Prehistoric seal carcass exploitation at the Shag Mouth site, New Zealand

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Abstract

Seal populations in New Zealand declined dramatically during the prehistoric period. The loss of this important resource significantly affected the foraging practices at the Shag River Mouth site. Previous research documented substantial changes to the diet with the decline of seals and the corresponding decline in foraging efficiency. In this study, I examine how New Zealand foragers altered their use of seal carcasses as the availability of these marine mammals declined. Otariid seal data from the Shag River Mouth site in southern New Zealand are analyzed to test changes in butchery/transport and skeletal element breakage patterns expected with resource depression and declining foraging efficiency. This research shows that at Shag Mouth, seal carcasses were used more intensively over time. However, bone breakage patterns showed little change in the exploitation of within-bone nutrients.
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Keywords: New Zealand; Seals; Foraging theory; Carcass exploitation; Butchery; Transport

1. Introduction

The impact of prehistoric humans on native fauna in New Zealand is well documented. The arrival of human colonizers about 800 years ago led to decline in population abundances and/or a reduction in geographic distribution of many fauna through predation by human and introduced mammals, as well as habitat alteration [1,27,41,42]. My previous research on the Shag Mouth fauna has documented how this change in the availability of faunal resources impacted human subsistence practices in southern New Zealand. Using foraging theory to model change, I found that dietary changes were linked to declines in abundances of large-bodied taxa such as seals and the extinct moas [31,32]. As the populations of these taxa were reduced due to human predation pressure, human foragers expanded their diet to include a wider range of vertebrate resources. In addition, animals smaller in size, and thus lower

in net caloric returns, comprised a larger proportion of the diet, resulting in an overall decline in foraging efficiency.

With the decline in availability of moas and seals, human decision making in regards to transporting and processing the carcasses of these large animal is likely to have changed. Indeed, my analysis of moa carcass exploitation demonstrates that foragers had to journey farther over time to hunt moas, and as a result of the increased travel costs, the range of body parts transported became restricted to mainly high utility elements [33]. In addition, moa elements that were transported back to the site were used more intensively over time for marrow and possibly grease extraction. Moa carcass exploitation strategy is clearly linked to a decline in foraging efficiency through time. Like moas, the exploitation of seal carcasses is also expected to change over time as foraging efficiency declined.

As one of the largest vertebrate resources in New Zealand, seals were also commonly exploited by human foragers. Because of prehistoric human predation pressure, seal populations, particularly New Zealand fur seals (*Arctocephalus forsterii*), declined dramatically and their geographic range became constricted [41,42]. When people arrived in New Zealand 800–1000 years ago, fur seals could be found across New

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Zealand, and were common in archaeological middens dating to this early period [40,41]. But by about AD 1500, fur seals disappeared from North Island archaeological sites. On the east coast of the South Island, breeding colonies were replaced by non-breeding colonies during late prehistoric times about AD 1500–1700 [41,42]. By European contact, fur seals were found only along the south and west coasts of the South Island where prehistoric human presence was limited.

Patch choice models predict that given the general decline in the availability of seals across New Zealand and the corresponding decrease in overall foraging efficiency at the Shag Mouth site, the intensity with which seals were exploited is expected to have changed over time. Specifically, carcass exploitation and bone fragmentation patterns should change. These expectations are tested here using the otariid seal assemblage from the Shag River Mouth site.

The Shag River Mouth site is located on the east coast of the South Island (Fig. 1). As the name implies the site lies at the mouth of the Shag River as the river flows into the Pacific Ocean. The extent of the site is about 30,000 m^2. Over the last 125 years, several areas of this expanse have been excavated. The material used in this analysis comes from the 1986 Dune excavation, for which an 8 m by 10 m unit was excavated [2].

The Dune excavation is one of the best stratified and best dated excavations in New Zealand. Nine cultural layers (layers 2, 4–11) were excavated to a depth of 2.5–4.0 m. Over 30 radiocarbon dates produced a sequence that spanned the early period of occupation in New Zealand (AD 1250–1450) [4]. The site is also important because it contained habitation features that were the best example of a prehistoric permanent village in the region [3].

In terms of zooarchaeological material, the excavation produced a large sample of vertebrate faunal remains with over 26,000 identified specimens representing 75 species of fish, bird, and mammal [30], as well as a large molluscan assemblage [18]. Two otariid seal species (New Zealand fur seal (*Arctocephalus forsteri*) and Hooker's sea lion (*Phocarctos hookeri*)), and one phocid seal (elephant seal (*Mirounga leonina*)), are represented at the site (Table 1). This study focuses on the otariid seals, because they comprise the vast majority of the seal assemblage.

In the Shag Mouth assemblage, New Zealand fur seals (*Arctocephalus forsteri*) are the most abundant mammal and the third most common vertebrate. Hooker's sea lions (*Phocarctos hookeri*) are much less abundant in the assemblage, but are found throughout the occupation of the site (Table 1). Many of the specimens that could be identified only as "otariid" were from juveniles. The diagnostic features that are used to differentiate sea lions from fur seals are not fully developed in younger individuals making it difficult to distinguish between species.

Overall, the Shag Mouth faunal material was well preserved (Table 2). Very few seal bones showed signs of weathering. Less than 8% of the otariid seal remains displayed evidence of carnivore damage. And a little more than one-fourth of the specimens showed signs of burning, much of which consisted of light burning on only part of the bone. Given that the Shag Mouth faunal assemblage provides a large well-preserved sample from a well-stratified site, it is ideal to test expectations about carcass exploitation. Hypotheses about these changes can be derived from foraging theory, in particular patch choice models.

2. Changing carcass exploitation of seals

Patch choice models such as the marginal value theorem (MVT) [14] or central place foraging models [34,38] have
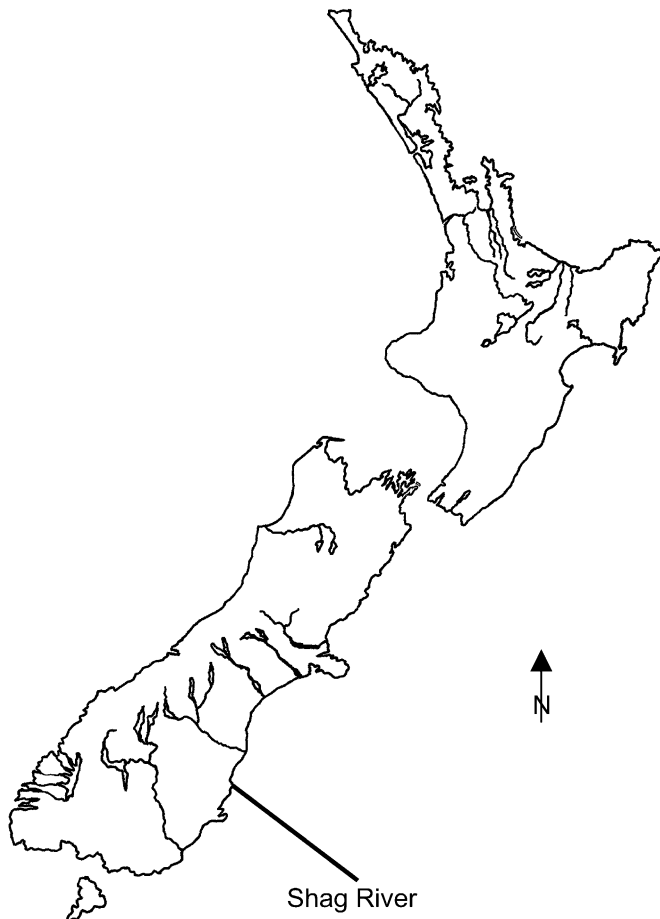
Fig. 1. Location of the Shag River mouth site, New Zealand.

Table 1

Number of identified specimens (NISP) of otariid seal by layer

Taxon	Layers									Total
	2	4	5	6	7	8	9	10	11	
Otariidae (eared seals)	19	31	46	52	71	17	24	2	10	272
Arctocephalus forsterii (NZ fur seal)	136	144	305	301	504	95	92	24	25	1626
Phocarctos hookeri (Hookers sea lion)		2	2	3		3	6	8	4	28
cf. *Phocarctos hookeri*		1			2			1	1	5
Total	155	178	353	356	577	115	122	35	40	1931

Table 2
Proportion of otariid specimens that showed evidence of burning, carnivore damage, and weathering

	2	4	5	6	7	8	9	10	11	Average
Burning	21.0	51.7	14.9	22.9	12.8	17.3	13.6	11.8	5.1	19.0
Carnivore gnawing	4.2	0.6	6.3	10.6	6.2	6.4	14.6	8.8	12.5	7.8
Weathering	0.7	0.0	0.6	1.8	0.2	0.9	1.9	0.0	2.5	1.0

typically been the foraging theory models used to test hypotheses about prehistoric carcass exploitation (e.g., [6,32]). However, each of these models has its drawbacks when applied to human foragers. Humans typically hunt from a central place or home base, and often process carcasses of large animals before transport. The MVT does not take into account foraging from a home base where additional costs are incurred from transporting carcasses back to a central place. While central place foraging models incorporate transport costs, these models do not include the costs of field processing carcasses. Recently, Cannon [12] created an archaeological foraging model to deal with these unique aspects of human foraging that are not accounted for in previous models. Cannon modified Orians and Pearson's [34] central place foraging model by adding a component on transport and processing decisions that is derived from Metcalfe and Barlowe's [28] archaeological research. In Orians and Pearson's model, foragers are assumed to maximize their net return rate. Cannon expanded the definition of net return rate to not only include handling and transport costs, but also processing costs, and calls the revised net return rate, the delivery rate. Thus, under Cannon's model foragers are expected to maximize the delivery rate.

Within this model, a distinction is drawn between butchering that is associated with handling costs and butchering considered as processing costs. The time required to transform the carcass into a load that can be carried is considered to be part of the handling costs. However, the processing costs include any extra butchering, such as the removal of riders, that maximizes the utility of the elements transported. It is assumed that handling costs should be relatively constant across prey of the same species and size. Thus, changes in butchering practices should be related to processing costs.

The amount of time a forager spends butchering, in particular processing a carcass, is affected by both transport distance and prey encounter rate. If prey encounter rates decrease, but transport distance remains unchanged, then field processing of prey may decline [14]. Instead, each individual carcass should be exploited more intensively so that a broader range of elements are returned. However, if foragers deplete resources such that transport distance increases with declining prey encounter rates [16], then processing may increase. Foragers will maximize the delivery rate by processing the carcass so that the utility per load transported back to the central place is high [12].

To determine if the delivery rate of transported elements changed over time, the mean utility or average returns per element for a given sample is examined [6,33]. Element frequencies are calculated by counting the number of elements present and dividing by the number of times the element occurs in the body. The utility for each element is then multiplied by the element frequency. The total utility across all elements is summed and then divided by the total element frequency to obtain the mean utility. 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 sample will be lower. Thus, if travel costs increased, mean utility of the elements transported should increase over time as foragers maximized their delivery rate. If travel costs did not significantly increase, then mean utility should decrease as foragers intensified their use of seal carcasses.

3. Changing bone fragmentation patterns of seals

In addition to changes in delivery rate, if foraging efficiency declined significantly, foragers may have also tried to extract more calories from skeletal elements transported back to the site through activities such as marrow and grease extraction. To model decisions made about the extraction of within-bone nutrients, the Marginal Value Theorem is used. This model examines the amount of time allocated to resource exploitation. As foraging efficiency declines, it is expected that foragers will spend more time extracting resources from within a patch. If each skeletal element is regarded as a patch, then the MVT predicts that more time will be spent extracting resources, such as within-bone nutrients, from skeletal elements as foraging efficiency declines. In other words, the exploitation of skeletal elements will intensify.

Unlike terrestrial mammals, however, the distribution of within-bone nutrients differs for seals such that bone breakage patterns may be different. The long bones of seals do not have significant amounts of marrow, and the fat that is present in the bones is in the form of oil rather than grease [35]. In addition, seals contain a significant amount of easily accessible subcutaneous fat; over 30% of their body weight can consist of blubber [25,37]. Thus, within-bone nutrients of seal bones may have been relatively low-ranked resource compared with that of terrestrial vertebrates. Foraging efficiency would have to decline significantly in order for more intensive exploitation of oil, grease, or marrow from skeletal elements to be profitable. However, if this is the case, then bone fragmentation should increase.

Researchers have used a variety of measures to document fragmentation patterns of skeletal elements. While more detailed analyses on bone fragmentation are possible [36], the goal of this analysis is simply to examine broad changes in element fragmentation across time. Are seal bones more or less fragmented over time? A summary measure such as the ratio of the number of identified specimens to the minimum number of elements (NISP:MNE) is a measure commonly used to document changes in fragmentation patterns associated with the extraction of within-bone nutrients [23,26,29]. Other measures such as the percentage of whole elements (% whole) and the mean percent scan sites have also been used to track changes in fragmentation patterns over time [10,26,43]. All three measures document different aspects of fragmentation. NISP:MNE

measures fragmentation intensity, while % whole measures the extent of fragmentation [22]. Fragmentation intensity refers to the degree to which an element is fragmented, whereas the extent of fragmentation is the proportion of bones in a sample that are broken.

Recently, analysts have begun to record which bone density scan sites are present for each specimen in order to create skeletal elemental frequencies that are directly comparable to the bone density scan sites. Scan site data can also be used as another means of measuring fragmentation intensity. The % scan site for each bone specimen represented is calculated by counting up the number of scan sites present and dividing that number by the total possible number of scan sites for that skeletal element, and multiplying by 100 [11]. Thus, for a skeletal element with five scan sites, if four scan sites are present for a specimen, then 80% of the bone is present. The mean % scan site is then calculated for all specimens within a sample. Thus, mean % scan site is similar to NISP: MNE in that it measures the intensity of fragmentation and is an estimate of fragment size. It differs in that fragmentation is calculated for each element individually and then averaged rather than being estimated at the sample level. Also, the lower end of mean % scan site values is limited by the number of scan sites per element. For example, if there are five scan sites for an element, the smallest fragment can be no smaller than 20%. Thus, NISP:MNE may be better at documenting a high degree of fragmentation. If overall foraging efficiency declined significantly and the exploitation of within-bone nutrient intensified, then there should be an increase in NISP:MNE, and a decrease in % whole and mean % scan site values over time.

4. Otariid transport, processing and breakage patterns at Shag Mouth

To determine if seal butchery and transport patterns change over time, mean utility for otariids is calculated. Savelle et al. [37] created an otariid meat utility index for individual elements (%MUI), as well as a modified meat utility index (%MMUI) for elements transported as a package. Since it is not known how otariids were processed prehistorically in southern New Zealand, I tested the expectations of the models using both measures of utility. Again, the expectations are that mean utility will increase or decrease depending on the nature of changes in travel costs. An increase in mean utility is expected if distance to otariids increased over time. If transport costs did not change significantly, then a decrease in mean utility is predicted.

Figs. 2 and 3 show mean utility for otariid skeletal elements by layer. In both plots, otariid mean utility declines over time. The relationship is significant at $p = 0.07$ when skeletal elements are treated individually (%MUI), and at $p = 0.05$ for the utility adjusted for riders (%MMUI). This shift in utility can also be seen in plots of proportions of high utility and low utility elements. The relative abundance of ribs, the element with the highest utility, decreased over time (Fig. 4). While the proportion of high utility elements declined, lower
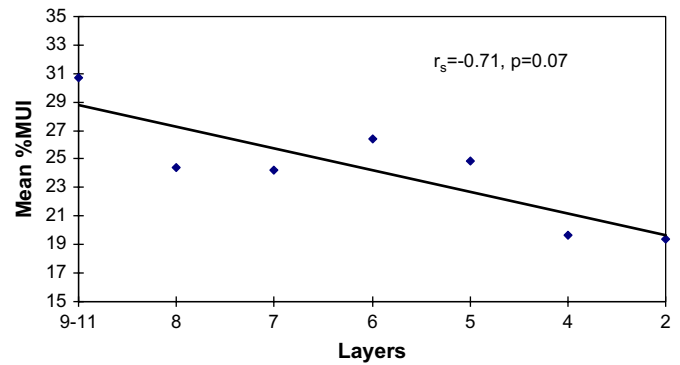

Fig. 2. Otariidae mean utility calculated using %MUI across layers.

utility elements, such as metapodials and phalanges, increased (Fig. 5). Thus, it appears that the range of elements returned to the site expanded over time. The increasing importance of lower return elements such as metapodials and phalanges suggests that the cost of traveling to exploit otariids did not change. Instead, exploitation of otariids became more intensive over time so that more of each carcass was transported.

While the Shag Mouth faunal assemblage appears to be well preserved, it is still possible that differential preservation has affected skeletal element representation in the assemblage [21,23]. The elements with the highest utility may have also been the densest elements (i.e., those that are least affected by taphonomic factors). If these high utility/high density elements were differentially preserved in the lower stratigraphic layers of the site, then the declining utility pattern could be the result of more significant taphonomic processes operating on the older deposits.

If bone density is a factor in otariid skeletal element representation, then elemental bone density should covary with a measure of elemental survivorship (% survivorship). Bone density values used in this analysis were derived for phocid rather than otariid seals [13]. 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 [20]. However, no bone density studies have been conducted on otariid skeletons. As
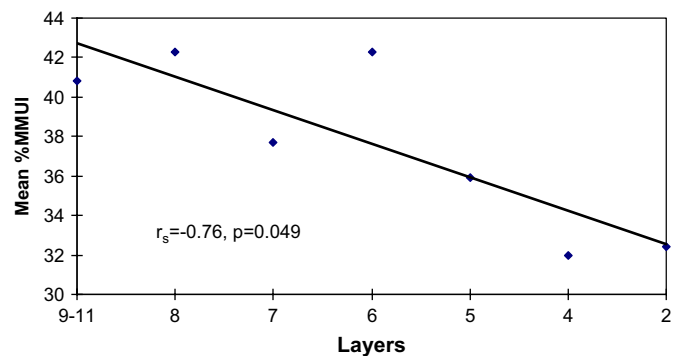

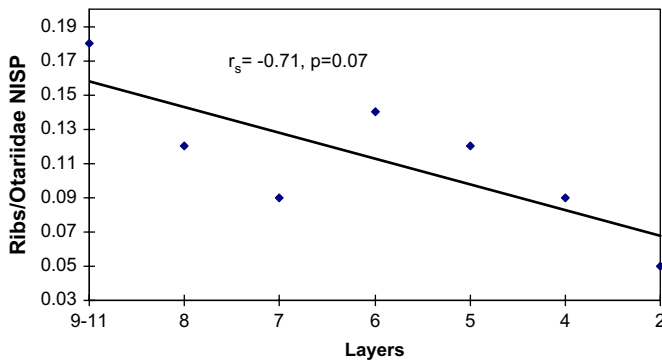Fig. 3. Otariidae mean utility calculated using modified utility (%MMUI) across layers.

Fig. 4. Relative abundance of a high utility otariid element (ribs) by layer.

Table 3
Results of the Spearman's rank correlation analysis between bone density and % survivorship for otariid elements

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

a result, I assume that at the ordinal level, phocid bone density values are appropriate for this analysis. Spearman's rank order correlation is used to test the relationship between bone density and percent survivorship for the samples from 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 but to carcass exploitation patterns. The results of this analysis are listed in Table 3. Bone density is not correlated with survivorship for samples from any layer. Thus, differential preservation does not appear to be affecting relative skeletal abundances of otariid seals in the Shag Mouth assemblage.

Instead, elemental representation is likely the result of changing transport decisions. The increase in the range of elements transported back to the site indicates that increasing transport costs were not a factor, and that seal carcass exploitation became more intensive with time. More of each individual seal was returned to the site as overall foraging efficiency declined. Since transport costs do not appear to be a significant factor, it is possible that foragers exploited seals from local rookeries or non-breeding colonies throughout the occupation of Shag Mouth.

An alternative explanation is that transport costs did not increase because the use of canoes made transporting seal carcasses, even across great distances, relatively efficient. In this case, foragers may have harvested local as well as distant populations of fur seals, but the use of canoes would have kept transport costs relatively low. Canoes were commonly used for

short trips and extended voyages in New Zealand and across Polynesia [5]. The rise in importance of offshore resources during the latter part of the Shag Mouth occupation demonstrates that canoes became important for obtaining resources [31]. In addition, fur seals were described ethnograhically as being taken from distant rookeries traveled to via canoe as part of seasonal hunting expeditions [39].

Since foragers used individual seal carcasses more intensively, it is possible that individual skeletal elements were also used more intensively. As discussed above, foraging efficiency would likely have to have declined significantly for within-bone nutrients to be advantageous enough to exploit intensively. To determine if extraction of within-bone nutrients intensified over time, changes in the three fragmentation measures (NISP:MNE, % whole, and mean % scan site) were examined. In an effort to create data comparable across all three fragmentation measures, only certain elements were included in the analysis. Both MNE and mean % scan site data were generated using scan site information. MNE was determined using the frequency of the most abundant scan site for each element. Percent scan site was calculated by counting the number of scan sites represented by each specimen and dividing that number by the total possible number of scan sites for that skeletal element, and multiplying by 100. The elements used in this analysis were pelves, femora, tibiae, fibulae, scapulae, humeri, ulnae, and radii. Other elements such as metapodials, phalanges, ribs and vertebrae were not included because scan site data were not collected for these long bones. In addition, since seal bone is very identifiable, there was very little 'indeterminate' or unidentified bone to contend with [36].

If individual skeletal elements were used more intensively as otariids became less abundant, then fragmentation is expected to have increased correspondingly. As Fig. 6 shows, the extent of fragmentation of Shag Mouth seal bones as measured by % whole increased over time, although this change is not statistically significant. There is a decline in the percentage of complete skeletal elements from about 45% in the early period to about 30% in the later period. The NISP:MNE data show a different pattern (Fig. 7). Across all layers, fragmentation is quite low, less than two fragments per element. In the lowest layers, a large proportion of the long bones are complete since the data are close to 1.0. Intensity of fragmentation increases slightly over time, although again, this pattern is not
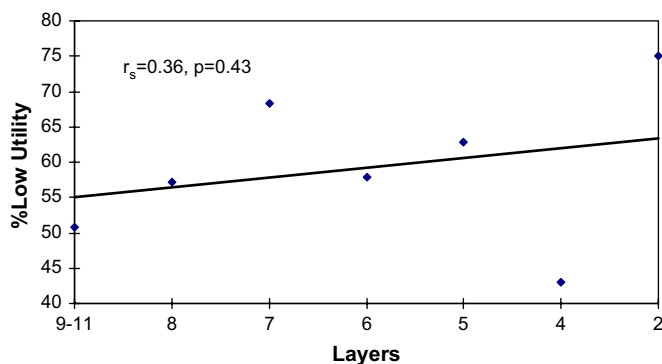

Fig. 5. Relative abundance of low utility otariid elements (phalanges, metapodials) by layer.
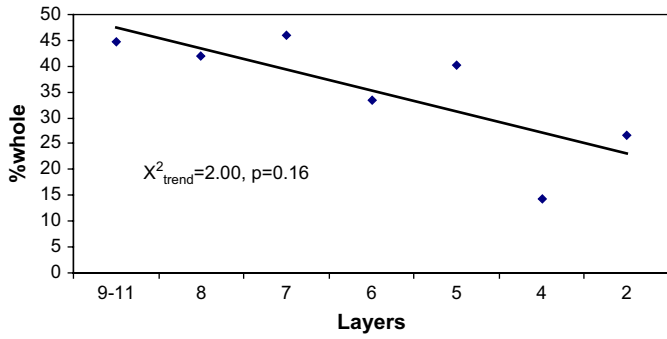
Fig. 6. Extent of fragmentation (% whole) for otariid specimens across stratigraphic layers.

Fig. 8. Mean percent scan site represented for otariid specimens.

statistically significant. The two fragmentation measures correspond to one another well. With fewer whole elements, the NISP to MNE ratio departed slightly from the one to one ratio expected if all skeletal elements were complete to nearly a two to one ratio.

It was expected that mean % scan site should produce similar information as the NISP:MNE data. Indeed, the overall pattern of fragmentation for the scan site data shows that there is no significant change in fragmentation over time and that on average, fragment size is about 40% of the element (Fig. 8). However, the mean % scan site data differs from the NISP:MNE data in that it displays much more variability across layers.

It was also expected that the relationship between NISP:MNE and mean % scan site should be inverse. As the number of fragments per bone increases, fragment size should decrease. However, a scatterplot of the two variables reveals that for the Shag Mouth otariid seals, there is no relationship between NISP:MNE and % scan site (Fig. 9). Thus, the number of fragments per element does not correlate with the size of the fragments. This pattern is likely due to the low fragmentation intensity and the limitations of scan site percentages. On average for the assemblage, most elements were whole or broken into two fragments. If all elements were broken into two, then the average % scan site for the sample should be 50%. The average % scan site across all layers was about 50%, however, the lack of correlation with the NISP:MNE data was
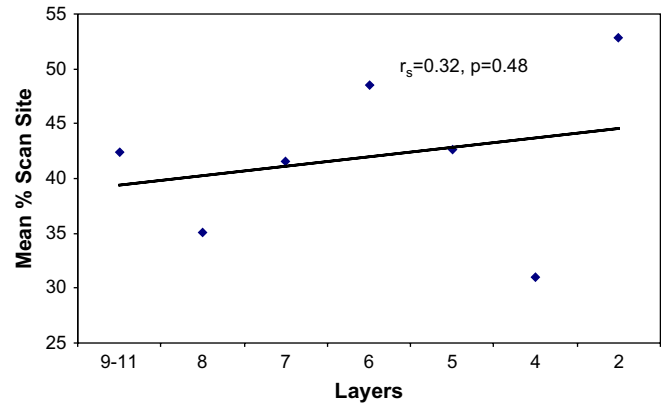
caused by the mean % scan site data varying randomly around that 50% mark for each layer.

For all three measures of fragmentation, the data for layer 4 stand out as different from the overall trend. The sample from layer 4 has fewer complete specimens, more fragments per skeletal element, and lower mean % scan site than the samples from other layers, indicating that the specimens from layer 4 are the most fragmented in the site. When the ratio of NISP to MNE is plotted against sample size (NISP), the specimens in the layer 4 sample are much more fragmented given the sample size than specimens from other layers (Fig. 10). However removing the layer 4 data and running the analyses again does not change the outcome; all trends are still not statistically significant (%whole: $\chi^2_{trend} = 1.54$, $p = 0.22$; NISP: MNE: $r_s = 0.71$, $p = 0.11$; mean % scan site: $r_s = -0.77$, $p = 0.07$).

So why is layer 4 different from the other samples? Are there taphonomic factors that could explain this pattern? After examining taphonomic characteristics of the assemblage, the best explanation seems to be extent of burning in the layer 4 sample of otariid specimens. About 65% of the specimens from layer 4 showed signs of burning compared to an average of 20% burning for specimens from the other layers (Fig. 11). The high degree of burning corresponds to the high frequency
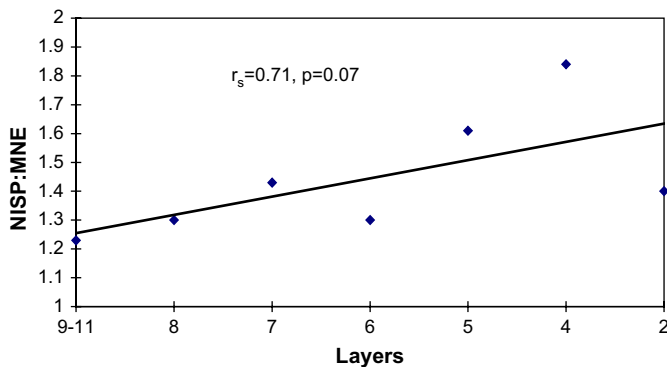

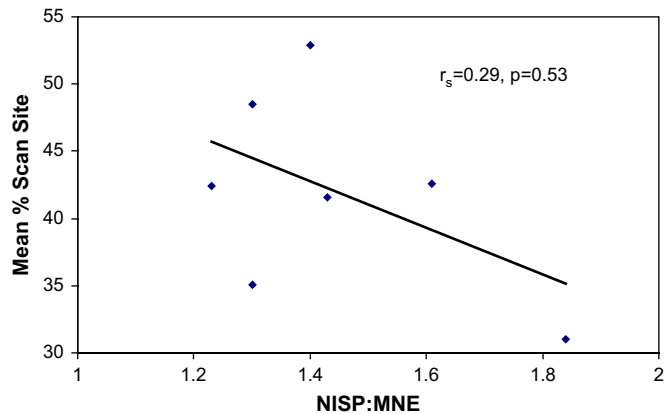Fig. 7. Intensity of fragmentation (NISP:MNE) of otariid specimens by layer.

Fig. 9. Scatterplot showing the relationship between two measures of fragmentation intensity: NISP:MNE and mean % scan site.
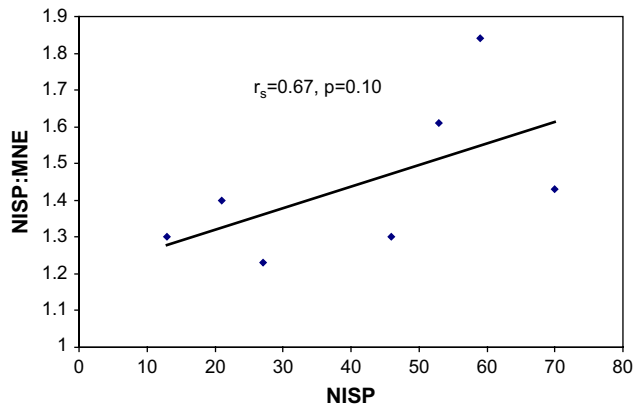
Fig. 10. Relationship between sample size (NISP) and fragmentation intensity (NISP:MNE).

of earth ovens found in the layer [2]. Burning may have made the bones more brittle and thus more susceptible to breakage resulting in higher fragmentation rate and smaller specimen size.

In sum, the otariid skeletal elements returned to the site do not appear to be used more intensively over time. Extracting fat from these bones may have been a very low return activity. Seals have significant amounts of blubber, another form of fat, which would greatly decrease the relative utility of bone oil. In addition, if transport efficiency increased, it may well be that blubber was easy to transport regardless of distance. Thus, it appears that foraging efficiency did not decline dramatically enough to motivate intensive extraction of the low return within-bone nutrients. Any differences in fragmentation patterns are likely due to other taphonomic factors such as burning.

5. Summary and conclusions

This research is part of a growing body of literature that uses foraging theory in many contexts from several areas of the world to explain changes in subsistence practices (e.g., [7−9,12,15,17,19,24,29,44]. The success of foraging theory models lies in their ability to offer a more complex and unified unders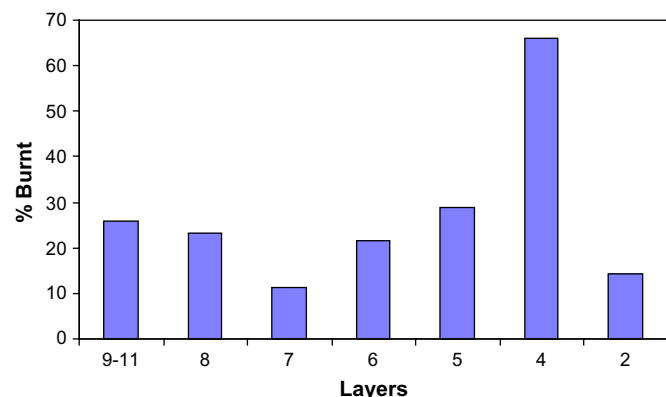tanding of subsistence change. While most research has focused on prey choice, this study demonstrates that foraging theory is also able to explain carcass exploitation decision-making processes. Butchery/transport patterns and skeletal element use are explained within the context of dietary changes under one analytical framework, providing a broader picture of subsistence change.

At the Shag Mouth site, changes in seal carcass exploitation are directly linked to changes in prey availability, prey distribution, and overall foraging efficiency. As a result the Shag Mouth record provides a rare glimpse into how humans modified their strategies as they altered the landscape in which they lived. With decreasing availability of seals and declining foraging efficiency at Shag Mouth, the exploitation of seal carcasses changed over time. During the early occupation of the site when seals were abundant, a higher proportion of high utility skeletal elements transported to the site. Over time, the range of elements transported expanded to include a higher proportion of low utility elements. The broadening in utility of transported elements suggests that distance was not a factor in transport decisions. Instead, as seal abundances and foraging efficiency declined, 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 declined, the drop in foraging efficiency does not appear to have been significant enough for individual elements to be used more intensively via the extraction of within-bone nutrients.

The exploitation patterns for seals are different than those seen for moa carcass exploitation at the Shag Mouth site [33]. Unlike seals, transport costs played a significant role in decisions about field processing of moa remains, thus the proportion of high utility elements increased over time as moa availability declined. In addition, some moa long bone elements appear to have been used more intensively. This difference is because within-bone nutrients of moa long bones were higher ranked than those of seals. Thus, foraging efficiency declined enough at Shag Mouth for extraction of marrow from even moa phalanges to become profitable, but not enough for the exploitation of within-bone nutrients of seals.

Fig. 11. Proportion of burnt otariid specimens in the assemblage.

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