNI. The skeletal mass allometry method quantifies adhering meat, and therefore specifically estimates *dietary* contribution. Taking the data one step further by multiplying biomass by caloric content, however imperfect, is also useful, since it provides a measure which is relevant to the nutritional status, and perhaps, indirectly, to the subsistence options and decisions, of the site occupants.

What, then, does this imply about dietary inferences based on NISP counts or MNI estimates? Such figures may provide what seems to be a more realistic picture of diet at the Coleman site (for example because fish are better represented in the NISP count, or because small rodents are better represented in the MNI estimate), but may, in fact, be further removed from taphonomic, dietary, and behavioural reality.

CONCLUSIONS

Quantification of zooarchaeological remains from the Coleman site illustrates the differing results obtained by faunal abundance measures based on NISP, MNI, and bone weight

Table 1. Quantification of the Coleman faunal sample

Taxon	Number of features ^a	NISP ^b	% NISP	MNI ^c	Bone weight ^d	Bio-mass weight ^e	Kcal ^f	% Kcal
Trout (<i>Salvelinus</i> sp.)	1	6	1			0	0	<1
Chub (<i>Semotilus</i> sp.)	3	39	5		1.1	1	2	<1
Longnose sucker	1	3	<1	2				
Sucker (<i>Catostomus</i> sp.)	1	107	13		8.9	6	6	<1
Greater Redhorse	1	1	<1	1				
Redhorse (<i>Moxostoma</i> sp.)	3	3	<1		.6	1	1	<1
Sucker (Catostomidae)	2	2	<1		.4	1	1	<1
Stonecat	2	4	<1	3	.2	0	0	<1
Catfish (Ictaluridae)	1	11	1		.4	0	0	<1
Rock bass	1	1	<1	1	.1	0	0	<1
Pumpkinseed	1	1	<1	1	.5	0	0	<1
Yellow perch	2	16	2	3	.5	1	1	<1
identified fish		194	24	1	12.8	11	1	<1
Mudpuppy	1	20	2	1	.3	4	3	<1
Salamander (<i>Ambystoma</i> sp.)	1	1	<1			1	1	<1
Toad (<i>Bufo</i> sp.)	2	2	<1					
Bullfrog	1	2	<1	1				
Frog (<i>Rana</i> sp.)	2	116	14					
Frog or toad (Anura)	1	52	6		3.9	58	4	1
identified amphibian		193	24	2	4.2	64	4	1
Snapping turtle	1	3	<1	2	10.4	16	1	<1
Painted turtle	1	1	<1	1	.4	2	2	<1
Garter snake	1	48	intrusive					
identified reptile		52	6	5	10.8	17	1	<1
Canada goose	combined	2	<1	1	.1	1	5	<1
Sandhill crane	combined	2	<1	1	.4	5	1	<1
Passenger pigeon	1	12	1	2	.3	4	1	<1
Ruffed grouse	2	2	<1	2	.4	5	9	<1
Barred owl	1	1	<1	1	.4	5	9	<1
identified bird		19	3	7	1.8	22	5	1
Eastern cottontail	4	2	<1	2	1.7	5	5	<1
Grey squirrel	4	24	3	4	.7	23	2	1
Red squirrel	2	4	<1	2	.4	6	7	<1
Woodchuck	4	82	10	6	19.7	207	2	5
Chipmunk	3	13	2	3	.7	11	1	<1
Beaver	combined	27	3	2	35.6	328	8	16
Mouse (<i>Peromyscus</i> sp.)	2	3	<1					

Taxon	Number of features ^a	NISP ^b	% NISP	MNI ^c	Bone weight ^d	Bio-mass weight ^e	Kcal ^f	% Kcal
Muskrat	6	36	4	6	16.9	180	2	5
Meadow vole	1	32	4	3				
Vole (<i>Microtus</i> sp.)	1	1	<1		1.4	18	2	<1
Dog	combined	41	5	2				
Dog or wolf (<i>Canis</i> sp.)	combined	1	<1		40	365	8	16
Red fox	combined	2	<1	1	.8	11	1	<1
Canid (<i>Canidae</i>)	combined	1	<1		.1	2	4	<1
Black bear	combined	41	5	3	59.6	522	8	16
Raccoon	combined	5	1	1	8.7	92	2	5
Marten	1	2		1	1.3	17	2	1
River otter	combined	1	<1	1	.5	7	1	<1
White-tailed deer	combined	27	3	4	143.	115	1	33
identified mammal		345	43	4	332.	294	5	98
total identified		803		6	361.	306	5	100

^aNumber of features from which this taxon was identified. For smaller (=uncombined) taxa this equals the number of separate biomass calculations.

^bNumber of bone fragments identified below class.

^cOnly applicable at species level.

^dTotal bone weight per taxon in grams. Allometric equations from Wing and Brown (1979) and Reitz et al. (1987).

^eIt is argued (Reitz et al. 1987:313) that the best level of prediction is often achieved at the genus level. Bone weight, biomass and caloric estimates are therefore entered and calculated at the genus level where feasible. For practical reasons, frog and toad, as well as mouse and vole, were weighed together (calculations appear under *Anura* and *Microtus* sp., respectively).

^fKilocalorie content per 100 grams of soft tissue, based on Bowes (1985), Danielle Broulet (personal communication 1992), Tom Wollever (personal communication 1992) (latter two using U.S. Dept. of Agriculture data).

"combined" indicates larger taxa for which weighing and biomass calculations were performed on the entire, undivided sample.

Note: fish vertebrae, rays, spines, ribs and scales were not identified below class.

allometry and calories. The latter methods allow for a more biologically-justifiable estimation of potential dietary importance than those based on bone counts or MNI.

Because of taphonomy and various problems inherent in the method, the results of the bone weight allometry and calorie-based faunal quantification provide a relative, indirect, and probably distorted quantification of what the inhabitants of the Coleman site actually ate. The reconstructed diet is undiversified, and consists primarily of large mammal meat. It does, however, present a more realistic quantification of the meat represented by the animal bones recovered archaeologically.

Acknowledgements. Financial support for the identifications was provided by the Ontario Heritage Foundation under ARG 573. I thank Rob MacDonald and Rosemary Prevec for allowing me to use their Coleman site data. I thank Stephen Cox Thomas for making his faunal database analysis program GFAUNA2 available to me and for providing logistical support. I thank Howard Savage of the Howard

Savage Faunal Archaeo-Osteology Laboratory at the University of Toronto, Anne Rick of the Zooarchaeological Analysis Programme at the Canadian Museum of Nature, and James Dick of the Department of Ornithology at the Royal Ontario Museum for allowing me to use their reference collections. Finally, I thank James Barrett, Debbie Berg, Anneke Clason, Alexander von Gernet, Edwin Jackson, Maxine Kleindienst, and two anonymous reviewers for their helpful comments.

REFERENCES CITED

- Barrett, J.H.
1993 Bone Weight, Meat Yield Estimates and Cod (*Gadus morhua*): A Preliminary Study of the Weight Method. *International Journal of Osteoarchaeology* 3:1-18.
- Bowes, A. de Planter
1985 *Bowes and Church's Food Values of Portions Commonly Used*, 14th ed. Perennial Books, New York.

- Casteel, R. W.
 1974 A Method for Estimation of Live Weight of Fish from the Size of Skeletal Elements. *American Antiquity* 39:94-98.
 1978 Faunal Assemblages and the "Wiegemethode" or Weight Method Method. *Journal for Field Archaeology* 5:71-77.
- Chaplin, R. E.
 1971 *The Study of Animal Bones from Archaeological Sites*. Seminar Press, New York.
- Cleland, C. E.
 1966 The Prehistoric Animal Ecology and Ethnozoology of the Upper Great Lakes Region. Anthropological Papers 29. Museum of Anthropology, University of Michigan, Ann Arbor.
- Emerson, T. E.
 1978 A New Method for Calculating Live Weight of the Northern White-tailed Deer from Osteoarchaeological Material. *Midcontinental Journal of Archaeology* 3(1):35-44.
- Grayson, D. K.
 1979 On the Quantification of Vertebrate Archaeofaunas. In *Advances in Archaeological Method and Theory*, vol. 2, edited by M. B. Schiffer, pp. 199-237. Academic Press, New York.
 1984 *Quantitative Zooarchaeology: Topics in the Analysis of Archaeological Faunas*. Academic Press, New York.
- Lennox, P. A., C. F. Dodd, and C. R. Murphy
 1986 The Wiacek Site: a Late Middleport Component Simcoe County, Ontario. The Ontario Ministry of Transportation and Communications Environmental Unit, Planning and Design Section Southwest Region, London.
- Jackson, H. E.
 1989 The Trouble with Transformations: Effects of Sample Size and Sample Composition on Meat Weight Estimates Based on Skeletal Mass Allometry. *Journal of Archaeological Science* 16:601-610.
- MacDonald, R. I.
 1986 The Coleman Site (AiHd-7): A Late Prehistoric Iroquoian Village in the Waterloo Region. Unpublished MA. thesis, Department of Anthropology, Trent University, Peterborough, Ontario.
- Needs-Howarth, S.
 1992 A Quantification of Diet at the Coleman Site, a Prehistoric Iroquoian Village near Waterloo, Ontario. M.Sc. research paper on file, Department of Anthropology, University of Toronto.
- Prange, H. D., J. F. Anderson, and H. Rahn
 1979 Scaling of Skeletal Body Mass in Birds and Mammals. *American Naturalist* 113(1):103-122.
- Prevec, R.
 1985 The Coleman Site (AiHd-7) Faunal Report. Ms. on file, Department of Anthropology, University of Toronto, Toronto.
- Purdue, J. R.
 1987 Estimation of Body Weight of White-tailed Deer (*Odocoileus virginianus*) from Bone Size. *Journal of Ethnobiology* 7:1-12.
- Reitz, E. J., and D. Cordier
 1983 Use of Allometry in Zooarchaeological Analysis. In *Animals in Archaeology 2. Shell Middens, Fishes and Birds*, edited by C. Grigson and J. Clutton-Brock. British Archaeological Reports, International Series 183, Oxford.
- Reitz, E. J., I. R. Quitmyer, H. S. Hale, S. J. Scudder, and E. S. Wing
 1987 Application of Allometry to Zooarchaeology. *American Antiquity* 52:304-317.
- Schaffer, B. S.
 1992 Quarter-Inch Screening: Understanding Biases in Recovery of Vertebrate Faunal Remains. *American Antiquity* 57:129-136.
- Stahl, P.
 1982 On Small Mammal Remains in Archaeological Context. *American Antiquity* 47:822-829.

- Stewart, F. L.
1991 Floatation for Fauna: Some Methodological Considerations using the Keffer Site (AkGv-14) Midden 57 Faunal Sample. *Canadian Journal of Archaeology* 15:97-115.
- Stewart, F. L., and P. W. Stahl
1977 Cautionary Note on Edible Meat Poundages. *American Antiquity* 42:267-270.
- Thomas, S. C.
1991 GFAUNA2 Database Entry and Analysis System. General Analysis Procedure for the Crawford Knoll Zooarchaeological Project. in *The Zooarchaeology of the Crawford Knoll Site (AdHo-5), a Late Archaic Multiple Occupation Site in Southwestern Ontario*. Ms. on file, Archaeological Services Inc., Toronto.
- White, T. E.
1952 Observations on the Butchering Technique of some Aboriginal Peoples: 1. *American Antiquity* 17:337-338.
1953a Observations on the Butchering Technique of some Aboriginal Peoples: 2. *American Antiquity* 19:160-164.
1953b A Method of Calculating the Dietary Percentage of Various Food Animals Utilized by Aboriginal Peoples. *American Antiquity* 19:396-398.
- Wing, E. S., and A. B. Brown
1979 *Palaeonutrition: Method and Theory in Prehistoric Foodways*. Academic Press, New York.

Suzanne Needs-Howarth

Biologisch-Archaeologisch Instituut, Rijksuniversiteit Groningen, The Netherlands.

Address for correspondence: 14 Grimthorpe Road, Toronto, Ontario M6C 1G3.