Economic anatomy, element abundance and optimality: A new way of examining hunters' bone transportation choices

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Abstract

The importance of studying skeletal part abundance, with respect to economic anatomy, is outlined. The current methodology in this field is discussed. A new method for examining archaeological skeletal part abundance, with respect to bone transportation models, is described. This method scrutinises the difference between observed abundance and economically expected abundance, according to food utility. This new method is closely linked to optimal foraging theory. The application of optimal foraging theory to the question of bone transportation by hunters is discussed. The use of the new methodology is illustrated by application to two ethnographic examples; the Inuit sites of Anavik and Anaktiqtauk (Binford 1978). Issues related to the application of such a methodology to archaeological assemblages are discussed.

Introduction

Having stalked and killed their prey, hunters of larger mammals are faced with the task of transporting their quarry back to their camp. They have to decide whether all the parts of the animal are worth transporting, and, if not, which ones are of greatest value to them. Such decisions will be affected by the food value of given skeletal elements, the number of people that are available to carry elements, the distance the kill-site is from the desired destination, the amount of time available for the task, the hunters' personal taste in food, the utility of different elements for craft purposes, the gross size of the animal in question, the ease with which each element can be transported and the immediate needs (*i.e.* "snacking" at the kill-site) of the hunters. The end result of this complex selection process will be that some bones are left at the kill-site and others will be transported to a camp site. Clearly, such patterning, if it occurs on a regular basis, will be visible in archaeological bone assemblages. If the archaeologist wishes to interpret these patterns, an attempt must be made to understand hunters' decisions. If bone transportation can be successfully modelled, anatomical part abundance is capable of revealing much about hunter-gatherer settlement patterns and subsistence economics.

Lewis Binford, with his landmark ethnoarchaeological account of the Nunamiut Inuit (Binford 1978), put this field of study on a sound footing. He observed the butchering and transport procedures of the Inuit and related their choices to the economic utility of anatomical elements. This was achieved by creating an index of utility for the elements of the body for both sheep and caribou (Binford 1978, 2). The amount of meat, marrow and bone grease was quantified for each element, hence creating an MUI (meat utility index), an MI (marrow index) and a WGI (white grease index). These indices were combined together to create a GUI (general utility index). Binford, however, noted that, according to his experience of Inuit butchering, there was a likelihood for bones of lower utility to be transported with those of higher utility simply because they were attached, rather than for their own utility. He referred to such elements as "riders". He, therefore, modified his GUI to take this effect into account. The finished index was called the MGUI (modified general utility index) (Binford 1978:4). He found that his index was a reasonable predicator of Nunamiut element transport choices.

Metcalfe and Jones (1988) reviewed Binford's methods for the creation of utility indices. They noted that Binford's derivation of his indices was over-complicated. He had used several subjective modifiers to his indices, to account for aspects of his Nunamiut informants' taste, as well as having to combine three separate indices to create the general index. Metcalfe and Jones found that a simple quantification of mass of edible tissue on each element was just as effective, more objective and easier to derive than the GUI. Their equivalent of Binford's MGUI, the FUI (food utility index), which accounted for "riders" in the same way, was found to fit with observed patterns just as well.

Current Methodology for Comparing Element Abundance with Economic Utility

Currently, the methodology for comparing element abundance with utility that was established by Binford (1978:Chapter 2) is still standard in the zooarchaeological literature. A scattergraph of standardised (usually standardised with the highest value raised to 100) element frequency (%MNI, %MAU) against standardised modified utility (MGUI, (S)FUI) is plotted. A line of best fit is then drawn through the points and interpreted with regard to a set of models.

Figure 1 represents the series of models for examining those bones which have been removed from the kill-site (*i.e.* have been transported to the camp site). Clearly, if elements have been transported purely according to utility then one would expect to see a straight line emanating from the origin. Metcalfe and Jones (1988: Figure. 6) refer to this as an unbiased strategy but, here, it will be referred to as the utility model (since "unbiased" is a little misleading as the strategy involves bias with regard to utility). The "bulk" model represents a transport strategy where more elements are transported than is suggested by their utility. In other words, the hunters are prepared to transport elements of little value in order to maximise the bulk of food they gain. The "gourmet" model represents a strategy where the hunters are only interested in transporting elements of higher utility.

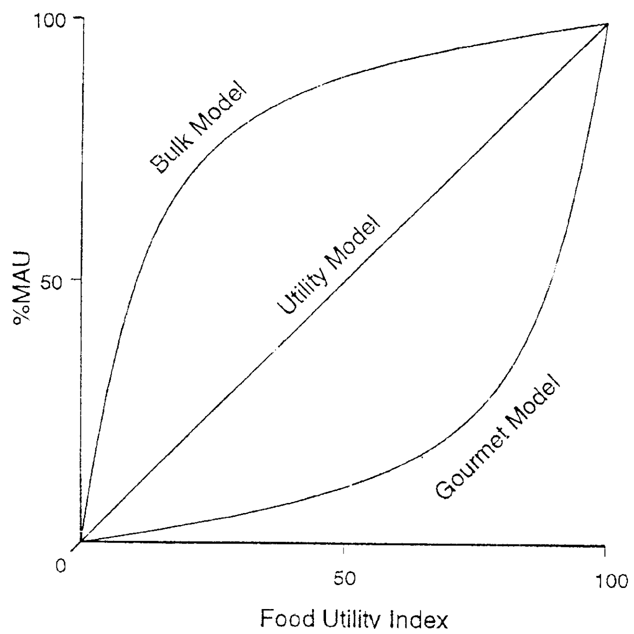

Figure 1: Models, showing the relationship between element abundance and element utility, for three different transport strategies as represented at a transport destination (camp site) (after Binford 1978).

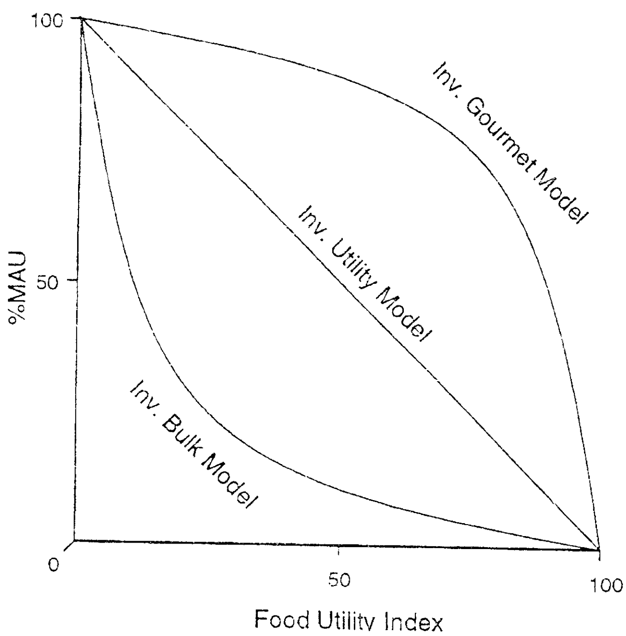

Figure 2: Models, showing the relationship between element abundance and element utility, for three different transport strategies as represented at a transport source (kill-site) (after Binford 1978).

They, therefore, take fewer elements than their utility suggests.

Figure 2 represents these same models but considers the elements that are discarded at the kill site. At the kill site, the utility model will produce a best-fit line showing an inverse proportional relationship between utility and element frequency. The inverse of the bulk model will be represented by a preponderance of very low utility elements with all the rest underrepresented with respect to utility. The inverse gourmet curve will show an overrepresentation of all but very high utility elements.

In Figures 1 and 2, one example curve for each model has been drawn in, however, the curve could take many forms and represent the model to varying degrees of severity.

Figures 3 and 4 are examples of this method in application. They are plots of two of Binford's ethnographically encountered Nunamiut sites; Anavik and Anaktiqtauk respectively. Both these sites were multiple caribou kill-sites (Binford 1978:75). In these figures, Binford's element abundance data has been plotted against the (S)FUI for caribou calculated by Metcalfe and Jones, 1988. The Anaktiqtauk curve seems to fit the inverse bulk model rather well, as does the Anavik data, if less well. This makes very good sense since there was no particular time stress regarding transport from the Anaktiqtauk site and, hence, many elements were transported (a bulk model). At Anavik, though, the transport was time-stressed by the breaking up of the ice and less was transported than desired, leading to a less perfect and less pronounced bulk model (Binford *ibid.*).

This example demonstrates the usefulness of Binford's methodology well, but there are some problems in using this approach. Firstly, it is often very difficult to establish exactly where the best fit should go and it is very easy to allow one's eyes to be drawn. The example given is a fairly clear one, but many archaeological applications require a great deal more faith and frequently quite significant outliers are ignored. Metcalfe and Jones (1988:491) try to get around this problem by attempting a statistical correlation. In order to be able to carry out a linear correlation, they take the reciprocal of the element frequency on the basis that "this transformation tends to straighten hyperbolic curves." This is certainly a good idea but a potentially flawed one. The curve need not be hyperbolic. It is interesting to note that Metcalfe and Jones plot only symmetrical hyperbolic curves on their model diagram (1988: Figure 6), whereas Binford illustrates more interesting possibilities (Binford 1978: Figure 2.18).

A second problem with the scattergraph method is the lack of ease with which one can see what the relationship between individual element abundance and utility is. In many examples, the data points on the graph are not labelled (like Figures 3 and 4) and, hence, it is impossible to note any pattern pertaining to any individual element. Binford, himself, does label all his points with abbreviated identifications. Even though, in such a case, all the relevant information is there, one is presented with a confusing array of dots and letters which are difficult to interpret at a glance.

The scattergraph also has the limitation that, although it is possible to see the level to which a model is being adhered to through the strength of the curve, it is not immediately obvious where the point in the hunters' strategy is arrived at,

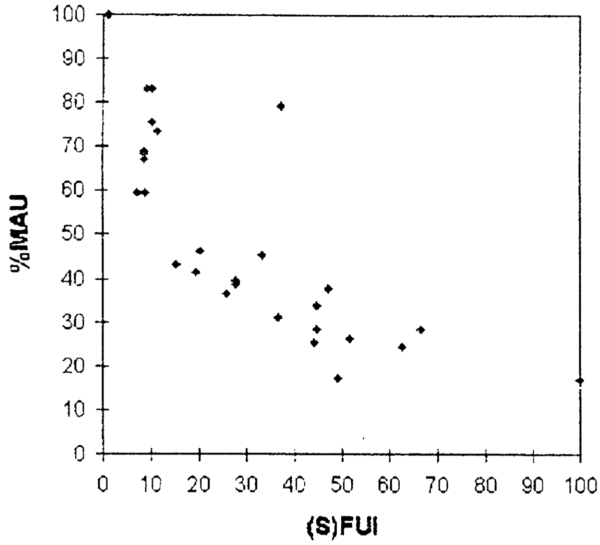

Figure 3. A scattergraph plotting the element abundance data (%MAU) from Anavik (Binford, 1978:table 2.9) against the food utility index ((S)FUI) for caribou (Metcalfe and Jones, 1988:table 2).

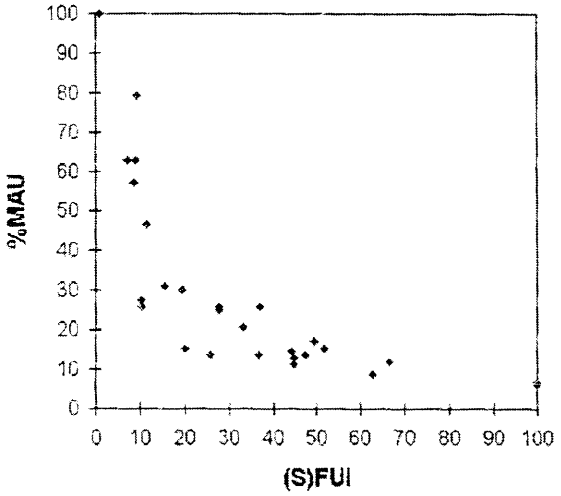

Figure 4. A scattergraph plotting the element abundance data (%MAU) from Anaktiqtauk (Binford 1978:table 2.9) against the food utility index ((S)FUI) for caribou (Metcalfe and Jones, 1988:table 2).

where they decide that elements are or are not worth transporting. This can be termed the "cut-off" point, and it is very important to identify this point if optimal foraging theory is to be applied to zooarchaeology.

Optimal Foraging Theory and Element Transport

The application of models of optimal behaviour, such as utility indices, to the archaeological record has frequently been criticised for being overly predictive and deterministic. Indeed, if optimal models are being used as a deterministic tool, this criticism is valid. Clearly, there are considerations in play, regarding human behaviour, other than the purely economic. However, as Higgs and Jarman (1975:2) noted, and this is irrefutable, "ultimately all human culture and society is based upon and only made possible by biological and economic viability." Our species must operate within economic constraints.

Optimal models and utility indices should not be constructed to act as a determining factor, but should be seen as a measuring stick against which behaviour can be evaluated. As Foley (1985:222) stresses, "behaviours should not conform to the template, but... it provides a standard measurement and comparison against which deviations can be assessed." There are few such standard measurements available to the archaeologist but utility indices for the anatomical elements of food animals, established through uniformitarian principles, are good examples. This valuable research tool should not be wasted and can perhaps be best applied if used in conjunction with optimal foraging theory.

Optimal foraging theory was adopted by anthropologists from biologists. It basically asserts, in the way it is used in anthropology, that in certain arenas humans will attempt to maximise their net rate of energy gain. This will involve choices in diet, foraging location, foraging group size, foraging time and settlement pattern (Bettinger 1991:4). Optimal foraging theory is still quite rarely applied in archaeology and has received criticism from Binford (1983:219). However, Binford is not consistent in his criticisms and there is a strong case that optimal foraging theory is a form of middle-range theory, in the way that Binford envisages it (Bettinger 1991:107).

Bettinger (*ibid.* Figure 4.8) compares Binford's (1978) bone transport models to the branch of optimal foraging theory known as diet breadth theory. Diet breadth models are related to the optimal number of items that should be consumed within a diet. Within this theory, items with low net energy value (considering calorific value, processing time, *etc.*) will only be added to the diet when times are hard (*i.e.* when resources are scarce enough to make it worth finding and processing that dietary item). This has clear relevance to the choice a hunter makes regarding element transport. Rather than ranking dietary items, as in a diet breadth study, elements of an animal can be ranked and the point at which a hunter chooses to stop exploiting (the hunter's perceived optimal *cut-off*) will tell us something of that hunter's economic situation.

An adaptation of the "marginal value theorem", however, might well prove a more powerful model to underpin the study of optimality and element transport. Anyone who has experience of collecting berries from along hedgerows knows plenty about the marginal value theorem. The berry picker has to decide at what point it is worth leaving a given bush to find another. This time of leaving is rarely when all the berries have been picked, but is at a time when one will clearly have greater success at another bush. Marginal value theorem dictates that the optimal time to leave a foraging patch is when the net energetic gain from that patch falls

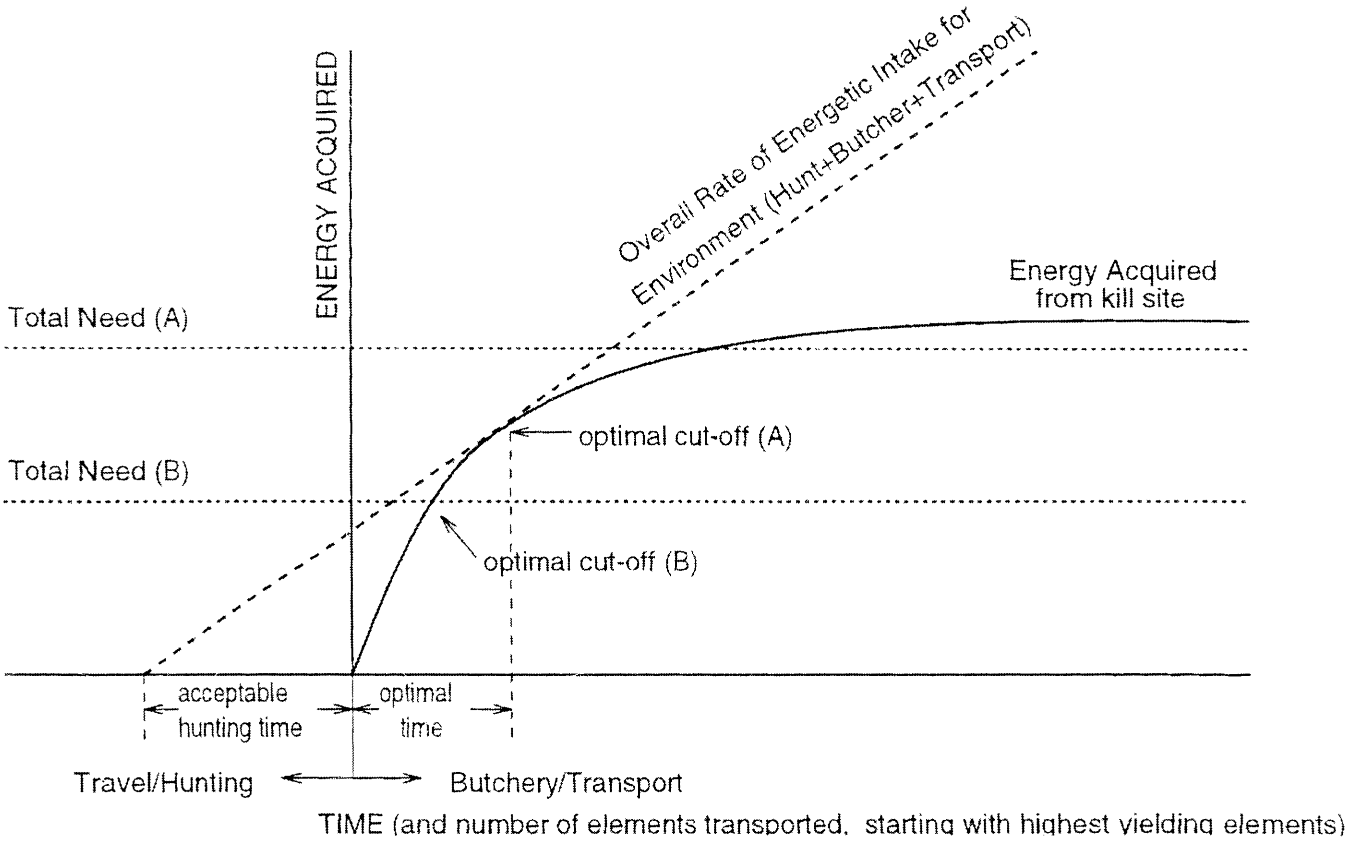

Figure 5: A diagram representing an adaptation of the Marginal Value Theorem (after Charnov 1976 and Bettinger 1991:Figure 4.3) for application to the study of element transport.

below the mean net energetic gain for the surrounding environment (this includes the time required to find a new foraging patch) (Bettinger 1991:Figure. 4.3, after Charnov 1976).

Figure 5 shows an adaptation of this theory for use with element transport choices. The x-axis on this figure relates to the time spent in the acquisition of energy through the hunting, transporting and processing of animals. To the left of the y-axis is time spent in hunting and to the right is time spent on butchery and transport of elements. For the consideration of this model, a diet breadth model is assumed and elements are transported in order of increasing food utility (energetic gain). The y-axis represents energy acquired. Following the marginal value theorem, the hunter will stop butchering and transporting when the rate of energy he can gain from further work on that animal (or group of animals) drops below the mean amount of energy he could gain from hunting down and processing another animal(s). This is represented in Figure 5 by the point at which the curve representing energy acquisition from the kill-site falls below that for hunting a new animal(s) in terms of gradient (i.e. rate) (optimal cut-off A). The lower the gradient of the line representing the mean for the environment, the later the optimal cut-off will be, and, therefore, the more bones of lower utility will be transported (and *vice-versa*). The point of cut-off is dictated by where the straight line representing the environment creates a tangent to the curve representing the current kill-site.

Incidentally, if the gradient of energy gain for the environment is low (*i.e.* shallow) this line will cut the x-axis further to the left of the y-axis. This means that a larger hunting time would be acceptable. There are fewer animals about, therefore it becomes acceptable to spend longer tracking them down.

A variable not considered in the marginal value theorem is that of total need. The model assumes infinite need (and when foraging for small things like berries and nuts this assumption makes sense). Infinite need cannot be assumed in the case of a large hunted animal. There may be no need to hunt another animal at all. If the total calorific requirement is higher than the marginal value theorem cut-off (as in the case of total need A in Figure 5) then the model is unchanged and the cut-off will be as before (cut-off A in the figure). However, if the hunters have more limited needs (such as total need B), at a level below that of cut-off (A), then the optimal cut-off will be at the point where their need is fulfilled. This is the point were the energy from the kill-site curve intersects the horizontal line of total need (B) (cut-off B).

This model is a powerful one for understanding the relationships between a hunter's transport choices, his resource environment and dietary needs. To be applied archaeologically, so that sites can be compared, it is necessary to identify hunters' perceived optimal cut-off points with regard to element transport. The current methodology does not do this in any clear way, although the data necessary are there.

A New Method

In discussing element transport models, it is the way in which abundance varies with regard to utility that is important. One of the most direct ways of portraying this graphically is to plot a histogram that represents the difference between standardised element abundance and element (S)FUI. This is the basis of the new method presented here.

If one first takes the case of examining the element abundance at a camp site (bone destination), the histogram should be constructed by placing skeletal elements in decreasing order of FUI value along the x-axis (see Figure 9 as an example). The y-axis will represent the difference between the element abundance and FUI (N.B. the (S)FUI is subtracted from the standardised measure of element abundance).

Figure 6 shows models for evaluating the transport destination. The graphs relevant at this point are those in the column labelled *decreasing FUI value.* If one first considers the "utility model", it is clear that if abundance follows utility there will be no difference between the two. Moving on to the "gourmet model", because only the highest utility elements have been transported, elements will, in general, be under-represented. Only the lowest value elements, which would not have been transported anyway, and the "gourmet" elements will be represented according to utility. This will lead to a curve along the ends of the histogram bars that looks like the gourmet model in Figure 6. The most underrepresented bones (the apex of the curve) will be at a point above 50% (S)FUI, where the highest value untransported element is.

The "bulk model", however, is the reverse since much more has been transported than utility suggests. Only the highest elements (which one expects to be transported anyway) and the very worst elements will be transported according to utility. The apex of the curve, over the top of the histogram bars, will be at a point below 50% (S)FUI, where the lowest value transported element is (see Figure 6).

To carry out the calculations of difference, in order to construct such graphs, standardised abundance and FUIs are used. This is important for two reasons. Firstly, if both measures are standardised so that their top value is 100, then the two measures will have the same total range. If standardisation did not take place then the abundance minus the FUI in a utility model would not equal zero (and this is essential). Secondly, in many applications to the archaeological record not all elements will be considered (usually because of taphonomy or identifiability). This would entirely invalidate this methodology if standardisation had not taken place. The method has important assumptions regarding which elements are most likely, and least likely, to be transported. There is no problem in eliminating elements

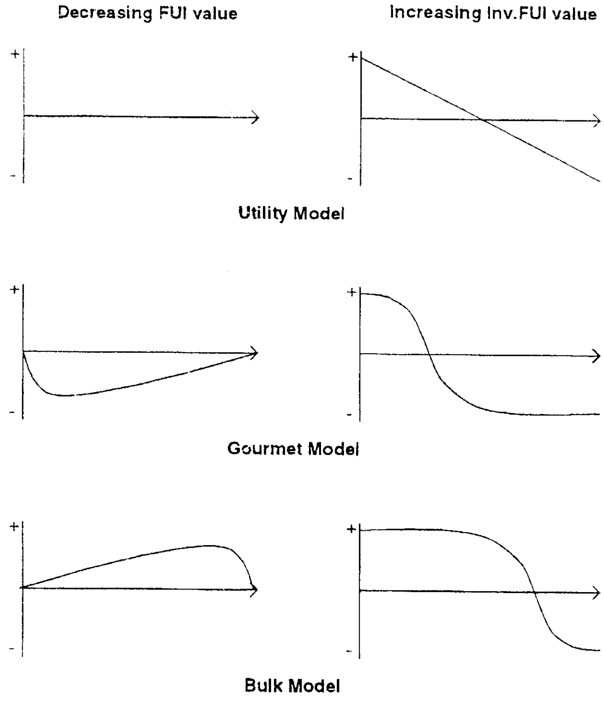

Figure 6: Transportation models for the destination site (camp site) using the new method. The models in the left-hand column have elements positioned in decreasing order of FUI value along the x-axis. These should be used for the study of a transport destination. The right hand column represents the way the same data would appear if plotted, incorrectly, against an x-axis with elements in increasing order of Inv.FUI. The difference between the element abundance and FUI (or Inv.FUI)(i.e. %MAU - (S)FUI) is plotted on the y-axis.

so long as the FUI is standardised to compensate. If the highest value element, for instance, is being missed out then the highest of the remaining elements must be raised to 100% (S)FUI (and the others adjusted accordingly).

Clearly, if one is expecting the highest ranking of the elements studied (100% (S)FUI) to be the most represented at the base camp (100% MAU) then the reverse must be true at the kill-site. The abundance of the highest-ranking element at the kill-site should be 0% MAU. This is not to say that that element is expected to be completely absent at the kill-site, all of them having been transported. Just as the 100% at the camp site represents merely that that element is the *most* abundant, the 0% at the kill-site simply represents that that element is the *least* abundant. For the kill-site, therefore, the standardisation is to zero. This is achieved, in the case of the (S)FUI by subtracting the (S)FUI value from one hundred (hence the highest-ranking element becomes 100-100=0). This can be termed the inverse FUI (Inv.(S)FUI), an index that predicts abundance in inverse proportion to actual utility. Before the abundance can be compared to the Inv.FUI they too must be standardised to zero. One cannot standardise to zero directly from raw abundance data (it is mathematically impossible), but first the most abundant should be raised to 100 (as before), and then the value of the least abundant be subtracted from all the values (the least abundant will then be equal to zero).

To summarise, for the study of the transport destination (base camp) the FUI and abundance values are standardised to 100 with respect to the highest ranking/most abundant element. This is because the model assumes the highest-ranking element will be the most abundant. The FUI is inverted for use at the element source (kill-site) because it is assumed that lowest ranking element will be the most abundant. If 100% of the highest-ranking element should be present at the base camp then 0% should be at the kill-site. The standardisation of the Inv.FUI is, therefore, to zero. To maintain a fair comparison the abundance values must also be standardised to zero.

Figure 7 shows the models for the kill-site. Concentrating now on the column labelled *Increasing Inv.FUI value*, one can see that, once again, the (inv.) utility model is represented by zero difference between abundance and Inv.FUI value (i.e. the elements have been left in inverse proportion to their utility). With the (inv.) gourmet model, bones are generally over represented at the kill-site creating a curve with an apex below 50% Inv.(S)FUI. That is because the elements that have not been transported with the highest FUI value (the lowest Inv.FUI value) will generate the greatest difference. With the (inv.) bulk model the curve will show an under-representation since more elements have been transported away than the Inv.FUI would suggest. The apex of this curve will be above 50% Inv.(S)FUI (i.e. the greatest difference is created by over-transported low value, high inverse value elements).

This may sound complicated but is, in fact, very simple. The FUI represents expectations for the camp site and the Inv.FUI represents expectations for the kill-site. The correct index should be used for the correct type of site. If one of the models is present at a site and the correct index is applied, the histogram bars should be all positive or all negative (accepting the odd outlier). However, if a model is represented at a site but the wrong index is applied, then the curve, generated by following the ends of the histogram bars, will cross the x-axis. Figures 6 and 7 show what the various models would look like if the incorrect index was applied. Each of these shapes is unique, so it would still be possible to identify which model is present. Beyond the identification of model, a graph plotted using the wrong index is meaningless and the graph should be re-plotted using the correct index.

The major strength of this methodology is that the apex of a correctly plotted graph will represent the optimal cut-off point in transportation, as perceived by that hunter(s). The point where the gradient changes marks the point at which the hunter begins to decide against the transport of a given element type. It will be clearer to see the benefits of this method with the use of an example application.

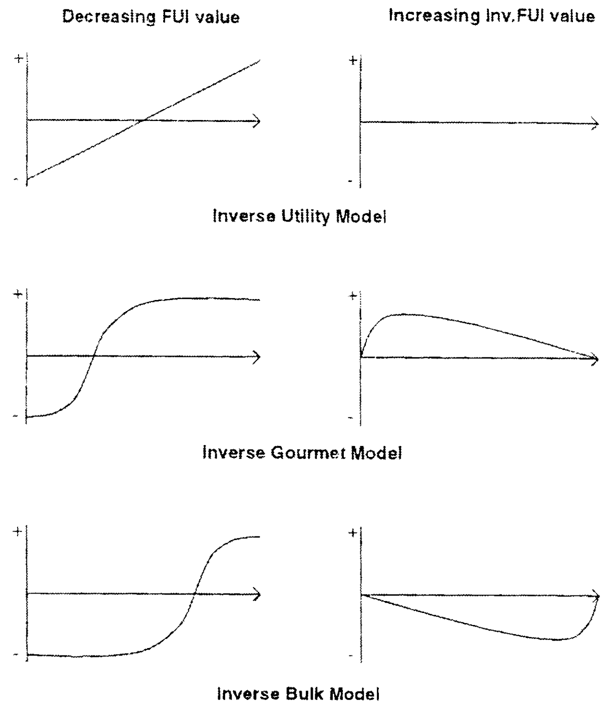

Figure 7: Transportation models for the source site (kill-site) using the new method. The models in the right hand column have elements positioned in increasing order of Inv.FUI value along the x-axis. These should be used for the study of a transport source. The left-hand column represents the way the same data would appear if plotted, incorrectly, against an x-axis with elements in decreasing order of FUI. The difference between the element abundance and Inv.FUI (or FUI)(i.e. %MAU - Inv.(S)FUI) is plotted on the y-axis.

The New Method Applied

Figure 8 shows the new method applied to Binford's (1978) Anaktiqtauk example (plotted the old way in Figure 2). In Figure 2 this kill site followed a clear inverse bulk pattern. Figure 8, using the new method and comparing against Inv.FUI, broadly agrees (compare to models in Figure 7). The first advantage of this method becomes clear. Because all the elements lie in strict order and are clearly labelled, it is possible to see exactly what each element is doing with respect to its expected frequency. For instance, it is clear that the value for the skull is somewhat anomalous. The advantage is that any deviation from the model is very obvious. There is no danger of the eye being led to see best fits which are, frankly, wishful thinking! In this case we see that, with some imperfections, the bulk model fits. Figure 9, incidentally, shows what the graph looks like if plotted, incorrectly, against FUI (compare to models in Figure 7).

If we now examine the Anavik site in Figure 10 (plotted the old way in Figure 1) we can make a comparison with Anaktiqtauk. Anavik clearly has many more anomalies than Anaktiqtauk, particularly the cervical vertebrae. This is clearly a much poorer fit to the inv. bulk model (compare to Figure 7). Compare also the Anavik data plotted against

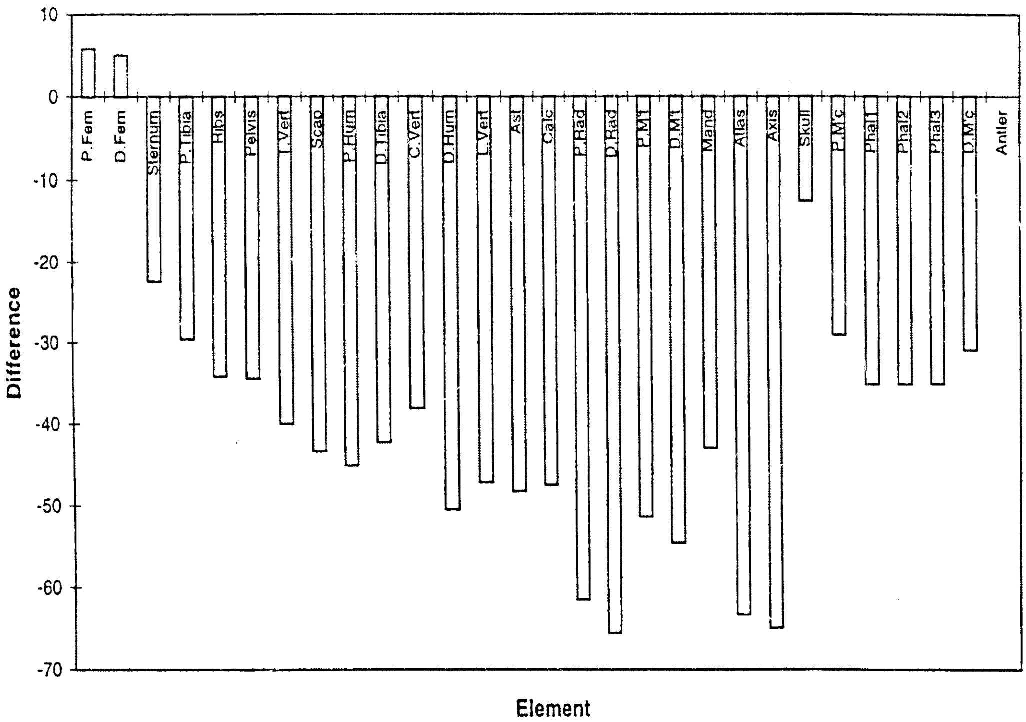

Figure 8: A histogram showing the difference between element abundance for the site of Anaktiqtauk (data from Binford 1978:Table 2.9) and Inv.(S)FUI for caribou (derived from Metcalfe and Jones 1988:Table 2) (i.e. %MAU - Inv.(S)FUI) with elements arranged in order of increasing Inv.FUI value along the x-axis.

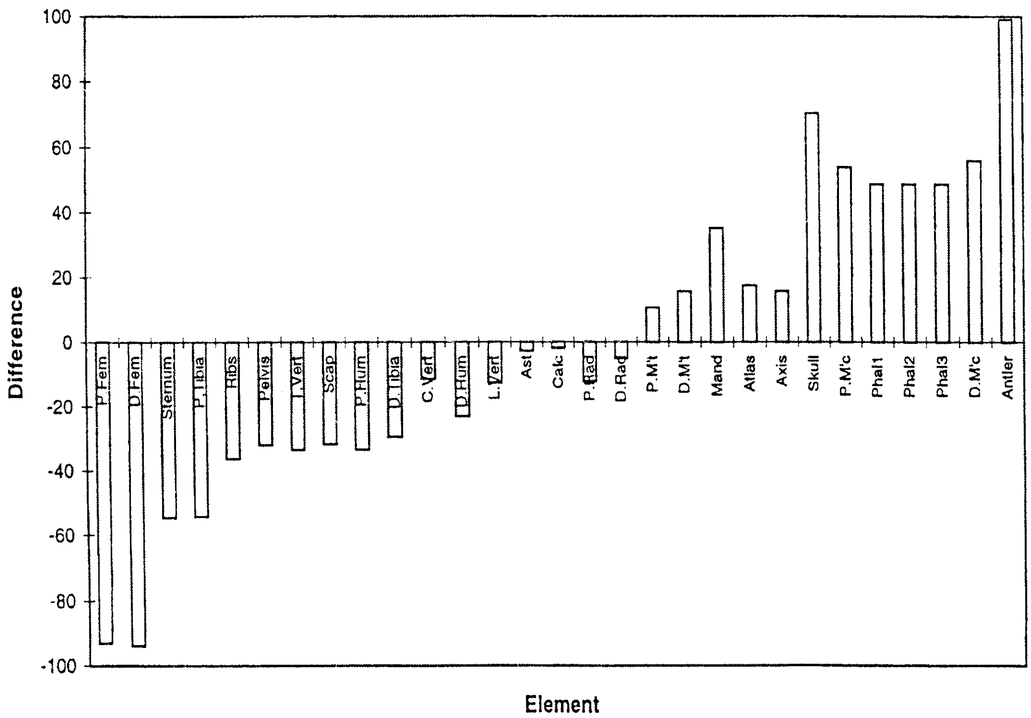

Figure 9: A histogram showing the difference between element abundance for the site of Anaktiqtauk (data from Binford 1978:Table 2.9) and (S)FUI for caribou (Metcalfe and Jones 1988:Table 2) (i.e. %MAU - (S)FUI) with elements arranged in order of decreasing FUI value along the x-axis.

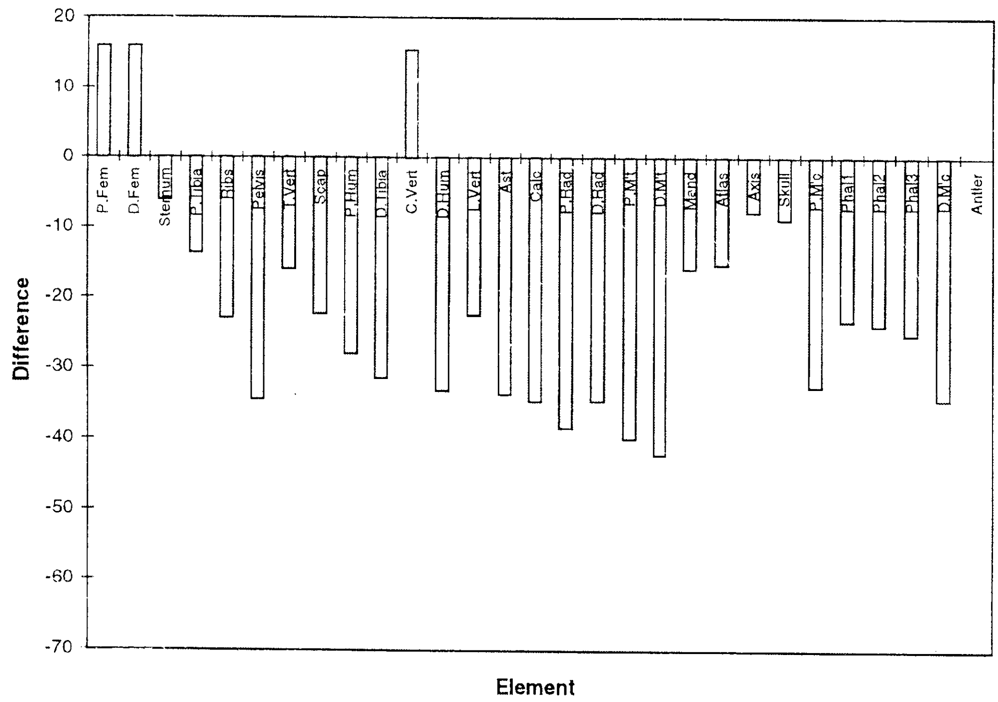

Figure 10: A histogram showing the difference between element abundance for the site of Anavik (data from Binford 1978:Table 2.9) and Inv.(S)FUI for caribou (derived from Metcalfe and Jones 1988:Table 2) (i.e. %MAU - Inv.(S)FUI) with elements arranged in order of increasing Inv.FUI value along the x-axis.

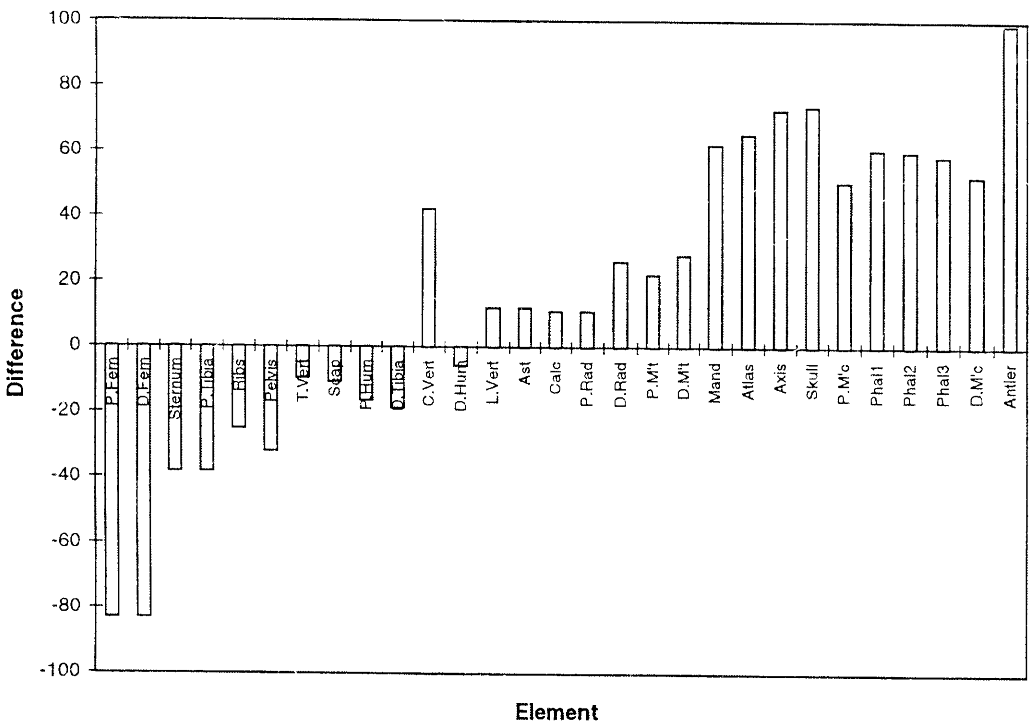

Figure 11: A histogram showing the difference between element abundance for the site of Anavik (data from Binford 1978:Table 2.9) and (S)FUI for caribou (Metcalfe and Jones 1988:Table 2) (i.e. %MAU - (S)FUI) with elements arranged in order of decreasing FUI value along the x-axis.

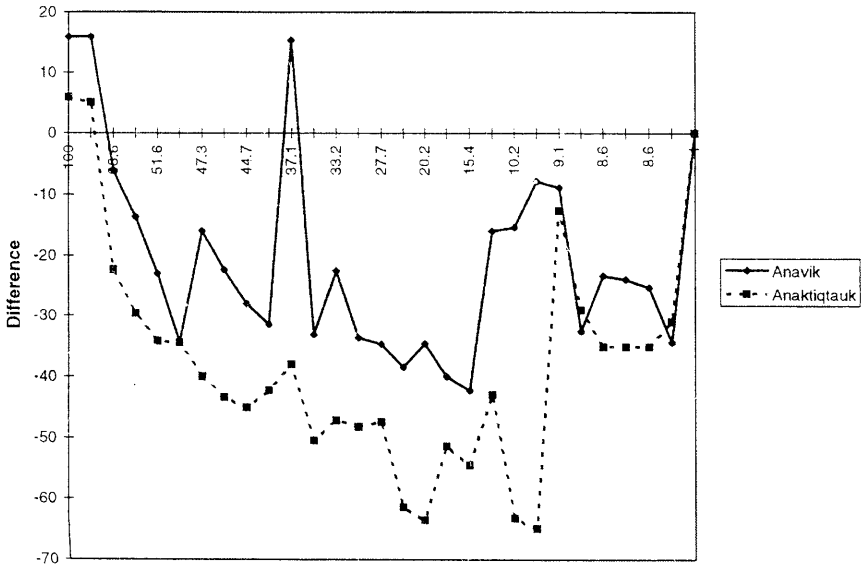

Figure 12: A graph plotting the difference between element abundance and Inv.(S)FUI for both Anavik and Anaktiqtauk (as in Figures 8 and 10). The elements are in order of increasing Inv.(S)FUI along the x-axis but, rather than being labelled by name, the (S)FUI value of each element is given.

FUI (Figure 11) with Figure 7. Furthermore, it is obvious at a glance that the model has not been practised to the same extent as at Anaktiqtauk since the histogram bars do not go anywhere near as negative. This effective comparison is possible instantly without recourse to drawing best fits and attempting statistical correlations. It is easy to see exactly how each element is represented with respect to its utility. Perhaps the greatest advantage of the method is, however, that the apex of the "curve", created by the ends of the histogram bars, represents the hunters' perceived optimal cut-off point.

Figure 12 re-plots Figures 8 and 10 on the same graph. Instead of labelling the x-axis with element names, this graph shows the FUI values for the elements. It is clear that the Anaktiqtauk "curve" has its apex somewhere between 20.2 (S)FUI (the distal radius) and 10.2 (S)FUI (the axis). It seems likely that it actually lies towards the bottom of this range since there is not a consistent fall off of the negative values until after 10.2 (S)FUI. It appears that the hunters at Anaktiqtauk perceived that their optimal cut-off for transport was somewhere in that FUI range (*i.e.* they tended to ignore elements with a lesser FUI value). This now gives us some information to feed into the optimality model.

Since the cut-off is quite far along, it suggests that total need was probably quite high and that the mean environmental yield was relatively low by comparison with need (*i.e.* in Figure 5, the environment line is shallow and touches the kill-site curve further along the x-axis.) This tells us much about the hunters' economic situation. In an archaeological context, one now has to consider other evidence such as environmental data, evidence of population size etc. This data can be fed into the optimality model and the palaeoeconomics of the subjects might become clearer.

In the case of the Anavik "curve" (Figure 12) it seems that the apex is somewhere around 15.4 (S)FUI (the distal metatarsal). There are many anomalies but the basic trend appears to be increasing negativity up to that point and then a fall off in values. This particular case is very interesting, because we know that the intention of these hunters was the same as that at Anaktiqtauk, but they were pressured by time (the ice flows were breaking up) (Binford 1978:2). The optimal cut-off is in the same range as that at Anaktiqtauk, but the fit to the model is less satisfactory (there are more anomalies) and bias towards bulk transport is less strong (the curve does not go as deep). Under time stress, therefore, the hunter's perceptions of values, in terms of optimal cut off, remained similar, but their ability to adhere to the model strongly was affected.

Discussion

This new method of examining element transport by hunters is potentially a powerful one. It allows the easy recognition of models but at the same time shows up anomalies very clearly. It is difficult to allow ones eye to be drawn erroneously. The method allows one to examine individual elements with ease, and therefore permits the examination of unusual patterns pertaining to single or groups of elements (resulting perhaps from craft activities or hunters' peculiar tastes). It allows for the identification of perceived optimal cut-off points, and is, therefore, more conducive to use with optimal foraging theory than the old method.

It should be stressed, however, that although the basic principle of this method is simple, care must be taken when graphs are plotted. Care should always be taken when using standardised data. Standardisation is often essential in carrying out relative comparisons, but it is very important that an analyst is sure that data has been standardised in the correct way for a given question and why it has been standardised that way. For instance, if re-standardisation has taken place because some elements have been eliminated from consideration, then one must remember to convert back to the original data for the final result. In the case of finding the optimal cut-off point, the FUI value for the whole set of elements must finally be used, not any value used within a subset during calculations!

Care must also be taken with regard to applying methodology such as this to archaeological assemblages. One must be very sure that one is dealing with an archaeological feature and not a taphonomic one. There has been much recent debate over the effect that density mediated attrition (Lyman 1994; Marean and Frey 1997) and carnivore gnawing (Brain 1981; Marean and Spencer 1991) will have on element abundance. It is very important to assess the way a site has been recovered by archaeologists (*e.g.* was it sieved?) and the way the zooarchaeologist (if one did not analyse the assemblage oneself) carried out the zoning for identification. Sample size is also a crucial consideration as well as quantification method.

Although little mentioned in the literature, the gross size of the animal being transported is very important. This general approach can only really be applied to large animals. The underlying assumption, in the above models, is that the whole animal is too big to be transported in one piece. The method is clearly not applicable to small animals like roe deer, for instance, which could be slung whole over the hunter's shoulder. Even less acknowledged in the literature is that, if an animal is too large, then it also will not conform to the above models. Another assumption underlying the models is that individual elements are transportable. This would probably not be the case with a mammoth, for instance. Outram and Rowley-Conwy (1988) found, in creating a utility index for horse, that the roll of meat alone (without the bone) from the femur of a horse would present quite a transport dilemma (as much as 28kg). It is, therefore, suggested that this method can only be applied to a limited size range of animals. This range would include animals like reindeer and red deer. Animals such as horse and bison are probably at the upper limit of the use of this methodology.

Despite these difficulties, there remains much scope for carrying out useful work on past hunting economies using the approach outlined above. If due care is taken, the use of optimal foraging theory, in combination with a comparison of economic utility with skeletal part abundance, could tell us much about past hunter-gatherer resource environment, settlement patterns and demography.

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