

Chapter 5: Changes in Prey Utilization

With a decline in foraging efficiency resulting from resource depression, the patch choice models predict that the manner in which prey are exploited may also change over time. As I have discussed in Chapter 2, changes in prey use can be examined at two scales: individual prey items and specific portions of individual prey items. The changes predicted by the patch choice models at these two scales can be measured by examining skeletal element representation and bone fragmentation patterns, respectively. In this chapter, I discuss the kinds of changes patch choice models predict when foraging efficiency declines. That is followed by a discussion of how these variables are measured and used in the analysis of archaeological faunal material. I then use the Shag River Mouth faunal data to test if the predicted changes in prey use are evident.

Measuring Changing Patterns of Prey Utilization in Archaeological Assemblages

Measuring Changing Use of Individual Prey Items

Although the patch choice models were developed to deal with the spatial distribution of prey types (Charnov 1976; Orians and Pearson 1979), their use can be expanded to treat foraging decisions made in the context of a single prey item (Broughton 1999; Stephens and Krebs 1986). When individual prey items are treated as patches, the patch choice models can be used to make predictions about time allocation to individual carcasses. Like prey types within a patch, each part of an animal is ranked based on its dietary value. Optimal time allocation should be reflected by how far down the rankings of elements foragers are exploiting. For example, periods of high foraging efficiency should be characterized by shorter foraging times resulting in only a few high-ranked elements being exploited per carcass. In contrast, periods of low foraging efficiency

should result in longer foraging periods, which would lead to the exploitation of more low-ranked elements per carcass.

The patch choice models provide different predictions of changing resource use that depend on whether distance to prey is a factor in the decision making process. When distance to prey is constant over time, the marginal value theorem (MVT) predicts that as encounter rates of prey decline, time allocation within patches should increase (Charnov 1976). When individual prey items are treated as patches, increasing time allocation within "patches" should be reflected by a broadening of the range of elements returned to the site so that both high and low return elements are represented.

In contrast, if distance to prey is increasing over time, then travel costs become important in transport decision process. In such cases, the central place patch choice model predicts that as travel costs rise, the net return for the prey taken in distant areas is also likely to increase (Orians and Pearson 1979; Schoener 1979). In terms of prey use, the expected increase in returns may be reflected by an increase in the amount of field processing and a narrowing in the pattern of transported body parts to mainly high return elements.

These predicted patterns of changing prey use can be measured archaeologically by comparing the relative abundance of skeletal elements from large-bodied taxa to ranked utility indices for those taxa to determine if element representation in assemblages correlates with nutritional value. Large-bodied taxa are more likely to be affected by transport decisions than small-bodied taxa because the size of the former may not allow the transport of whole carcasses. Thus, I will focus this portion of the analysis on the large-bodied taxa of Shag Mouth -- moas and seals.

The common measures of element nutritional value in archaeological studies are utility indices that reflect the amount of meat, marrow, and grease associated with each skeletal element (Binford 1978, 1981; Metcalfe and Jones 1988). There are generally two types of utility indices. The first is a skeletal element utility index where each element is given a utility value (e.g., general utility index or GUI: Binford 1978; food utility index or FUI: Metcalfe and Jones 1988). The second utility measure is a modified index that adjusts for the possibility that groups of elements are returned to the site as a package (e.g., modified general utility index or MGUI: Binford 1978; modified meat utility index or MMUI: Savelle *et al.* 1996). These groups of elements often contain low utility elements called "riders". The utility values for riders are calculated by taking the mean utility of the high utility elements with which they are transported, which is a higher value than if the riders were transported alone. If both types of indices are available, information about prehistoric butchering techniques is typically used to determine which index is appropriate.

The measure of the frequency of skeletal parts commonly used is the minimum animal unit, or MAU (Binford 1978, 1981; Lyman 1994). MAU is calculated by taking the minimum number of an element represented in an assemblage (MNE) and dividing the MNE by the number of times that element occurs in a skeleton. Often MAUs are scaled to 100, in which case they are called %MAU.

The relationship between skeletal element representation of an assemblage and nutritional value can be examined graphically by plotting utility and %MAU against each other in a graph on an assemblage-by-assemblage basis. In principal, the shape of the scatter reflects the kind of strategy used for transporting elements (Binford 1978; Thomas and Mayer 1983). For each time period of interest, a new plot would be generated.

Because the purpose of this analysis is to determine if the range of elements being brought back is changing over time, a simpler method can be used. Rather than comparing two measures in a scatterplot, a simpler means is to create an index that incorporates both a measure of utility and skeletal part frequency. The mean utility, or the average returns per element for a given layer, is such a measure (Broughton 1999). Mean utility is calculated by multiplying the skeletal part frequency of each element by the utility for that element. These values are then summed for each layer and divided by the total number of skeletal elements for the layer. Each layer or sample is represented by a single number, which can then be plotted to examine changes in mean utility amongst samples.

Another simplifying method involves the use of relative skeletal abundance (RSA) instead of %MAU as a measure of skeletal part frequency. RSA is simply the number of identified specimens per element divided by the number of times that element occurs in the skeleton (Broughton 1999). For example, there are two tibiotarsi in a moa skeleton. If there are ten moa tibiotarsi recovered from a layer, then the RSA for moa tibiotarsi in that layer would be five. Since the data will be tested at an ordinal level, the data are not scaled to 100 because the rank of the elements would not change.

Samples with a high mean utility have a large proportion of high utility elements. If a broader range of elements is represented, then the mean utility for that layer will be lower. Thus, if time allocation is increasing due to declining encounter rates with high-ranked resources, we may expect a decrease in mean utility over time. In contrast, if time allocation is decreasing due to increasing travel costs, then the opposite trend, an increase in mean utility, is expected.

As discussed in Chapter 2, transport decisions can also be affected by other factors such as processing time and transport mechanisms. Consequently, the effect of these variables on the analyses will need to be evaluated. In addition to these cultural variables, the role of mechanical factors, such as differential preservation, must also be examined.

Measuring Changing Use of Skeletal Elements

With declining overall foraging efficiency, it is also expected that when individual skeletal elements are treated as separate patches, increases in time allocation may be reflected by more intensive use of each skeletal element transported back to the site. Intensification may be in the form of marrow and grease extraction, particularly for large animals such as moas and seals. Marrow and grease extraction require that individual elements be broken. Thus, if these two endeavors are increasing over time, as is expected, then the fragmentation of elements should increase (Broughton 1999).

Fragmentation can be measured by comparing the number of specimens in the sample (NISP) to the minimum number of elements represented by those specimens (MNE) (Grayson 1984*b*; Lyman 1994). In this analysis, MNEs are calculated for the minimum number of whole elements rather than for portions of elements such as MNEs for the distal, proximal, and shaft. To calculate the MNE for elements, the number of times a portion of an element occurred is counted. The portion with the largest count is used as the MNE for that element. For example, if a layer contains 5 proximal ends, 3 shafts, and 4 distal ends of femurs, the MNE for femora in that layer would be five. The ratio of NISP to MNE should increase if fragmentation is increasing due to marrow and grease extraction.

Changing Patterns of Prey Utilization at Shag River Mouth

Changing Use of Moas

As was shown in the previous chapter, inland patch use and overall foraging efficiency decline over time as populations of high-ranked taxa decline. As foraging efficiency declines, the pattern in which individual moas are utilized is expected to change as well. If distance is increasing over time, we would expect that foraging will narrow to mainly high utility elements, i.e., the mean utility of elements per layer will increase. The alternative is that distance to moas is not changing. In this situation, the mean utility is expected to decrease over time as moas are used more intensively.

Since moas are extinct, it is impossible to derive utility indices for them directly. Instead, I have used a utility index developed for kiwis (*Apteryx* spp.), ratite relatives of moas that are endemic to New Zealand (Kooyman 1990). Kiwis, while much smaller than moas, are similar in shape. They, like moas, are stocky and have more robust legs compared to other ratites such as ostriches, which tend to have longer, more gracile legs designed for cursorial locomotion. To derive his kiwi utility index, Kooyman (1990) weighed the meat taken from each element of eight kiwi carcasses, then ranked these values and normalized them by setting the top value to 100 and adjusting the remaining values accordingly (Table 5.1).

Using Kooyman's utility data and the relative skeletal abundances of moa specimens in the Shag Mouth assemblage, I calculated the mean utility of elements for each layer. As Figure 5.1 shows, there is a significant increase in mean utility of moa elements over time ($r_s=0.82$, $p=0.02$). High utility elements (femura, tibiotarsi, fibulae, and cervical vertebrae) steadily increase (Figure 5.2), while the relative abundance of elements with

the lowest utility (phalanges, tarsometatarsi, caudal vertebrae) declines over time (Figure 5.3). Thus, the range of elements transported is narrowing from the initial use of both higher and lower utility elements toward a focus on higher return elements later on. This is the pattern expected if the distance traveled to moas is increasing over time.

With the increasing focus of transport on higher utility elements, we should expect that processing is likely to increase as well. The increase in processing of moa carcasses can be seen in the differences in the relative abundance of high and low utility moa elements (Figures 5.2 and 5.3). The relative abundance of the suite of high utility elements steadily increases over time, as is expected. In contrast, the pattern for the group of low utility elements does not decrease constantly, but rises slightly until Layer 6 before declining. This pattern suggests that low utility elements may have been transported as riders with higher utility elements up until Layer 6. Later, processing may have increased so that these low utility elements were removed and thus became less common.

Evidence from the neck region of moas also suggests that field processing of moas is increasing over time. Tracheal rings and cervical vertebrae are both neck elements. But while cervical vertebrae support sizable amounts of meat as evidenced in their high utility value, tracheal rings, the ossified segments of the windpipe, have little to no utility. If field processing is increasing relative to element utility, then we should see a difference in the way these two neck elements are represented over time. Indeed, the relative abundance of tracheal rings at the site decreases significantly over time while cervical vertebrae remain relatively constant (Figure 5.4). The decline in tracheal ring abundance suggests that off-site processing of moas is increasing to create easily transportable packages, and thus maximize returns for distant sites.

The evidence of increased processing and the narrowing of the range of elements to higher utility elements suggest foragers became more selective about what they were transporting. The increasing selectivity may be linked to increasing travel costs as more distant hunting grounds are used. Initially, local populations of moas were exploited and a broad range of high and low utility elements were brought back to the site. As local populations dwindled and people traveled farther to obtain moas, the cost of transporting moa remains back to the site increased. Processing of carcasses to remove low utility elements increased, with mainly high utility elements transported to the site.

These interpretations must remain tentative until the effects of bone density are assessed. Taphonomic factors, in particular bone density, have been shown to influence skeletal part frequency (Lyman 1994). Elements of low density are less likely to preserve than high density elements (Lyman 1984, 1994). If bone density and element utility are correlated, then the narrowing to mostly high utility elements may be just as likely due to differential destruction of low density bones in the upper layers as it is to changing transport decisions. Currently, there are no bone density data for ratites, or for birds in general, that could be used to test the role of density in structuring the moa assemblage. Lacking these data, I have not explored this issue.

Changing Use of Moa Elements

With declining moa populations, the MVT predicts that the moa elements transported back to the site may be used more intensively. One manifestation of intensification would be an increase of marrow and grease extraction, which would result in a higher rate of bone breakage. In general, long bones are the best elements from which to extract both marrow and grease, thus only moa leg elements are examined for this analysis. To

determine if moa leg elements were being used more intensively, the ratio of NISP to MNE is used as a measure of fragmentation. An increase in fragmentation should be represented by a corresponding increase in the NISP:MNE ratio.

As Figure 5.5 shows, fragmentation increases, though not significantly ($X^2_{\text{trend}}=0.74$, $p=0.39$). Based on his analysis of fracture frequency data from the Shag Mouth assemblage, Kooyman (1996) suggests that only tibiotarsi were regularly broken for marrow extraction. In fact, the fragmentation rates of moa bones do appear to vary across elements. The ratio of NISP to MNE for tibiotarsi increases slightly (Figure 5.6), while fragmentation rates of the other leg elements remain relatively unchanged (Figure 5.7). It appears that the slight increase in fragmentation rates of moa long bones seen in Figure 5.5 is driven mainly by the tibiotarsi data.

The increase in tibiotarsi fragmentation may indicate that marrow and/or grease were extracted from only this element as Kooyman has suggested. Tibiotarsi are as wide or wider, and longer than other leg elements, and thus they would have larger marrow cavities. The differential fragmentation across leg elements may indicate that the decline in foraging efficiency was not large enough to motivate significant effort into extracting resources like grease and marrow across all elements, but only from the one element that contains a significant amount of marrow.

The apparent pattern of differential fragmentation, however, may also be due to other factors, such as differential identifiability, differential preservation, or the tool utility of particular elements. For example, differential identifiability across elements may cause some skeletal elements to be underrepresented, which would affect the NISP to MNE ratio. The bone structure of tibiotarsi is distinctive, and fragments are identifiable even when the pieces are small. Other leg elements, however, are more difficult to

differentiate unless the fragments are relatively large. Thus, fragmentation may be increasing across all elements, but the increased fragmentation may be causing a significant decline in the identifiability of fragments for all elements but tibiotarsi.

If identifiability of elements is decreasing, then we may expect an increase in the proportion of specimens that could only be identified as coming from an unspecified leg element. Indeed, the relative abundance of specimens identified to 'leg' increases significantly over time (Figure 5.8), indicating that fewer fragments are identified to specific elements. This trend is not correlated with sample size ($r_s=0.42$, $p=0.27$). Since identifiability appears to be decreasing over time, the NISP:MNE ratios for the later layers, especially for elements other than tibiotarsi, may be underestimated.

As discussed above, differential preservation due to factors such as bone density can also affect skeletal element representation. Tibiotarsi appear to be denser than either femora or tarsometatarsi, thus it is expected that they should preserve better. If there are differences in bone density and preservation conditions are changing over time to favor more robust elements, then the relative abundance of the less dense leg elements may be underrepresented. Thus, the fragmentation rate of the other leg elements may be similar, but because they are underrepresented due to differential preservation conditions, this pattern is not apparent. A bone density study is required to assess this possibility, but, as noted earlier, the relevant data are unavailable.

The difference in bone breakage patterns across elements may also be due to the value of the element as a raw material for tools rather than its nutritional value (Sharp 1989). If this is the case, then the nature of the artifacts created from moa elements will dictate the amount of bone breakage. Moa tibiotarsi were often used as raw material for fishhooks and other artifacts. The medial-anterior surface of the bone is large, flat and

very thick, from which large, durable artifacts could be made. The increase in tibiotarsi fragmentation relative to other leg elements may indicate that tibiotarsi were being used more intensively for tools. Intensification may be related to changes in the size of fishhooks made from this element.

One-piece fishhooks required larger pieces of raw material than composite fishhooks. With composite fishhooks and lures, smaller pieces of bone are used. The shanks of the composite fishhooks were made of wood or shell, with only the point being made of bone. Thus, more fishhooks could be made from each piece of bone. If the increase in tibiotarsus fragmentation is a product of more intensive fishhook manufacture, particularly smaller fishhooks, then we can expect that the frequency of two-piece fishhooks to increase relative to one-piece fishhooks.

Over time, there is a shift in the type of fishhooks made from bone (Table 5.2). Early on, the one piece fishhooks were common at the Shag Mouth site, as they were across southern New Zealand, while two piece fishhooks and lures occur later (Hjarno 1967; Anderson and Gumbley 1996). Unfortunately, information on moa bone breakage due specifically to fishhook manufacture is unavailable from published sources. Additional research on the changes in the frequency of fishhook manufacturing traits such as cut marks, drill holes, tabs, and cores will be required to determine if tool utility is affecting moa bone breakage patterns.

Thus, there remain several possible explanations for the fragmentation pattern of moa elements at Shag River Mouth. First, foraging efficiency did not decline sufficiently to warrant the more intensive use of all elements through marrow and grease extraction. Instead, only tibiotarsi may have been targeted for marrow extraction because of the relatively large marrow cavity.

An alternative explanation is that the pattern of increasing fragmentation for tibiotarsi was due to its value in the manufacture of tools rather than its nutritional value. If tibiotarsus fragmentation is due to tool utility, then marrow or grease extraction for any of the leg elements did not have increase over time. To fully evaluate this possibility, a study of the moa bone fragments used in tool manufacture is required.

Another possibility is that foragers may have been using all elements more intensively, but differential identifiability is obscuring the pattern in the data. Tibiotarsi might show a pattern of increasing fragmentation because even small fragments can be readily identified. Fragmentation may be increasing in the other elements as well, but because larger pieces are required to identify bone fragments to those elements, the other leg elements may be underrepresented. Thus, fragmentation of all leg bones for the extraction of marrow and grease may be increasing, but differential identifiability is masking this pattern.

Finally, differential preservation due to bone density differences may have led to an underrepresentation of some elements, which would result in the same pattern I have documented for the Shag River Mouth faunas. Until bone density data are available for birds in general, and ratites, in particular, this remains an untested hypothesis.

Changing Use of Otariids

As with the moa data, it is possible to determine if seal use is changing over time by comparing the relative skeletal abundances of otariids in the Shag Mouth assemblage to utility indices for otariids. Savelle *et al.* (1996) created an otariid meat utility index for individual elements (%MUI), as well as a modified meat utility index (%MMUI) for elements transported as packages (Table 5.3). Since it is not known how otariids were

processed prehistorically in southern New Zealand, I tested the expectations of the models with both measures of utility.

Again, the expectations are that mean utility will increase or decrease depending on the nature of changes in the travel costs. An increase in mean utility is expected if distance to otariids is increasing over time. If transport costs are not changing significantly, then a decrease in mean utility is predicted.

Figure 5.9 and 5.10 show mean utility for otariid skeletal elements by layer. Otariid utility declines over time. The relationship is significant at $p=0.07$ for %MUI and $p=0.05$ for %MMUI. The proportion of ribs, the element with the highest utility, decreases over time (Figure 5.11). While high utility elements declined, lower utility elements, such as metapodials and phalanges, increased (Figure 5.12). One notable exception is the low proportion of metapodials and phalanges in Layer 4. This may be linked to a higher rate of fragmentation than other layers, which is discussed in the next section. The changes in the proportion of the low or high utility elements is not statistically significant. In general, however, it appears that the range of elements returned to the site expands over time. The increasing importance of lower return elements suggests that the cost of traveling to exploit otariids did not significantly increase. Instead, exploitation of otariids became more intensive over time.

As discussed above, differential preservation can play a role in structuring skeletal element representation (Lyman 1984, 1994). It is possible that the apparently narrow pattern of elemental transport in the lower layers is an artifact of preservation, where only the densest elements (i.e., those that are least affected by taphonomic factors) are represented. If bone density is a factor in elemental abundance, then density should covary with a measure of elemental survivorship.

In contrast to the lack of bone density data for moas, limited density studies have been conducted on pinnipeds. To determine if differential preservation is influencing the pattern of elemental abundances, bone density values derived for phocids (Table 5.4; Chambers 1992) were compared to otariid elemental survivorship. Phocids differ structurally from otariids in that they are typically larger and use a different form of terrestrial locomotion. Research has shown that body size and patterns of locomotion can affect bone density values for taxa such as artiodactyls (Kreutzer 1992*a*, 1992*b*). However, no bone density studies have been conducted on otariid skeletons. As a result, I assume that at the ordinal level, phocid bone density values are appropriate for this analysis.

To determine if bone density may be influencing the relative abundance of elements in the Shag Mouth assemblage, a measure of elemental survivorship is compared to bone density values for each element. Survivorship for each layer was determined by comparing the observed to the expected elemental representation (Lyman 1994). The expected number of elements was calculated by taking the number of times an element occurs in the body and multiplying it by the minimum number of individuals (MNI) represented in the layer. Percent survivorship is the number of observed over expected multiplied by 100. Spearman's rank order correlation is used to test the relationship between bone density and percent survivorship for each layer. If the two variables are not correlated, then it is likely that the patterns in the utility data are not due to differential preservation. The results of this analysis are listed in Table 5.5. Bone density is not correlated with percent survivorship of elements in any layer. Thus, differential preservation does not appear to be affecting relative skeletal abundances of seals.

The increase in the range of elements transported back to the site indicates that increasing transport costs are not a factor in transport decisions. Instead, it appears that unlike for moas, the use of seals is becoming more intensive. More of each individual seal is being returned to the site as overall foraging efficiency declines. Since transport costs do not appear to be a factor, it is possible that foragers are exploiting seals from local colonies, and possibly rookeries, throughout the occupation of the site. Thus, the changing pattern of otariid skeletal elements may reflect the effects of a declining local population that has been constantly harvested over many years.

An alternative explanation is that transport costs are not increasing because of the use of efficient transport mechanisms such as canoes. In this case, foragers may be harvesting local as well as distant populations of fur seals, but the use of canoes may have kept transport costs relatively low. Canoes are commonly used for short trips and extended voyages in New Zealand and across Polynesia (Best 1925). The rise in importance of the offshore patch during the latter part of the Shag Mouth occupation demonstrates that canoes were important for obtaining resources. Smith (1996*b*) suggests that because the fur seal assemblage is dominated by juveniles and subadult males, non-breeding colonies were being harvested. However, he also acknowledges that the few pup specimens suggest that a rookery was exploited, although this is thought to be non-local. Unfortunately, since it is difficult to differentiate between the exploitation of local and distant colonies, either explanation is possible.

Fur seals are likely to return to the same rookery year after year, even with increasing predation pressure (King 1983). For foragers, fur seals are predictable resources both spatially and temporally. Anderson and Smith (1996*d*) suggest that prehistoric settlements in southern New Zealand were often built near fur seal rookeries because of

this resource predictability. Foragers who settled near fur seal rookeries would have easy access to a high return resource year after year until the rookery eventually was abandoned.

In sum, the expanding range of transported otariid elements over time suggests that otariid use is intensifying due to declines in their population. Differential preservation does not appear to be a mediating factor in this pattern. It is likely that changes in transport costs were not a factor in otariid use. It is unknown, however, whether only local populations were exploited or if an efficient transport vehicle such as canoes was used to exploit populations up and down the coast.

Changing Use of Otariid Elements

With the decline in otariid populations, otariid elements may have been used more intensively through such activities as marrow and grease extraction. Marrow and grease fragmentation should result in a higher rate of elemental fragmentation. To determine if otariid leg elements were being used more intensively, the ratio of NISP to MNE was used as a measure of fragmentation. Both fore- and hind-limb long bones are examined.

As with moas, an increase in fragmentation should be represented by a corresponding increase in the NISP to MNE ratio. It is also expected that individual elements will be used more intensively as otariids become less abundant. If grease and marrow extraction increases over time, then long bone fragmentation is expected to increase correspondingly.

As Figure 5.13 shows, fragmentation of otariid long bones does not increase significantly over time at Shag River Mouth. Rather, the NISP:MNE ratio remains fairly constant, with the exception of Layer 4. The otariid skeletal elements returned to the site

do not appear to be used more intensively over time. Thus, it is likely that the foraging efficiency did not decline sufficiently to motivate more intensive use of seal elements.

Summary

With declining foraging efficiency at Shag Mouth, we see two patterns of prey use emerge. Moa use initially encompasses a broad range of low and high utility elements. Over time, as moa populations dwindle, field processing appears to increase and a narrower range of elements, those with higher nutritional value, is transported back to the site. Thus, it appears that transport decisions are changing due to increasing distance traveled to find moas as local populations decline.

With the decline in moa populations and thus in foraging efficiency, it was expected that the elements returned to the site would be used more intensively through such activities as marrow and grease extraction. However, the analysis produced ambiguous results that resulted in four possible explanations, only one of which supported the expectations. Each of the possibilities requires further research to determine if elemental use is intensifying over time.

Within the coastal patch, the pattern of seal use is the opposite of that seen for moas. Early on, the seal elements transported to the site are mainly of higher utility. Over time, the range of elements broadens to include both high and low utility elements. The broadening in the utility of elements transported suggests that distance may not be a factor in transport decisions. Instead, as seal abundances and foraging efficiency decline, the use of local seal populations became more intensive, i.e., more of each individual was returned to the site over time. Although seal populations were declining, the drop in

foraging efficiency does not appear to have been significant enough for individual elements to be used more intensively through such endeavors as marrow and grease extraction.

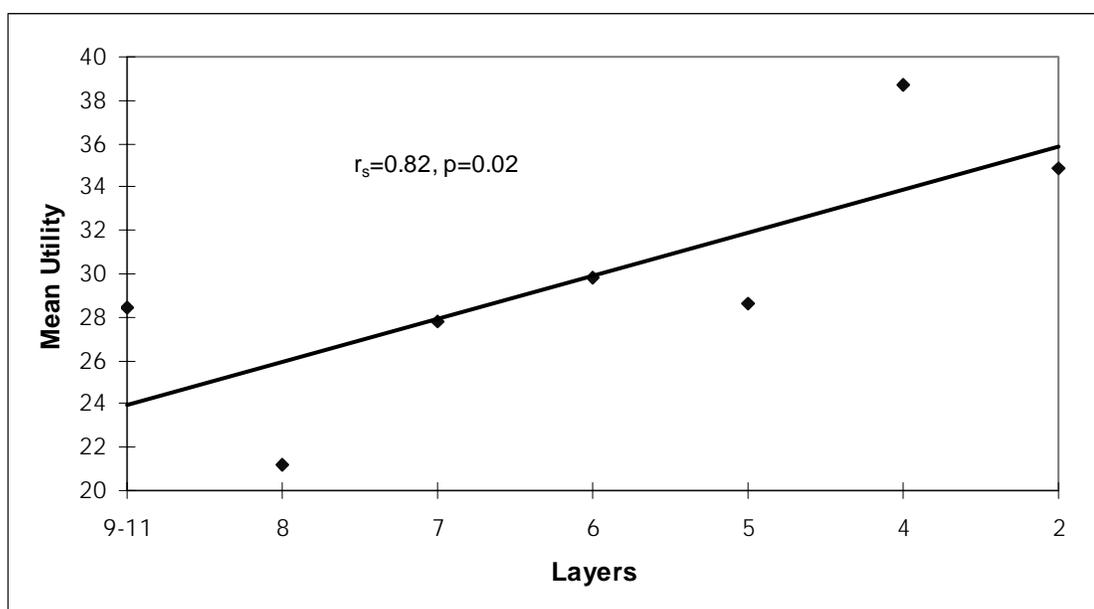


Figure 5.1. Mean moa utility across layers.

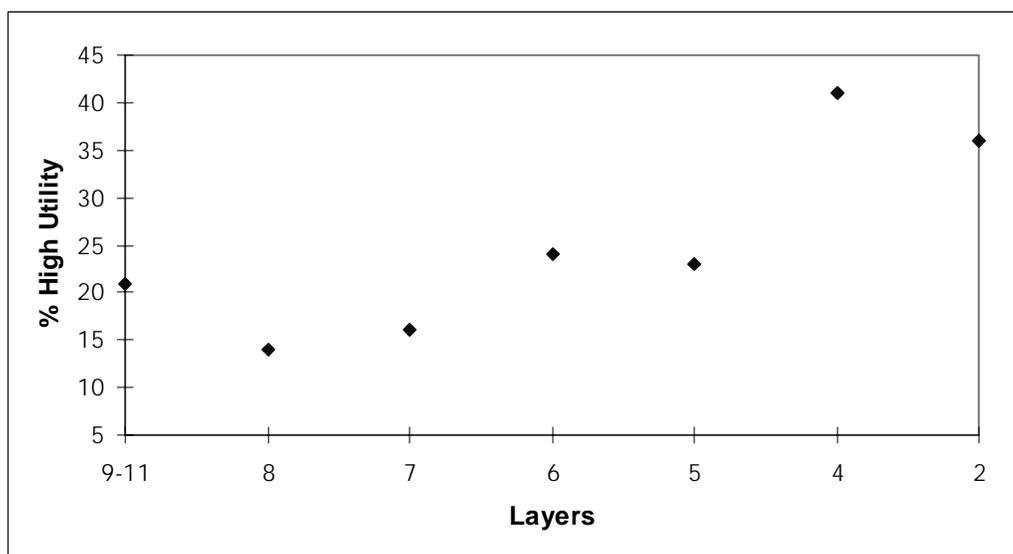


Figure 5.2. Relative frequency of high utility elements (femura, tibiotarsi, fibulae, cervical vertebrae) across layers.

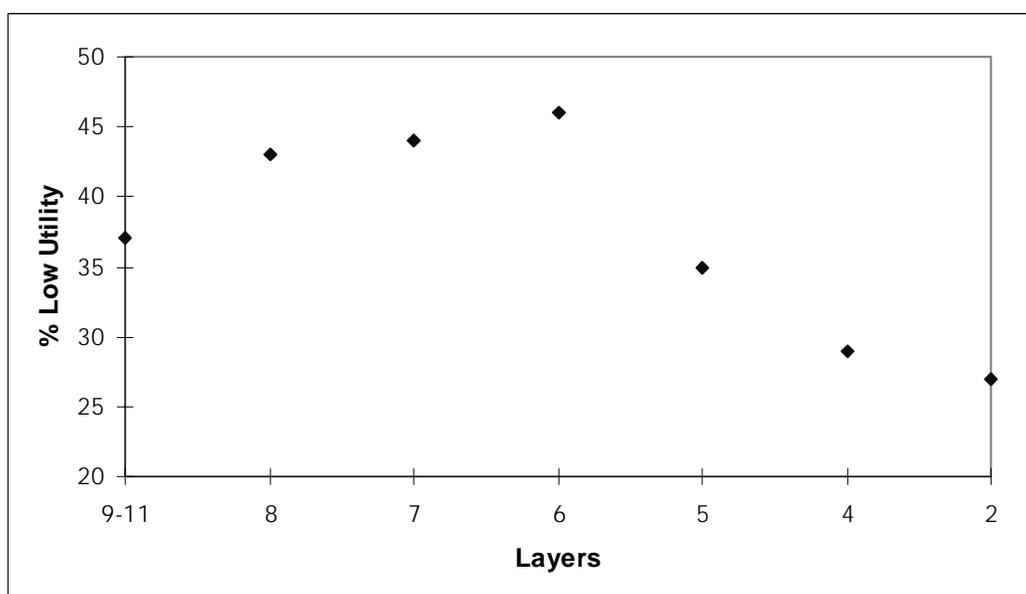


Figure 5.3. Relative frequency of low utility elements (phalanges, tarsometatarsi, caudal vertebrae) across layers.

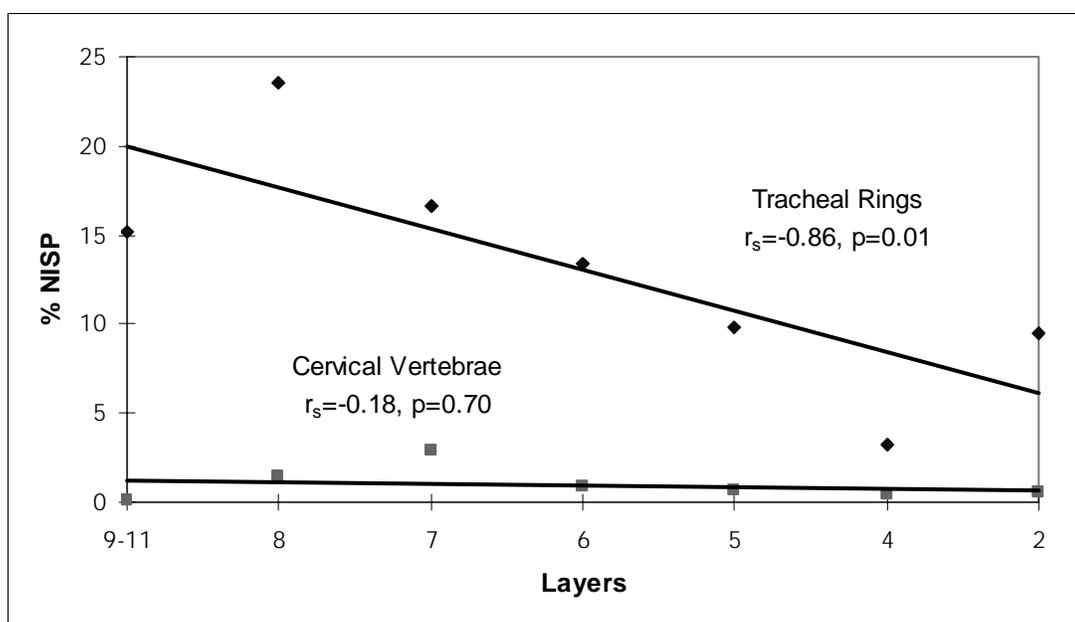


Figure 5.4. Relative frequency of moa cervical vertebrae and tracheal rings across layers.

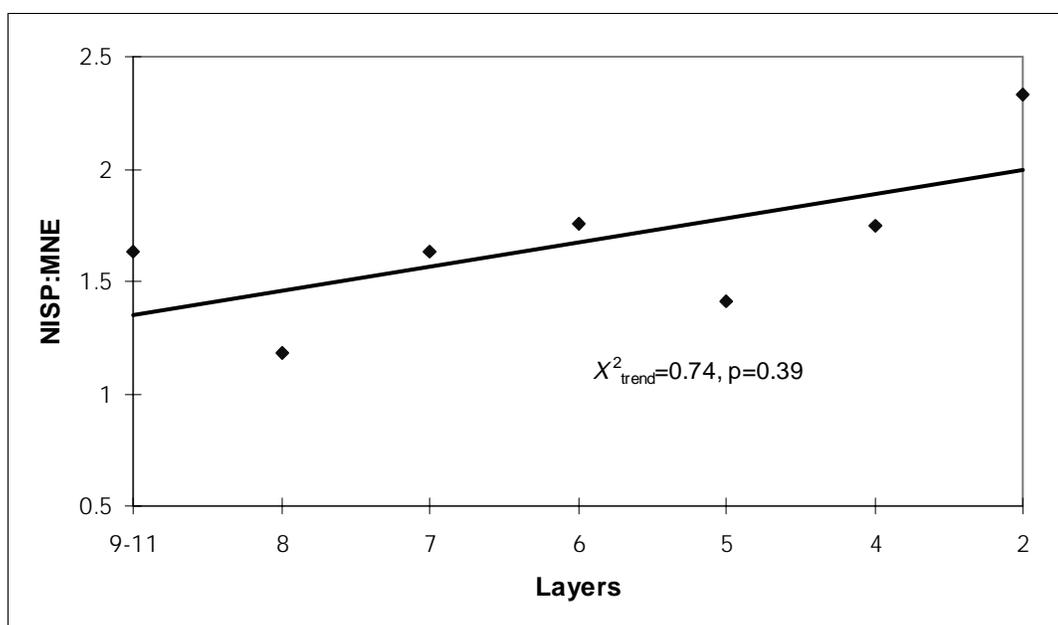


Figure 5.5. Moa bone fragmentation across layers.

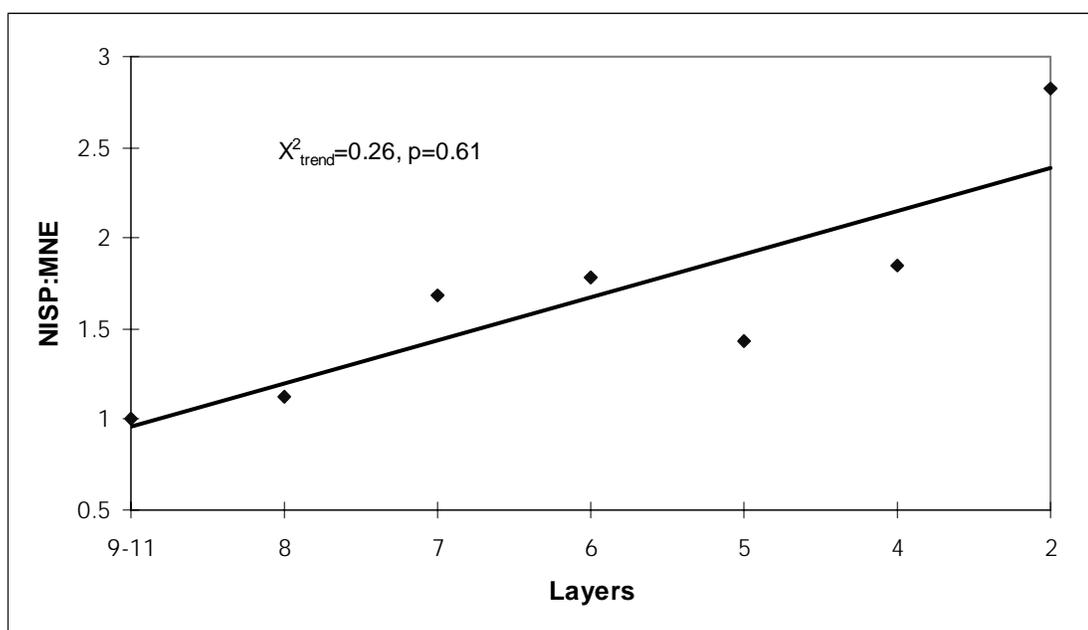


Figure 5.6. Fragmentation of moa tibiotarsi across layers.

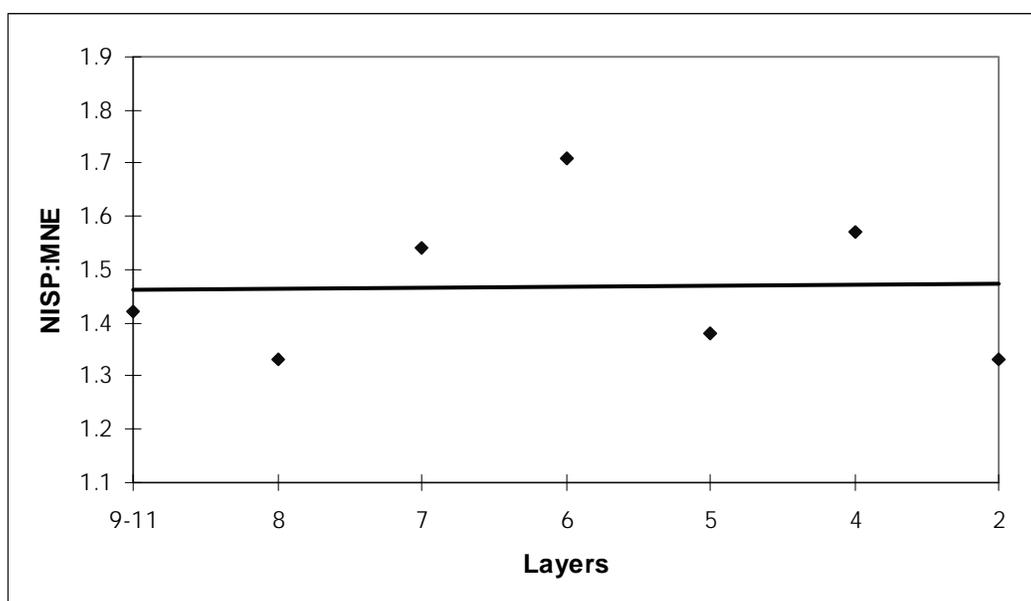


Figure 5.7. Fragmentation of moa leg elements, excluding tibiotarsi, across layers.

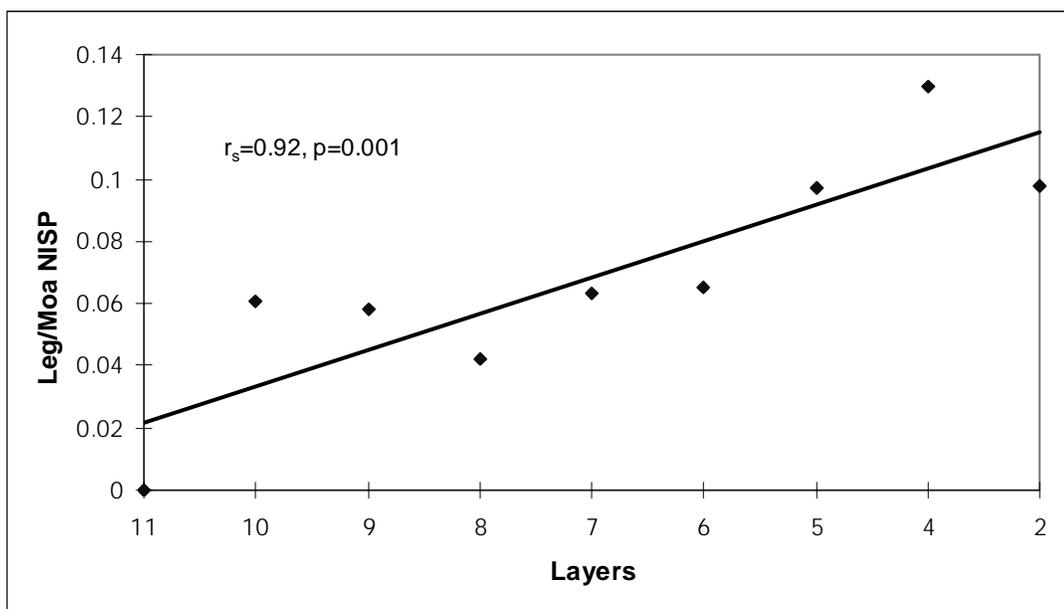


Figure 5.8. Relative abundance moa specimens identified as leg elements.

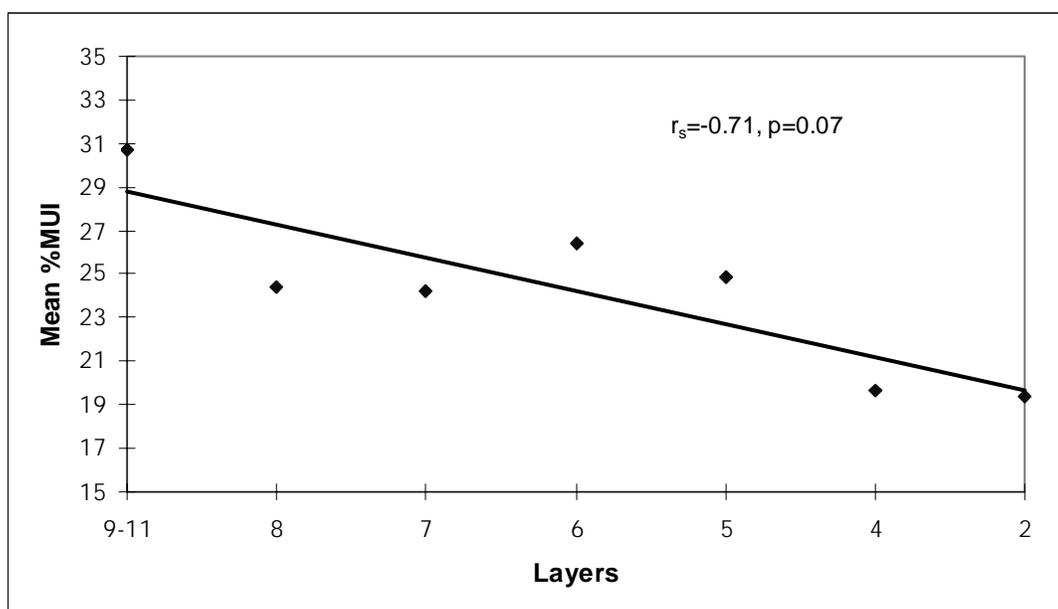


Figure 5.9. Otariidae mean utility (%MUI) across layers.

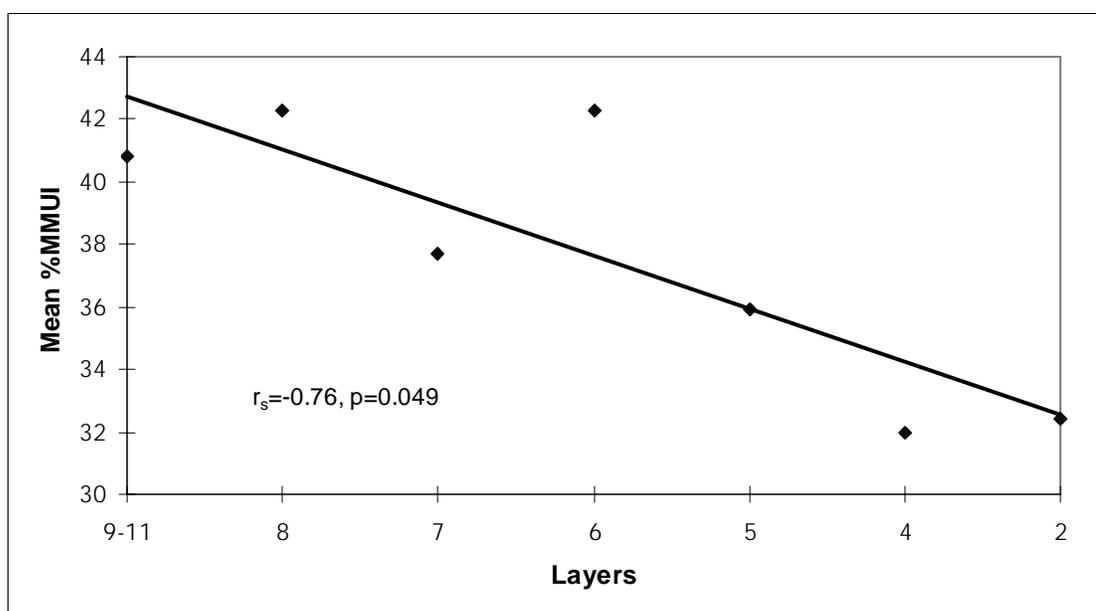


Figure 5.10. Otariidae mean utility (%MMUI) across layers.

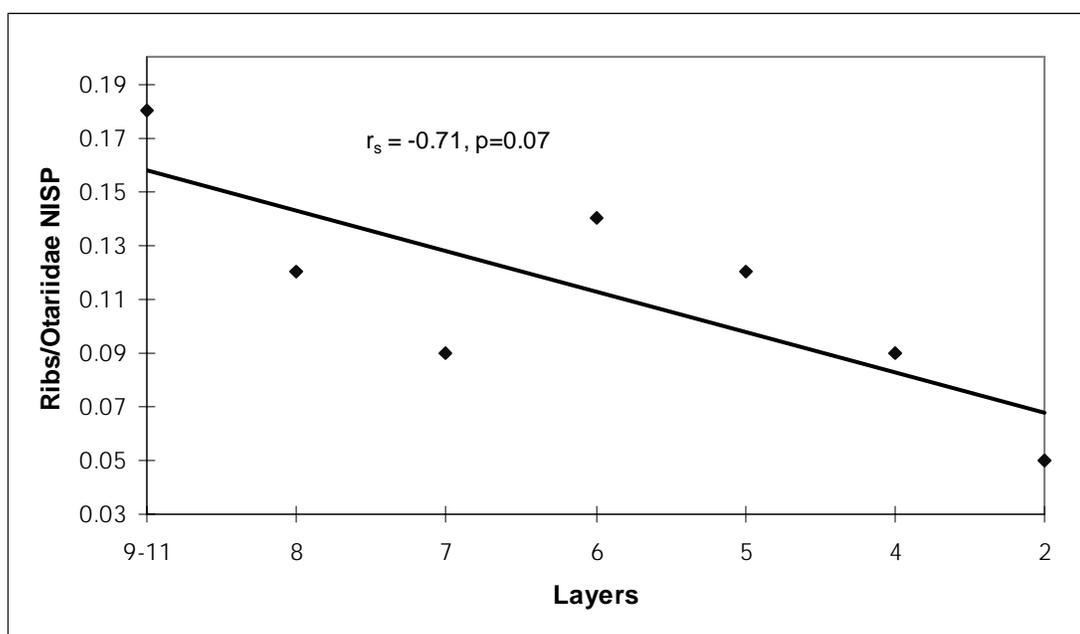


Figure 5.11. Relative abundance of a high utility otariid element (ribs) by layer.

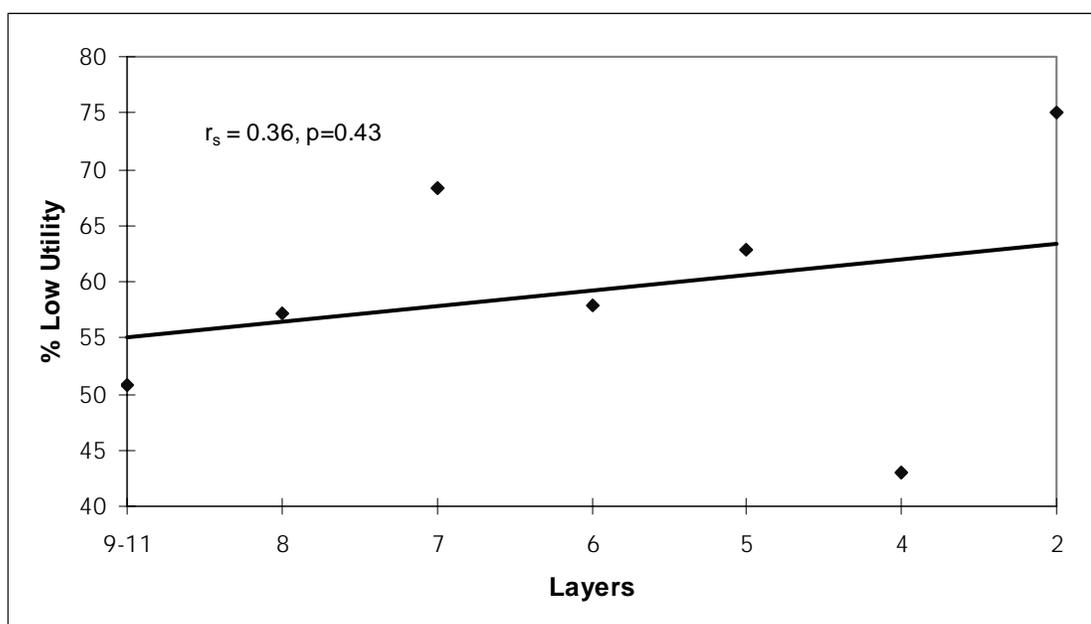


Figure 5.12. Relative abundance of low utility otariid elements (phalanges, metapodials) by layer.

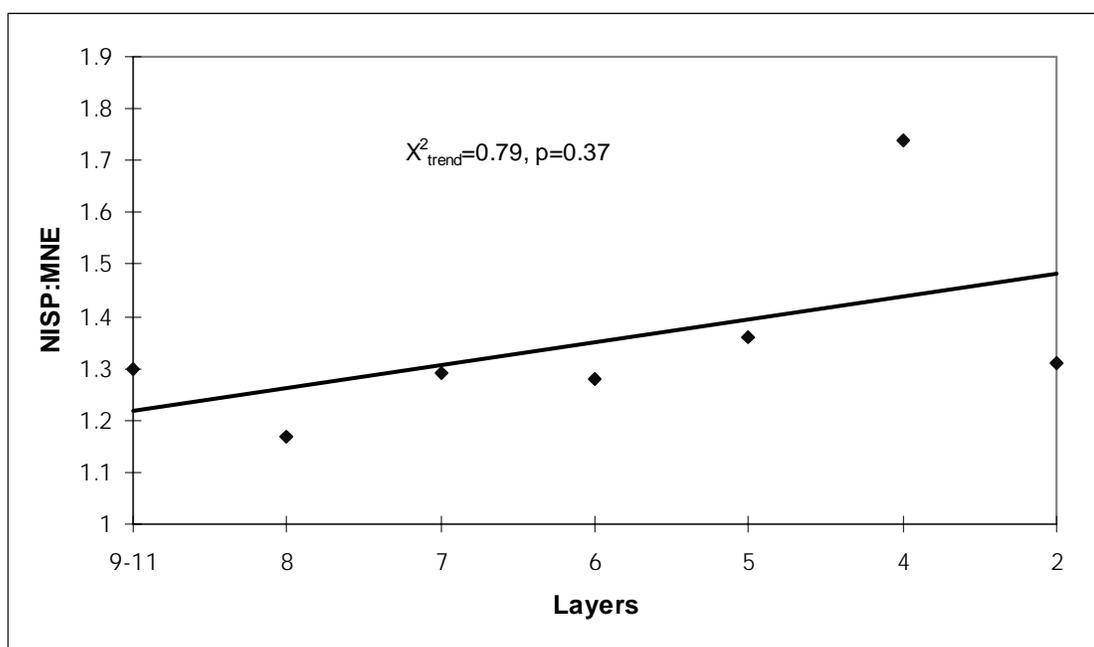


Figure 5.13. Otariid skeletal element fragmentation by layer.

Table 5.1. Utility index for kiwis (from Kooyman 1990).

Anatomical Portion	Meat Utility
Skull	3
Quadrate	3
Mandible	3
Atlas	80
Axis	80
Cervical	80
Thoracic	13
Rib	18
Sternal Rib	18
Sternum	7
Pelvis	28
Femur	100
Tibiotarsus	53
Fibula	53
Tarsometatarsus	1
Phlanges	0

Table 5.2. The relative abundance of fishhooks and lures from the Shag Mouth site.

Layer	N	Barracouta Lure	Minnow Lure	Two-Piece Fishhook	One-Piece Fishhook
2	16	18.8	6.3	18.8	56.3
4	36	11.1	5.6	13.9	69.4
5	8			12.5	87.5
6	1				100.0
7	1				100.0
8	1				100.0
9	1				100.0

Table 5.3. Utility indices for otariid seals (from Savelle *et al.* 1996).

Anatomical Portion	% MUI	%MMUI
Head	30.7	62.8
Cervical	94.8	94.8
Thoracic	22.0	97.4
Lumbar	13.8	21.7
Pelvis, sacrum, caudal	21.4	21.4
Rib	100.0	100.0
Scapula	9.2	54.6
Sternum	28.6	64.3
Humerus	15.8	22.2
Radius/ulna	11.5	13.6
Front flipper	3.4	7.5
Femur	3.9	13.9
Tibia/fibula	6.4	6.4
Rear flipper	3.2	4.8

Table 5.4. Bone density values for phocid seals (from Chambers 1992).

Element	Scan Site	Density
Mandible	DN2	0.84
Atlas	AT1	0.54
Axis	AX1	0.56
Thoracic	TH1	0.34
Lumbar	LU1	0.38
Sacrum	SC1	0.43
Scapula	SP1	0.49
Humerus, proximal	HU1	0.43
Humerus, distal	HU5	0.60
Ulna, proximal	UL1	0.44
Ulna, distal	UL4	0.79
Radius, proximal	RA1	0.63
Radius, distal	RA5	0.45
Innominate	AC1	0.47
Femur, proximal	FE1	0.50
Femur, distal	FE6	0.57
Tibia, proximal	TI/FI1	0.39
Tibia, distal	TI5	0.48
Fibula, proximal	TI/FI1	0.39
Fibula, distal	FI5	0.76
Calcaneus	CA1	0.45
Astragalus	AS1	0.45

Table 5.5. Results of the Spearman's rank correlation analysis between bone density and % survivorship for otariid elements.

Layer	Correlation Coefficient
2	$r_s=0.21, p=0.36$
4	$r_s =0.27, p=0.23$
5	$r_s =0.15, p=0.50$
6	$r_s =0.26, p=0.25$
7	$r_s =0.25, p=0.27$
8	$r_s =0.08, p=0.74$
9	$r_s =0.10, p=0.67$
10	$r_s =0.04, p=0.87$
11	$r_s =0.15, p=0.51$