Chapter 4: Temporal Changes In Foraging Efficiency and Diet Breadth

The prey and patch choice models predict that with declining abundances of high-ranked resources, foraging efficiency will decrease, and in response, diet breadth may increase. In addition, if overall foraging efficiency declines significantly, the number of patches exploited may also increase. As discussed in Chapter 2, changes in diet breadth and foraging efficiency can be measured archaeologically by examining the number of resources and the proportion of high to low-ranked resources taken within patches. In this chapter I discuss the measures I will use in my analysis of the archaeological faunal data from the Shag River Mouth site. I then use the Shag Mouth faunal data to test if these predicted changes are evident.

Measuring Changes in Foraging Efficiency

The prey choice model predicts that as high-ranked prey abundances decline, more effort will be spent foraging for prey with lower return rates, thus resulting in a decline in foraging efficiency. As discussed in Chapter 2, foraging efficiency can be measured by examining the relative proportion of high and low-ranked prey. In this analysis, I use two different means of measuring foraging efficiency: evenness and indices of the abundance of large-bodied taxa relative to small-bodied taxa.

Evenness measures proportional abundances of classes (Magurran 1988). In ecological studies, evenness refers to the relative abundances of different species. A perfectly even distribution is where each class, or species, is represented equally. As the distribution shifts away from equal representation, evenness values decrease from a maximum of one to a theoretical minimum of zero.

Evenness measures have not been used more widely in archaeological contexts to measure foraging efficiency because they do not track changes in specific taxa or their position in a rank-ordered set. For example, an evenness measure can remain unchanged even though resource exploitation is changing. For example, at Time 1, Taxon X may comprise 70% of the diet, while Taxon Y makes up 30%. At Time 2, Taxon X declines to 30% while taxon Y rises to 70%. The evenness values for the two samples are the same, yet the two diets are markedly different. Thus, when evenness measures are used, the relative abundance of individual taxa must be examined to determine if and how resource exploitation is changing.

Although evenness as a measure of foraging efficiency can be misleading, it may still track the changing importance of high-ranked versus lower ranked taxa in some situations (Grayson and Delpech 1998). For example, when high-ranked prey types are abundant, they should comprise a large proportion of the diet since they are expected to be taken every time they are encountered. If there are only one or two abundant high-ranked prey taken in an otherwise broad spectrum diet, then the distribution in such a case is expected to be uneven. As the abundant high-ranked prey dwindle in number, lower ranked taxa will comprise an increasingly large proportion of the diet and the shift from high to low-ranked prey may result in a more even distribution across all taxa.

Another means of measuring changing proportions of high to low-ranked taxa can be provided by a comparison of the proportion of large-bodied to smaller bodied prey (Bayham 1979; Broughton 1999). These comparative indices have been used more extensively than evenness for measuring foraging efficiency because they lack the ambiguity that plagues evenness measures (Bayham 1979; Broughton 1994, 1997, 1999; Szuter and Bayham 1989). If body size is assumed to be an appropriate proxy for prey

rank, then it follows that the relative abundance of large to small-bodied taxa will measure foraging efficiency. Indices are created that compare a large-bodied or high-ranked taxon to a smaller one within each patch:

$$\Sigma \text{ large taxon}/\Sigma \text{ [large taxon} + \text{small taxon]}.$$

Larger index values indicate higher proportions of the high-ranked taxon and thus, greater foraging efficiency. If foraging efficiency is declining, then there should be a decline in the index values over time.

Measuring Changes in Diet Breadth

If high-ranked resources decline sufficiently to significantly lower the mean foraging return rate, then lower ranked resources will become increasingly important. The mean foraging rate may be lowered so that diet breadth also expands (Stephens and Krebs 1986). In this analysis diet breadth is measured two ways. One way is to examine changes in taxonomic richness; the other examines the relationship between richness and sample size. Since these measures have their strengths and weaknesses, as discussed below, both are used to assess changes in diet breadth.

Richness is a measure of the number of classes represented (Magurran 1988). A rich sample has a large number of classes, while a poor sample has few classes. In ecological studies, richness is often measured by the number of species present (Magurran 1988; Pielou 1975). In archaeological faunal studies, richness is defined more broadly as the number of taxa (NTAXA) present (e.g., Broughton and Grayson 1993; Grayson and Delpech 1998).

NTAXA are counted so that the taxa are non-overlapping (Grayson 1991). For example, there are three different *Anas* species present in the Shag Mouth assemblage (*A*.

chlorotis, *A. gracilis*, *A. superciliosa*), each of which is counted as an individual taxon. The counts from the generic level category, *Anas* spp., are not included either as a separate taxon or with the three *Anas* species because any of the three species or another species of duck or teal could be represented.

For the Shag Mouth assemblage, NTAXA is represented mostly by species-level identifications. However, there are a few notable exceptions. Because only a few specimens of moa could be identified to the sub-order level, all specimens were lumped into the order, Dinornithiformes, or just moas. Several taxa are also taken to generic level groupings such as the albatrosses (*Diomedea* spp.), wrasses (*Pseudolabrus* spp.), black cods (*Notothenia* spp.), and parakeets (*Cyanoramphus* spp.). While the level of the taxonomic groupings may vary, none of the taxa overlap with one another. However, one consequence of having different levels represented in NTAXA is that changes occurring at the species level may not be recognized because some groupings are at a higher level of identification. Thus, a lack of change in NTAXA over time may be due, in part, to the use of these more inclusive groupings.

The use of NTAXA has been criticized as being an inappropriate measure of diet breadth because it represents the *average* diet breadth taken over a given length of time (Madsen 1993). Critics suggest that as an average, NTAXA is not likely to be sensitive enough to track subtle changes in diet over time. Others, however, argue that NTAXA measures the *maximum* not the average diet breadth for a given time period, thus an increase or decrease in NTAXA can indicate that diet is expanding or contracting, while a lack of change in the measure is ambiguous (Broughton and Grayson 1993; Grayson and Cannon 1999; Grayson and Delpech 1998). For example, during a 100 year period diet breadth may increase from 12 to 20 resources. However, if that 100 year period is

lumped into one archaeological sample, then NTAXA only records that 20 resources

were utilized, even though diet breadth has increased significantly over the 100 years.

NTAXA is not often used alone as a measure of diet breadth because like all diversity

measures, it often correlates with sample size (Grayson 1984*b*). As the sample increases

in size, the number of taxa present may also increase. When the two variables covary, it

is difficult to determine if the changes in NTAXA over time are due to changing diet or

simply sample size differences.

Fortunately, the relationship between NTAXA and sample size (NISP) can be used as

another means of measuring changes in diet breadth (Grayson and Delpech 1998). The

slope and intercept of the regression line describing the relationship between NTAXA

and sample size (NISP) reflect the rate at which taxa are being added as sample size

increases. A sample that produces a steep slope and/or a high intercept value has more

taxa represented at any given sample size than a sample with a gradual slope and a low

intercept value. Thus, if diet breadth is increasing as predicted, we should expect the

regression coefficients describing the relationships between NTAXA and NISP to

increase significantly. By examining the changes in the rate at which taxa are added,we

can thus determine when diet breadth changes significantly.

Defining Patches

As discussed in Chapter 2, the fine-grained prey choice model assumes that prey

distribution is not patchy so that the encounter of a prey type does not affect the

probability of encounter that prey type again. Prey distribution, however, is often

clumped so that certain prey types are more likely to be encountered in particular areas

across space. In such cases, dietary studies that rely on foraging theory must first define patches that create more homogeneous groupings of prey types.

Since human foragers tend to forage widely, it is likely that multiple patches are being exploited. Ethnographically, patches have been defined using a number of different variables such as habitat types, procurement methods, and seasonality of use (Smith 1991). Because most of these variables require a significant amount of reconstruction to identify, defining patches to meet the fine-grained assumption has been problematic in archaeological dietary studies. Usually patches are broadly defined according to environments or habitats. Since these patches, such as "terrestrial" or "marine", are still fairly coarse, and encounter rates within these patches still may not be random. For example, Broughton (1999:52-53) places deer and elk in the same patch, but acknowledges that while there is some overlap, elk tend to favor grasslands while deer are more likely to be found in woodland areas.

The alternative is to create patches that define more specific environments, such as woodland, grassland, or estuarine. Again, this can be problematic because prey may crosscut a range of environments. For example, in Polynesia, marine fish are often categorized as inshore, offshore, or pelagic. However, a number of taxa such as jacks (Carangidae) and barracuda (Sphyraenidae) can be found and procured in all of these patches (Allen 1992).

The New Zealand situation also requires that other factors be taken into consideration. Patch definition is constrained by the paleoenvironmental reconstructions currently available, which tend to be at a gross scale (Anderson and McGlone 1992). In addition, our knowledge about the life histories of extinct species is often limited. Given these two constraints, the patches defined are necessarily broad.

In this analysis, I have compromised between the need for specificity and the quality of available paleoenvironmental and life history reconstructions. Thus, three patch types are defined for this analysis: offshore, coastal and inland. These analytical patches tend to minimize the overlap of prey across other patches. However, because these units are broadly defined, prey distribution may not be completely homogeneous within each patch. The inland patch, in particular, is diverse in terms of the habitats represented, and thus may create a situation where sequential encounters with prey within this patch would not have been random. Thus, in the analyses to follow, I will assess how well the fine-grained assumption of the prey choice model is being met.

Taxa have been divided into patches based on their life histories and ethnographic data on procurement techniques as described in the previous chapter (Tables 4.1-4.3). For the purposes of this analysis, offshore resources, such as barracouta and albatrosses, are defined as those that require canoes to access. The coastal patch includes resources encountered along the shore and coastline. They include seals, sea birds, and fish that can be taken from shore. Inland resources are all other terrestrial resources that can be obtained inland of the coast. The predictions of the models will be tested for each of the three patches separately.

The data used includes only those taxa identified to species level. One notable exclusion is the Polynesian rat. They are known to have been procured by traps set in the forest and among the grass. In addition, the gnawing on bones in the site midden indicates that rats also occurred in and around the site. Thus, they could be pursued in either the inland or the coastal patch. Since I could not determine from which patch they were being exploited, I excluded them from the analysis.

Changes in Foraging Efficiency and Diet Breadth within the Inland Patch

The changes predicted by foraging theory models that are discussed above are contingent upon the declining encounter rates of high-ranked taxa within patches. Since body size is likely to be a good indicator of prey rank, it is assumed that moas, as one of the largest taxa in New Zealand, will be high-ranked taxa within the inland patch. As high-ranked prey, encounter rates for moas is expected to decline over time due to human foraging efforts.

The expected decline of moa abundances is well-documented in the New Zealand archaeological record. Anderson's (1989*a*) analysis of dated moa hunting sites in southern New Zealand documents the timing of the decline of moas regionally. Between 1000 and 400 BP, there are numerous sites with an abundance of moa remains. The peak of moa hunting occurred between 600 and 700 BP. After 400 BP, there are very few sites that contain moa remains, suggesting a dramatic decline in moa abundance. By the time of European discovery of New Zealand in the late 1700s, moas were extinct.

The Shag Mouth site was occupied during the period when the number of moa hunting sites across New Zealand was declining. As a high-ranked taxon, moas should have been taken every time they were encountered. Thus, their relative abundance within the Shag Mouth faunal assemblage should reflect population abundances. The proportion of moas in the Shag Mouth assemblage decreases significantly from about 95% to 65% during the occupation of the site (Figure 4.1; r_s=-0.93, p=0.003). Given the decline in the abundance of the large-bodied, high-ranked moas, it follows that foraging efficiency declined and diet breadth may have increased with the decrease in moa populations.

Foraging Efficiency within the Inland Patch

As discussed above, the prey choice model predicts that with the decline of high-ranked prey, foraging efficiency will decrease. One means of measuring foraging efficiency is through evenness. In the case of the inland patch, it is known that moas were once abundant, and thus likely comprised a large proportion of the diet. If resource utilization in the inland patch was initially uneven (i.e., biased towards moas), then it may be expected that as the high-ranked moa declined, the corresponding decrease in foraging efficiency may be detected as an increase in evenness. The evenness index used in this analysis (Shannon index/ln(NTAXA)) varies between 0 and 1. A measure of 0 indicates that only one class is represented. When the index is 1, each class is represented in equal numbers (Magurran 1988).

Examination of Figure 4.2 shows that evenness of resource use within the inland patch increases significantly over time (r_s=0.89, p=0.007), varying from very low values of 0.04 to 0.36 (note that for this, and the analyses to follow, Layers 9 through 11 are combined because of their very small sample sizes). The extremely low evenness values in the bottom layers indicate that a small number of taxa are disproportionately represented.

As discussed, when using evenness, the rank and proportion of each taxon should be examined to determine if the changes in evenness are reflecting a shift from high to low-ranked prey. The rankings and relative abundance of the five most abundant taxa are presented in Table 4.4. Moas are the most abundant taxa throughout the occupation of the site. In addition to moas, the common taxa are New Zealand Quail, New Zealand Pigeon, Red/Yellow-Crowned Parakeets, and New Zealand Pipit. These and other taxa are taken in increasingly larger numbers over time while moas comprise a smaller

proportion of the diet. Thus, the increasing evenness values seen in Figure 4.2 appear to be reflecting a shift from the high-ranked moas to lower ranked taxa.

Because the prediction is that foraging efficiency should decrease with the decline in moa abundances, then the proportion of moas should be negatively correlated with the evenness values. Moas comprise a large proportion of the inland assemblage, ranging from 59% to 99% of the inland sample. As predicted, the relative abundance of moa in the patch is negatively correlated with evenness (r_S=-0.93, p<0.001). Initially, when moas are abundant, evenness is very low. As moa abundance declines, evenness increases, indicating that the composition of the diet is shifting from a reliance on high-ranked moa to other lower ranked taxa. This strongly suggests that foraging efficiency is declining within the inland patch.

Another means of measuring foraging efficiency is to compare the abundances of large- and small-bodied prey. If foraging efficiency is decreasing due to the decline in high-ranked prey abundances, then the ratio of large to small-bodied taxa, as representatives of high and low-ranked taxa respectively, is expected to decrease.

In the inland patch, moas are the large-bodied, high-ranked prey type. For comparison, the index requires a small-bodied taxon found in the same habitat as moas. The extinct New Zealand quail (*Coturnix novaezelandiae*) meet both of these criteria. In contrast to moas, the quail was very small in size, weighing only one to two pounds. Thus, a shift away from moas and toward a reliance on quail would indicate a significant decline in foraging efficiency, given the presumed differences in net returns. Most importantly, quail inhabited open country like many moa species, particularly *Euryapteryx geranoides* and *Emeus crassus*, which are the most common moa taxa in the

assemblage. As such, quail and moa are likely have been encountered simultaneously. In addition, as discussed in Chapter 3, early historic accounts describe how Maori took quail individually by snares placed along well-traveled paths in the grass. Thus, any shifts in the index are not likely to be due to changes in procurement techniques from individual to mass capture. And as the second most abundant taxa in the inland assemblage after moas, quail comprises about 9% of the total inland sample. Thus, their abundances are less likely to be affected by sample size than a rarer taxon would.

A decrease in the moa-quail index, (Σ moa/Σ (moa + quail)), would represent increasing exploitation of the diminutive quail and thus, decreasing foraging efficiency within the inland patch. The statistic used to test the significance of this relationship is Cochran's test of linear trends (Cannon 1999, Zar 1996). This is a chi square analysis that takes into account the natural ordering of a sequence, such as a temporal trend across stratigraphic layers. In the case of the moa-quail index, the statistic tracks changes in the proportion of moas relative to quail across layers or time.

Cochran's statistic is comprised of three types of chi square analyses. The first is the traditional chi square, called the total chi-square, which tests the relationship between the two variables. The total chi-square is subdivided into two components: one tests the variation that is due to the linear trend; the other examines the departure from the linear trend. It is the chi square for the linear trend (X^2_{trend}) that is used to test whether the proportion of moa to quail changes significantly over time.

Figure 4.3 shows that the moa-quail index decreases significantly over time (X^2_{trend}=734.7, p<0.001), and the index is not correlated with sample size (r_S=-0.48, p=0.194). In the lower layers, the very low index values indicate that moa dominates to

the near exclusion of quail. Between layers 2 and 6, the index drops significantly. The

pattern shows that within the inland patch, moas comprise less of the diet through time,

suggesting that foraging efficiency is declining.

As I have discussed in Chapter 2, the assumption behind the comparisons between

high and low-ranked taxa like the moa-quail index is that changes are due to resource

depression. That is, I postulate that the decline in the index is caused by the depression

of the high-ranked taxa rather than an increase in the lower ranked one, and that the

decline in prey abundances is due to human foraging rather than natural environmental

change (Broughton 1999; Grayson and Cannon 1999). There is little question that moa

decline and extinction was due not to exogenous causes, such as climate change, but to

human action through habitat alteration and predation (Anderson 1989*a*). However, there

is evidence for environmental change that could have affected the quail population

positively in such a way that resource depression may not be the cause of the declining

foraging efficiency.

During the prehistoric era, widespread deforestation led to the creation of more open

habitat across New Zealand (McGlone 1983). At the Shag Mouth site, pollen data

document a similar pattern of local vegetational change (Figure 4.4). The vegetation in

the area shifts from closed forest to more of an open forest with a shrubby understory,

and finally to an open habitat dominated by grass and bracken ferns (Boyd *et al.* 1996).

The creation of more open country may have favored quail populations, which would

have increased the encounter rates of quail. Quail appear to have been a part of the diet

throughout the occupation of the Shag Mouth site (Table 4.4), thus it is likely that they

were always taken on encounter. Consequently, if quail encounter rates increased, then

the proportion of quail in the diet should also increase. Thus, the changes in the moa-

quail index may be due in part to increasing quail populations rather than just decreasing moa populations.

To determine if quail abundances increased due to the creation of new habitat, the proportion of quail in the Shag Mouth assemblage is compared to that of a forest bird, the New Zealand Pigeon. The pigeon was chosen because it a large forest bird that, like the quail, is present throughout the assemblage. It is expected that the open habitat required by quail would be created through the clearing of forested areas. This, in turn, would be detrimental to pigeon populations. To test this prediction, I compare quail and pigeon abundances with the following index:

$$\Sigma \text{ quail}/\Sigma \text{ (quail + pigeon)}.$$

It is expected that if deforestation led to an increase in quail populations and a decline in pigeon populations, then the quail-pigeon index should increase over time. The quail-pigeon index does increase slightly, but the change is not significant (Figure 4.5; $X^2_{trend}=0.12$, p=0.74). Thus, it appears that while vegetation patterns changed in and around the Shag Mouth site as demonstrated by the pollen data, these local changes did not have a significant impact on the proportion of pigeons and quails within the entire inland patch. This supports the conclusion that the changes in foraging efficiency tracked by moa-quail index are caused by declining abundances of moa and not by increases in quail populations.

Diet Breadth within the Inland Patch

As I have discussed, a decline in the abundance of high-ranked taxa may lower the mean foraging return rate to the point where diet breadth increases. To determine if diet

breadth is expanding as moa populations are declining, I first examine changes in NTAXA across time, and then the relationship between NTAXA and NISP.

Figure 4.6 shows a plot of NTAXA across layers. Spearman's rank order correlation was used to test the significance of the relationship. Over time, NTAXA increases significantly (r_s=0.89, p=0.007), and is not significantly correlated with sample size (r_s=0.47, p=0.28). Thus, for the inland patch, resource exploitation appears to have broadened to include more resources over time.

By examining the relationship between taxonomic richness and sample size, we can determine when a significant increase in diet breadth occurs. A regression analysis between NISP and NTAXA describes the rate at which taxa are added at any given sample size. The regression coefficients can be used to examine changes in this relationship. A higher slope indicates that taxa are added at a higher rate than a sample with a low slope. Along the same lines, a higher intercept value means that more taxa are added at any given sample size than a sample with a lower intercept. If diet is broadening, then the regression coefficients between earlier and later samples should change significantly over time.

Since changes in diet breadth should be linked to the decline in the abundance of the high-ranked taxa, which for the inland patch are moas, we can examine the relative abundance of moa in the sample to determine when diet breadth may be expected to increase. A drastic decline in the relative abundance of moas occurs during that period between Layers 5 and 6 (see Figure 4.1). Therefore, Layers 2-5 and 6-11 should produce significantly different regression coefficients if diet breadth is increasing due to declining

moa abundances. Specifically, the sample from Layers 2-5 should have a steeper slope and/or large intercept value than Layers 6-11 if diet breadth is increasing over time.

As can be seen in Figure 4.7, two significantly different populations are indeed represented in the inland patch data (t=4.84, 0.05>p>0.02). The sample from the younger layers (Layers 2, 4, 5) is described by a regression line with a much larger intercept and a slightly steeper slope than that from the older layers (Layers 6-11). While the correlation between the variables in the upper layers is extremely high, there are so few points that the relationship is not statistically significant. The presence of two statistically different relationships between NISP and NTAXA indicates that for any give sample size, there are more taxa found in the upper layers than in the lower layers and the rate at which taxa are added is higher. In other words, more taxa are being utilized in the later occupation of the site. In addition, the increase in diet breadth is directly linked to the decline of moas in the diet. Moas comprise a higher percentage of the inland sample in the lower layers than in the upper layers (Figure 4.8).

While NISP-NTAXA relationships can reflect diet breadth, they can also be influenced by other factors. In particular, differential fragmentation and skeletal element representation can lead to an overrepresentation of NISP or an underrepresentation of NTAXA that can cause the differences seen in the NISP-NTAXA relationship (Grayson and Delpech 1998). As a result, the influence of these factors on the NISP-NTAXA relationship must be examined. The effects of differential fragmentation and skeletal element representation in the Shag Mouth assemblage are explored in depth in Chapter 5. Here I present only a brief analysis to examine the effects of these variables on the relationship between richness and sample size.

The degree of skeletal element fragmentation can affect the number of identifiable specimens represented. A higher fragmentation rate will increase the NISP per NTAXA, resulting in a regression line with a lower slope. Thus, if the NISP-NTAXA analysis above is affected by differential fragmentation, we should expect that the sample with the lower slope, in this case the sample from the lower layers, will have a higher fragmentation rate than the upper layers sample.

To determine if the rate of fragmentation is changing, I have compared the proportion of NISP to the minimum number of elements (MNE), which measures the bone fragments per skeletal element, for the upper and lower layers. An increase in the proportion indicates that there are more fragments per skeletal element represented, i.e., fragmentation is increasing. Thus, if differential fragmentation is causing the differences between the NISP-NTAXA relationships, the sample from the lower layers should have a significantly higher NISP relative to MNE than the upper layer. Chi square analysis shows that the proportions of NISP to MNE from the upper and lower layers, however, are not significantly different (Table 4.5: X^2=0.05, p=0.82). Since fragmentation between both samples is similar, differential fragmentation is unlikely to have affected the NISP-NTAXA relationship (Figure 4.9).

Differential representation of skeletal elements has also been identified as a factor that can affect the NISP-NTAXA relationship (Grayson and Delpech 1998). The proportion of elements may change over time due to changes in field processing (Bartram 1993; O'Connell *et al.* 1988, 1990) or preservation factors (Lyman 1984, 1989). If the number of elements being returned to the site or preserved changes over time, it will appear that the NISP has decreased relative to the NTAXA, or more specifically that NTAXA has increased, resulting in a higher slope between NISP and NTAXA. Thus, if

skeletal element representation is affecting the NISP-NTAXA analysis, we should expect that the high slope sample should have significantly fewer elements represented.

To test for the effects of differential elemental representation, the frequency of moa elements from the upper and lower layers sample was compared using chi square (Grayson and Delpech 1998). The proportion of elements represented in the two samples is significantly different (Table 4.6; $X^2=300.8$, p<0.001). Examination of the adjusted residuals shows that several elements are significantly over- or underrepresented in each assemblage. Those elements that are significantly (p<0.05) underrepresented in the high slope, or in this case, the upper layers sample, are most likely to affect the analysis.

The underrepresented elements in the high slope sample are the phalanges and the tarsometatarsi. If they significantly affect the NISP-NTAXA analysis, then their removal from the data should produce plots between the upper and lower layers that are not significantly different. Figure 4.10 shows the replotted NISP-NTAXA data. Both samples are still statistically different (t=4.65, p<0.05). Thus, although there may be differences in the elements being transported back to the site, they do not appear to be significantly affecting the NISP-NTAXA relationships.

In sum, both the richness and the NISP-NTAXA relationship data demonstrate that a major shift in diet seems to occur between Layers 5 and 6. At this time, there is a substantial decline in moa abundances that appears to have lowered foraging efficiency to the point where the number of taxa represented in the inland assemblage increases significantly. Thus, in addition to a decline in foraging efficiency, diet breadth for the inland patch is increasing with the declining abundances of the high-ranked resource, moas.

Changes in Foraging Efficiency and Diet Breadth within the Coastal Patch

As with the inland patch, the predicted dietary changes within the coastal patch are contingent upon the declining encounter rates of high-ranked taxa within patches. Based on body size, the high-ranked resources within the coastal assemblage are the pinnipeds. As discussed in Chapter 3, the distribution of pinnipeds, particularly the New Zealand fur seal, changed significantly after the colonization of humans. The range of breeding colonies and their populations declined dramatically during the prehistoric period. Smith (1985, 1989) argues that this restriction in range of pinnipeds is due to human foraging and not environmental factors. By the time of European contact, successful rookeries were found only in areas of New Zealand far removed from human occupation.

At the Shag Mouth site, pinniped abundances also declined. Figure 4.11 shows that the relative abundance of fur seals declines significantly over time (r_s=-0.82; p<0.023). A similar pattern is seen for sea lions (Figure 4.12; r_s=-0.72; p=0.007) and elephant seals (Figure 4.13; r_s=-0.68; p=0.09). Since these large-bodied, and thus high-ranked, taxa show a pattern of declining abundances, it follows that within the coastal patch foraging efficiency should have declined and diet breadth may have increased.

Foraging Efficiency within the Coastal Patch

As in the inland patch, foraging efficiency is expected to decline as the abundance of the high-ranked prey, in this case, pinnipeds, declines. The decreasing importance of high-ranked prey in the diet may be measured by evenness. Since seals were once an abundant resource, initial exploitation in the coastal patch may have been uneven, with a few high-ranked resources comprising a large proportion of the diet. If this is the case, then as seal abundances declined, it may be expected that resource exploitation would

have become more evenly distributed with lower ranked prey comprising an increasing proportion of the diet.

As can be seen in Figure 4.14, evenness does increase through time. However, the correlation between evenness and stratigraphic layers as a measure of time is not significant (r_s=0.57; p=0.18). Examining the proportion and rank of taxa may be able to explain why the expectations were not met. Table 4.7 presents the rankings and relative abundances of the top five most abundant taxa. Fur seal is the most abundant coastal resource in the sample throughout most of the sequence, but foraging in the coastal patch does not focus on seals alone. Other taxa, such as dog, shags, penguins, and fish are also being taken in significant numbers. Thus, as also indicated by the larger evenness values, resource exploitation of the coastal patch appears to be more generalized than in the inland patch.

Although evenness does not appear to be increasing significantly, there is evidence that foraging efficiency may be declining. Larger taxa like Hooker's sea lion, New Zealand fur seal, Stewart Island Shag and Yellow-eyed Penguin comprise a greater percentage of the sample in the earlier layers, whereas smaller taxa such as Blue Penguin, blue cod, and wrasses are more common in the later layers. Thus, although the evenness values do not change significantly, resource exploitation in the coastal patch may be shifting to smaller taxa.

To better determine if foraging efficiency in the coastal patch is changing, the relative abundance of large to small-bodied prey types can be compared in similar fashion to the comparisons I made using the moa-quail index. Since foraging efficiency is expected to decline as populations of high-ranked taxa decline, an index that measures the changing abundances of large-bodied, and thus high-ranked taxa relative to small, low-ranked ones

should track these changes in foraging efficiency. As the largest taxa in the coastal

assemblage, the three pinniped species (New Zealand fur seal, Hooker's sea lion, elephant

seal) are the large-bodied prey used in this analysis. Two taxa are used as small-bodied

prey to compare against the pinnipeds: dog and wrasses.

The *kuri* or Maori dog was chosen to compare with seals because of its size and

relative abundance in the assemblage. Like most Polynesian dogs, the *kuri* is a small

breed that is estimated to weigh about 13 to 15 kilograms (Clark 1997). Dogs were one

of the three domesticated animals transported by Polynesians as part of the colonization

process (Kirch 1984). In New Zealand, they were a part of the diet until the introduction

of other meat sources such as cattle and pigs (Buck 1950). After the New Zealand fur

seal, it is the most abundant taxon in the coastal assemblage.

The pinniped-dog index,

$$(\Sigma \text{pinniped}/\Sigma(\text{pinniped} + \text{dog}),$$

tracks changes in the abundance of large-bodied seals relative to the smaller Maori dog.

Lower pinniped-dog index values represent declining foraging efficiency as more dog is

taken relative to the much larger pinnipeds.

The pinniped-dog index shows a pattern of declining foraging efficiency similar to

that of the inland patch (Figure 4.15). Pinnipeds decline significantly relative to dog

($X^2_{trend}=312.6$; $p<0.001$), although the decline seems to occur a little later than that seen

in the inland patch. The pinniped-dog index declines between Layers 4 and 5 while a

dramatic decline in the moa-quail index occurs between Layers 5 and 6 (see Figure 4.3).

The pinniped-dog index is not correlated with sample size ($r_s=-0.41$, $p=0.355$). Thus, as

seals comprise a smaller portion of the diet, foraging efficiency in the coastal patch

declines.

There are a couple of potential problems with using dog in this comparison. Dogs may have been found mostly around human habitation areas, and thus they may not have overlapped significantly with seals, which inhabited the nearby rocky or sandy coastline. Since the site is located along the shoreline, the likelihood of encountering both prey in the same patch may have been highest during the initial occupation of the site when nearby seal habitats were being exploited. In addition, because dogs were likely to have been in close proximity to human habitation, pursuit costs may have been much lower for dogs and are less likely to have changed than pursuit costs for seals. If the exploited seal habitat shifted further from the site, then the pinniped-dog index may be measuring changing distance costs rather than foraging efficiency. However, as will be shown in the next chapter, the analysis of relative skeletal abundance and utility suggests that the distance to seals did not change significantly over time.

A more severe problem is that domesticated animals such as dogs may not fit the assumptions of the prey choice model. The issue of incorporating domesticated animals into foraging theory models is complex, and has not been adequately addressed in the literature. In particular, domesticated animals are not always taken upon encounter and essentially have pursuit costs that are zero.

Because dogs need not always be taken upon encounter, their harvest does not compete with the foraging effort for pinnipeds. Dogs, then, should constitute a distinct patch. If this is the case, then the pinniped-dog index may not be measuring changes in foraging efficiency within the coastal patch, but changes in patch use resulting from changes in foraging efficiency across patches.

Given the possible problems of using dogs, another index was created using wrasses to examine changing foraging efficiency. These inshore fish are small, weighing under a

kilogram. If foraging efficiency is declining in the coastal patch, then the pinniped-wrasse index (Σpinniped/Σ(pinniped + wrasse)) should decrease. Like the pinniped-dog index, the pinniped-wrasse index declines significantly over time (X^2_{trend}=151.4; p<0.001). The decline is relatively steady with the exception of Layer 4, for which the proportion of wrasse to pinnipeds is much greater than expected (Figure 4.16). The index represents a shift from the larger pinnipeds to the smaller wrasses, indicating a decline in foraging efficiency over time.

While predation undoubtedly affected prehistoric seal distributions (Smith 1985, 1989), the possibility that climatic change could have influenced seal abundances, and thus the pinniped indices, must be explored to determine if resource depression is the cause of the decline in foraging efficiency. Environmental or climatic change could affect breeding patterns or the availability of food. For example, breeding success can be linked to thermoregulation: males with territories that have access to tidepools or are close to the water are able to cool themselves more readily and have higher reproductive success than males that do not (Reidman 1990).

If climatic changes caused the prehistoric decline in fur seal abundance and distribution, this change would have to be unidirectional. That is, if temperatures rose continually over the course of the last 1000 years, the pinniped breeding success of seals would have decreased, causing a decline in population abundances across New Zealand, and/or a shift in the distribution of fur seal populations to cooler regions. The climatic data, however, does not show a steady directional trend in temperatures that may have led to a decline in seal populations during the prehistoric occupation of New Zealand (Grant 1994). Instead, temperature fluctuated between warmer and colder periods during the prehistoric period (Figure 4.17). Oxygen isotope data on a speleothem from the north

end of the South Island produced a pattern where the mean average temperature has

fluctuated significantly since Polynesian colonization (Wilson *et al*. 1979).

Dendrochronological and δ^{13}C data from a 1000 year old kauri tree (*Agathis australis*)

produced a pattern of troughs and peaks similar to the speleothem data (Figure 4.18).

However, the two differ on the timing of those warmer and cooler periods. Grinstead and

Wilson (1979) argue that the kauri dates are more accurate than those for the speleothem

data, are thus more appropriate for describing the timing of temperature fluctations. In

either case, there is no unidirectional change in temperature during the prehistoric period.

At the time scale represented by the occupation of the Shag Mouth site, the pattern is

similar. As I have discussed, the Shag Mouth site was occupied for 50 to 200 years,

probably from some time between the AD 1200 and AD 1400 depending on

interpretations of the radiocarbon dates. Whether using the speleothem or kauri tree data,

the temperature fluctuated during this period of time, rather than steadily declined or

increased. As a result, the data do not suggest that changing seal abundances during the

prehistoric period were the result of changing climate. Human foraging remains the best

explanation for the decline of seal populations.

In sum, the analyses indicate that large prey comprise an increasingly small

proportion of the diet over time. Thus it appears that foraging efficiency is declining in

the coastal patch. In addition, the evidence suggests that human foraging efforts are

likely to have been the cause of this shift in foraging efficiency.

Diet Breadth within the Coastal Patch

With a decrease in the encounter rates of high-ranked taxa and the corresponding decline in foraging efficiency, diet in the coastal patch may broaden. To test if the number of resources utilized increases over time, I once again examine changes in the number of taxa (NTAXA) and the relationship between richness and sample size. Figure 4.19 shows that NTAXA increases significantly over time (r_s=0.76, p=0.046). However, since NTAXA is significantly correlated with sample size (r_S=0.764, p=0.046), it is difficult to determine if the change in NTAXA is due to an increase in diet breadth or the effects of sample size, or both.

Examining the relationship between NISP and NTAXA may allow us to resolve this issue. Changes in diet breadth are expected to be linked to the decline of the high-ranked prey, which for the inland patch are seals. Thus, the relative abundance of pinnipeds can be examined to determine where the change in the rate at which NISP and NTAXA is expected. The decline in pinniped abundances appears to be less marked and occurs later than for moas in the inland patch (see Figures 4.1, 4.3, 4.8). The relative abundance in pinnipeds seems to decrease between Layers 4 and 5 (Figure 4.20). The sample is subdivided into two, with Layers 6-11 comprising the lower layer sample and Layers 2-5 in the upper layer sample. As the apparent inflection point in the pinniped relative abundance plot, Layer 5 could be included in either the lower or upper layer sample. However, it is included with Layers 2 and 4 as the upper layer sample as a matter of convenience so that the decrease can be described statistically. If diet breadth is increasing in the coastal patch, then it is expected that the upper layer sample should have a steeper slope and/or larger intercept value than the lower layer sample.

As with the inland sample, the NISP-NTAXA relationship for the upper layers (Layers 2, 4, 5) is significantly different from that of the lower layers (Layers 6-11) (Figure 4.21; t=115.4, p>0.001). The sample from the upper layers has a slightly higher slope and a larger intercept than that from the lower layers. The correlation between NISP and NTAXA for both the upper and lower layers is very high, but while the NISP-NTAXA relationship for the lower layers sample is significant, there are so few points in the upper layer sample that the relationship is not statistically significant. The significant differences between regression coefficients of the two samples indicate that the NTAXA found in the upper sample is greater than that found in the lower layers, i.e., diet breadth is expanding significantly over time.

If diet breadth is increasing in the coastal patch due to declining pinniped abundances, then the lower layer sample should have higher proportions of pinnipeds than the upper layers sample. Figure 4.22 shows the NISP-NTAXA regression plots with the seal proportions for each of the layers. Although the pattern is not as dramatic as in the inland sample, in general, the proportion of pinnipeds is greater in the lower than in the upper layers. The low relative abundance of pinnipeds in Layer 11 (0.51) is likely due to the small sample size for the layer. Thus, it appears that the increase in diet breadth is related to the decline in seal abundances.

As discussed in the analysis of the inland patch, differential fragmentation and skeletal element representation can affect the NISP-NTAXA relationship in a manner similar to diet breadth changes (Grayson and Delpech 1998). Thus, the effect of these two factors must be determined before interpretations about diet change can be made. Differential fragmentation can inflate NISP and lower the slope of the regression line. The relevant fragmentation values are presented in Table 4.7. Once again, chi square

analysis shows that the NISP and MNE values from the upper and lower layers are not significantly different (Table 4.7: X^2=0.195, p=0.67). Thus, it is unlikely that fragmentation has led to the patterns seen in the NISP-NTAXA analysis.

Because differential skeletal element representation can affect the NISP-NTAXA relationship by underestimating NISP, elemental data for otariids and dogs is examined. These two taxa were chosen because they comprise about two thirds of the coastal assemblage. Elemental counts from the upper and lower layers (Table 4.8) are compared using chi square. Because the skeletal element representation from the two layers differs significantly (X^2=55.2, p>0.001), it is possible that differential skeletal element representation is affecting the NISP-NTAXA relationships.

Since elements that are significantly underrepresented in the high slope sample are likely to create differences between the two samples, these elements need to be removed from the NISP-NTAXA datasets and the data reanalyzed in order to test for their effect on the analysis. The vertebrae and podials were the two elements underrepresented in the high slope sample (Table 4.8). These were removed from the NISP counts and the relationship between NISP and NTAXA recalculated (Figure 4.23). The two samples remain significantly different (t=93.7, p<0.001). Thus, it appears that the NISP-NTAXA relationships are not being affected by differential fragmentation or differential elemental representation.

In sum, resource exploitation appears to be more generalized in the coastal patch than it is in the inland patch. However, the outcome of declining abundances of high-ranked prey remain the same. Foraging efficiency appears to have declined as the larger taxa comprised a smaller proportion of the diet. In addition, a wider range of taxa were likely

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to have been taken as pinniped abundances decline. That is to say, diet breadth in the coastal patch increased over time.

Resource Explotation in the Offshore Patch

The pattern for the offshore patch is expected to be different from that of either the coastal or inland patches because it contains no large-bodied resources such as moas and seals. As such, the offshore patch may have been the lowest ranked of the three patches, and would have been the last patch to be added to the subsistence regime. If offshore resources were not exploited initially, then the patch choice models predict that this patch should have been added when the mean foraging return rate for all utilized patches declined below the expected return rate of the offshore patch. Alternatively, if the offshore patch was being utilized, but only minimally, foraging theory predicts that patch residence time will increase as the mean foraging return rate declines.

Indeed, it appears that the offshore patch was not regularly used until late in the Shag Mouth sequence. The offshore component makes up less than 10% of the Shag Mouth faunal assemblage until the uppermost layers where it comprises up to nearly 60% of the total assemblage (Figure 4.24), a trend that is not significantly correlated with sample size (r_S=0.71, p=0.11). During the early period of the site's occupation, the offshore patch appears to have been used only occasionally.

The marginal value theorem predicts that patches will be added if foraging efficiency and the mean foraging return rate for all utilized patches declines significantly (Charnov 1976). To demonstrate that this late use of the offshore patch is due to declining foraging efficiency within the two utilized patches, and thus over all patches, I compare the

relative abundance of an offshore resource to high-ranked resources from the other two patches. In particular, barracouta, the primary resource used in the offshore patch, is compared with the high-ranked resources, pinnipeds and moas, from the coastal and inland patches:

$$(\Sigma \ moa/\Sigma \ (moa + barracouta).$$

$$(\Sigma \ pinnipeds/\Sigma \ (pinnipeds + barracouta).$$

Barracouta are much smaller than either moas or pinnipeds, weighing about 1 to 3 kilograms. Thus, a decrease in the indices would indicate a shift in resource exploitation from the coastal and/or inland patches to the offshore patch, as well as a decrease in foraging efficiency across all patches.

Both the moa-barracouta and the pinniped-barracouta indices show the increasing importance of barracouta. The moa-barracouta index decreases significantly over time (Figure 4.25; X^2_{trend}=5755.3, p<0.001). Moa dominates until Layer 5 when barracouta becomes important. A similar pattern can be seen for the pinniped-barracouta index (Figure 4.26; X^2_{trend}=4167.2, p<0.001). Pinnipeds decline significantly relative to barracouta. This shift begins earlier in the sequence and is slightly more gradual than for moas. Thus, it appears that resource exploitation expanded to include significant use of the offshore patch as the foraging efficiency for the other patches declined.

Over time, the pattern of exploitation within the offshore patch also appears to change. As was seen for the other patches, evenness measures can characterize whether exploitation patterns are more generalized or specialized. High evenness values indicate that the pattern of exploitation is generalized, whereas low evenness values indicate a specialized pattern of exploitation. Within the offshore patch, evenness values for the

lower layers are relatively high, suggesting that initial use of the offshore patch was generalized. Over time, evenness declines significantly indicating increasingly specialized use of the patch (Figure 4.27; r_s=-0.77, p=0.07).

One possible interpretation of the barracouta indices and evennness results is that initial exploitation of the offshore patch may have been opportunistic, possibly in conjunction with travel to other areas via canoes. In other words, the entry into the patch may not have initially been for foraging purposes. Later, around Layer 5, the offshore patch became a regular part of the subsistence regime as foraging efficiency declined in the other patches. The significant decrease in evenness suggests that after the offshore patch was added, exploitation focused primarily on barracouta. Indeed, barracouta eventually comprise a large portion of the overall diet.

An alternative interpretation is that the offshore patch was always included in the foraging regime, but time allocation was initially low. As foraging efficiency declined in the other two patches, time allocation within the offshore patch increased and/or technological improvements occurred. The decline in evenness over time may represent a change in hunting types or pursuit technology used to capture offshore resources. While barracouta is the dominant resource exploited in the offshore patch, red cod and albatross are also exploited throughout the sequence. Initially, a hook-and-line technology may have been used with hand lines that were deployed vertically via jigging for pursuing resources that can be found around offshore reefs. This type of technology is quite generalized in the type of prey that it can capture, providing access to predatory fish, such as red cod and barracouta, within the entire water column. Later on, in addition to the jigging technique, the more specialized technique of trolling may have been added

to pursue schooling barracouta feeding on the surface, as well as albatross that may have been associated with these schools.

In essence, the offshore patch may actually consist of two hunt types (see Smith 1991): one characterized by trolling, the other by jigging. Hunt types have been used elsewhere to define patches (see Smith 1991), thus the offshore patch may consist of two separate patches based on the different hunt types represented. If this is the case, then the jigging hunt type/patch may have been used throughout the sequence, while the trolling hunt type/patch may have been added late during the occupation of the site. At Shag Mouth, jigging fishhooks are found throughout the sequence, while barracouta lures were only recovered from Layers 2 and 4, suggesting that trolling is a late phenomenon (Anderson and Gumbley 1996).

Although barracouta lures enter the record late, it is likely that the trolling technology was brought by the Polynesian colonists. The exact origins of the form of trolling lures used for barracouta is uncertain, but they may have derived from minnow lures, and ultimately developed from the East Polynesian bonito lures, a trolling technology that would have arrived with the colonists (Anderson and Gumbley 1996). It is likely then, that since trolling technology was always available, the apparent increase in barracouta exploitation during the later occupation of the Shag Mouth site is driven not by innovations in procurement technology, but to resource depression of seals and moas within the coastal and inland patches.

In sum, the differences in the two interpretations arise from an inability to identify the nature of the earliest exploitation of the offshore patch. The patch may have been included in the foraging radius throughout the sequence and the amount of time allocated to the patch simply increased after a significant decline in the overall foraging efficiency.

Alternatively, the offshore patch may not have been used initially, but was added to the foraging radius later. While the nature of changing offshore resource use is unclear, it appears to be linked to declining overall foraging efficiency. Only after moas and seals decline do offshore resources play a significant role in overall subsistence patterns at Shag Mouth.

Summary

Early in the Shag River Mouth sequence, the inland and coastal patches were the main focus of resource exploitation. Within the inland patch, foraging specialized on moas. As moa populations declined, foraging efficiency declined as lower ranked, smaller taxa came to comprise a larger percentage of the diet. Foraging efficiency within the inland patch declined to the point where lower ranked resources that were previously ignored were added to the diet.

The pattern for the coastal patch is similar, although not as clear. Resource exploitation in the coastal patch was broader than for the inland patch throughout the occupation of the Shag Mouth site. While seals were the most important taxon in the patch for most of the sequence, a number of other resources such as shags, penguins, dogs, and fish were taken in significant numbers throughout the occupation of the site. But, as in the inland patch, as the large-bodied, high-ranked pinnipeds declined, more foraging effort was invested in obtaining lower ranked resources and foraging efficiency declined. Thus, through time the diet expanded to include lower ranked taxa.

As the foraging efficiency for the inland and coastal patches, and thus overall foraging efficiency decreased, use of the offshore patch increased. The patch may not have been used early on because of the travel costs of exploiting the patch (i.e.,

exploitation via canoes), as well as the relatively low returns for resources within the patch. Or the patch may have been used throughout the occupation, but time spent foraging in the patch only increased later. In either case, only after moa and seal populations start to decline are offshore resources with a focus on the exploitation of barracouta contribute significantly to the overall diet.
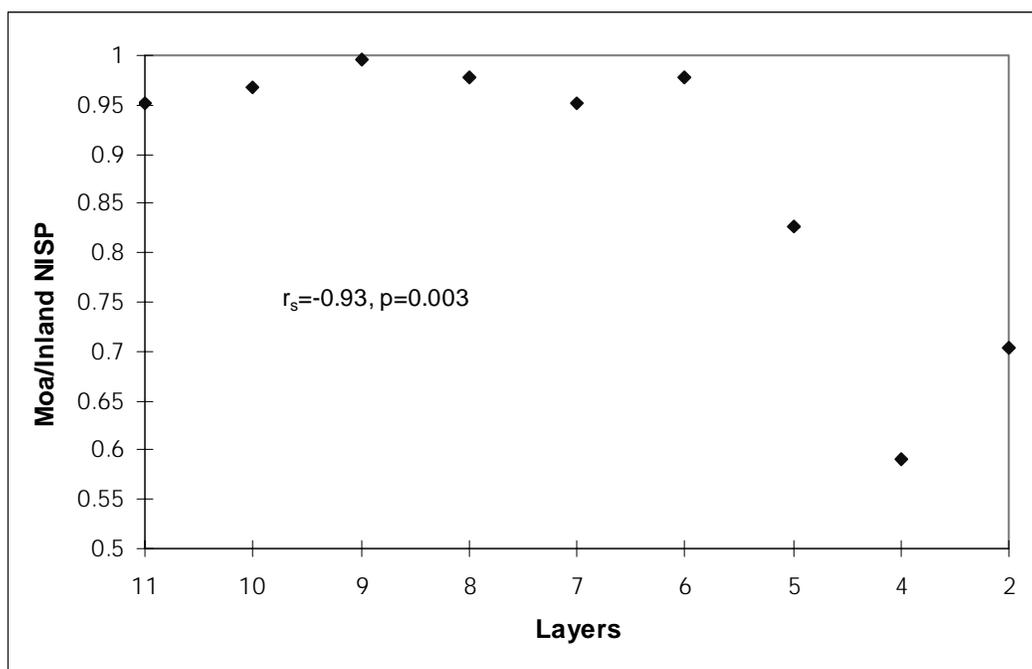
Figure 4.1. The relative abundance of moa in the inland sample across layers.
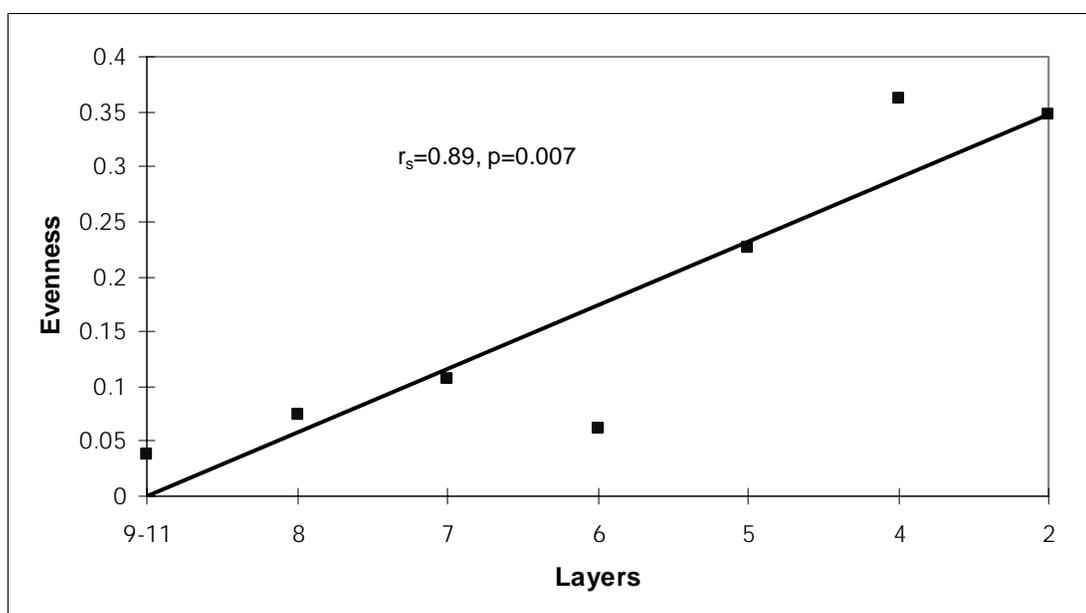
Figure 4.2. Evenness values for the inland patch across layers.

The chart shows data points plotted for Moa/(Moa+Quail) versus Layers, with the annotation $X^2_{trend} = 734.7$, $p<0.001$.
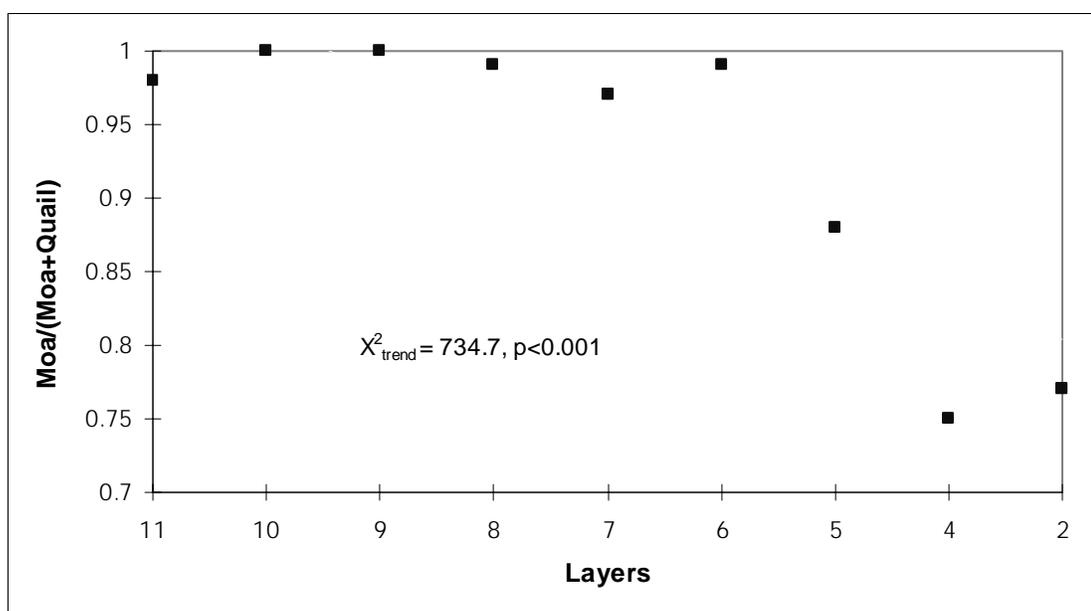
Figure 4.3. The moa-quail index of the inland patch by layer.

Figure 4.4. Pollen diagrams from samples taken near the Shag Mouth site (from Boyd *et al*. 1997).
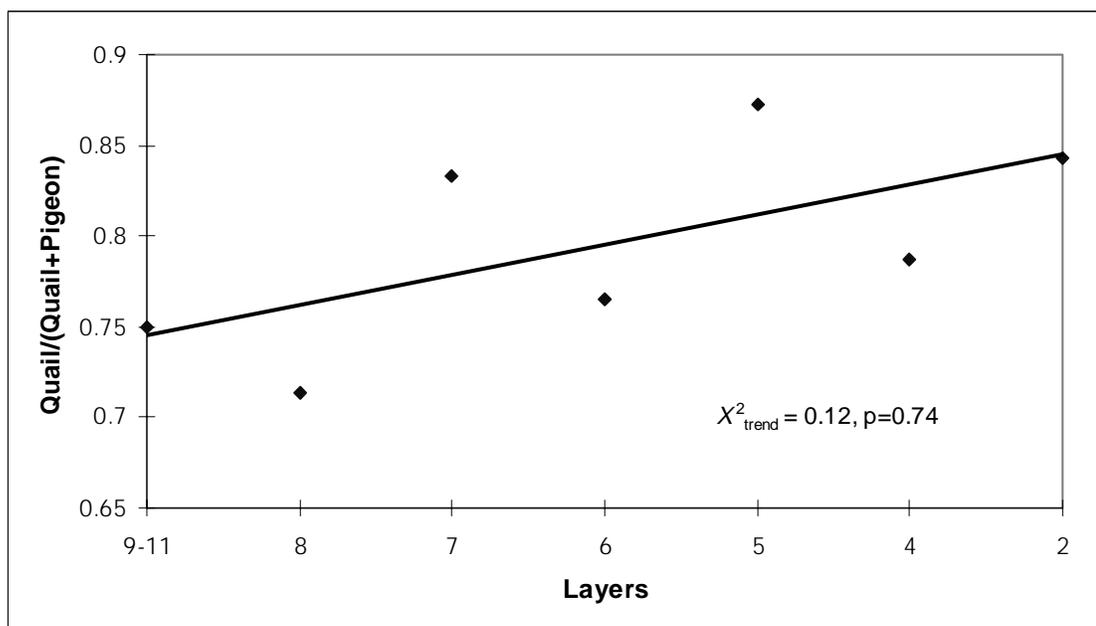
Figure 4.5. The quail-pigeon index for the inland patch by layer.
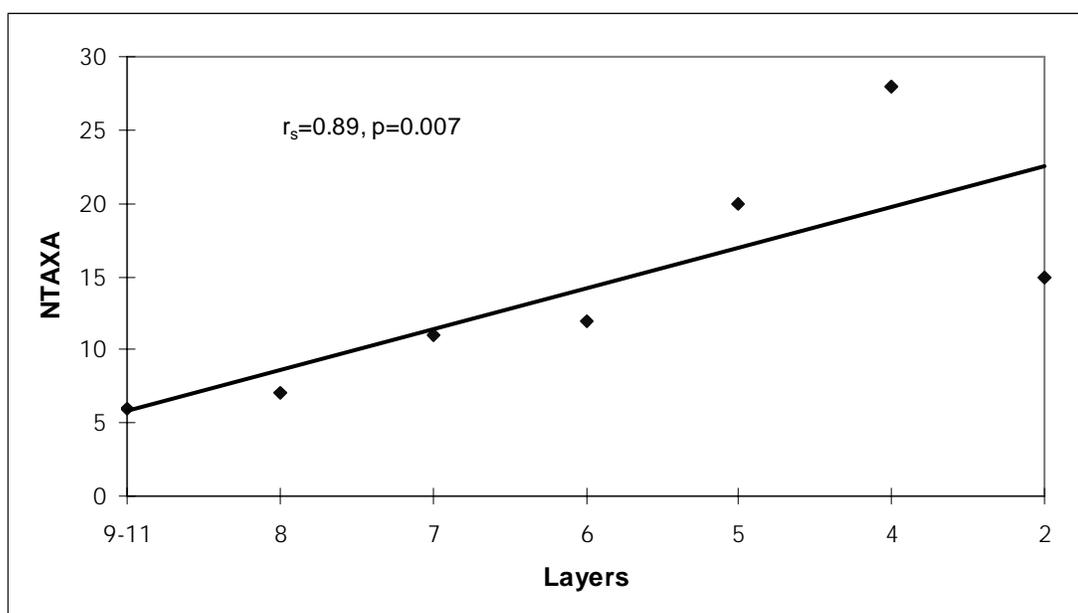
Figure 4.6. Plot of richness by layers for the inland patch.
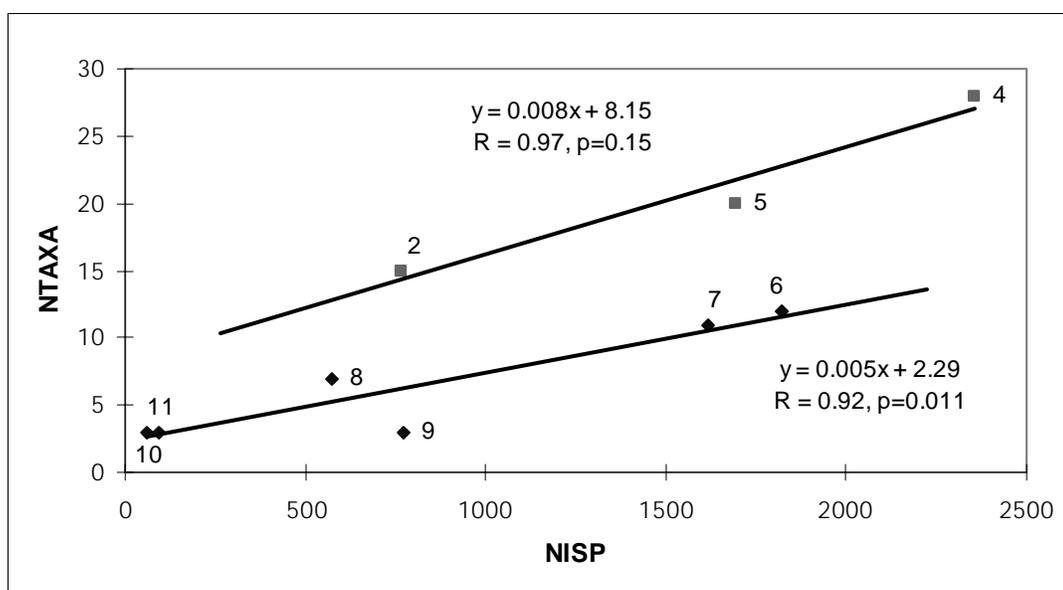
Figure 4.7. The relationship between NISP and NTAXA for the upper and lower layers of the inland patch sample.
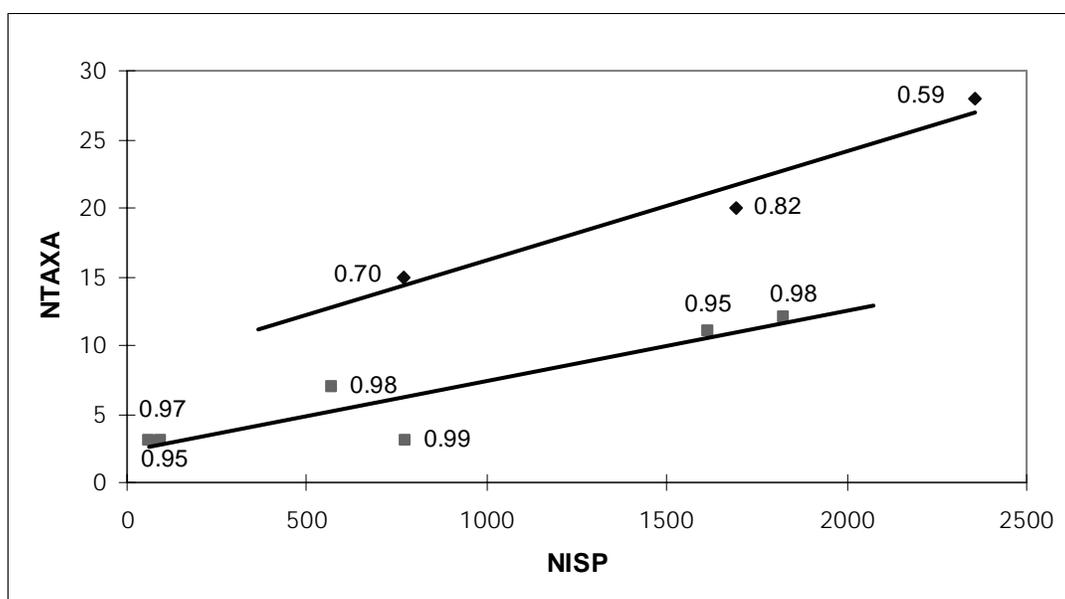
Figure 4.8. The relationship between NISP and NTAXA with the proportion of moas for each layer.
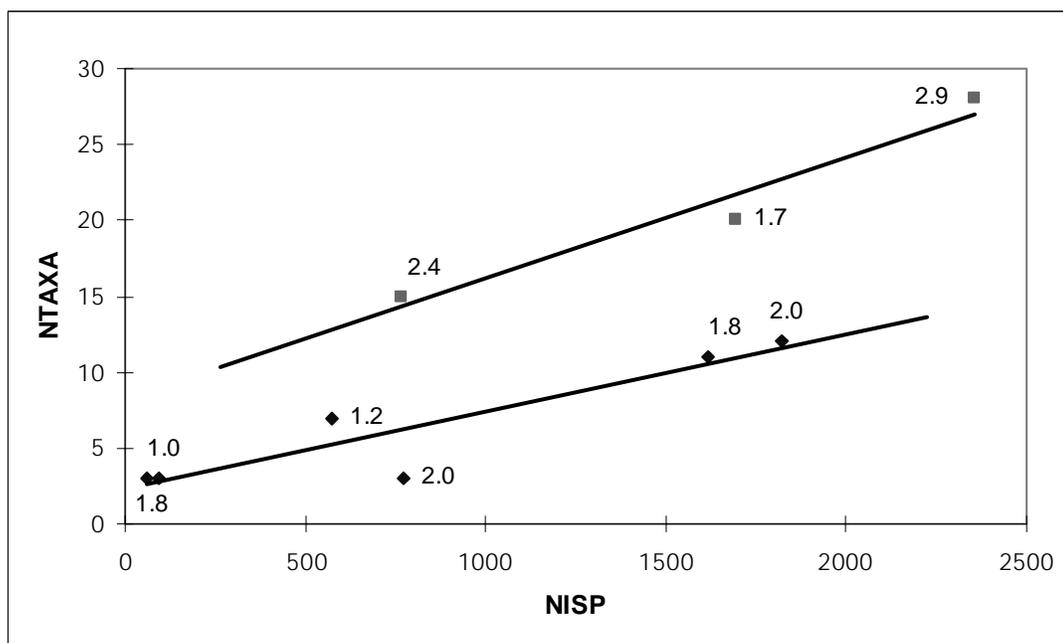
Figure 4.9. The NISP-NTAXA relationships with the NISP-MNE fragmentation index for each layer.
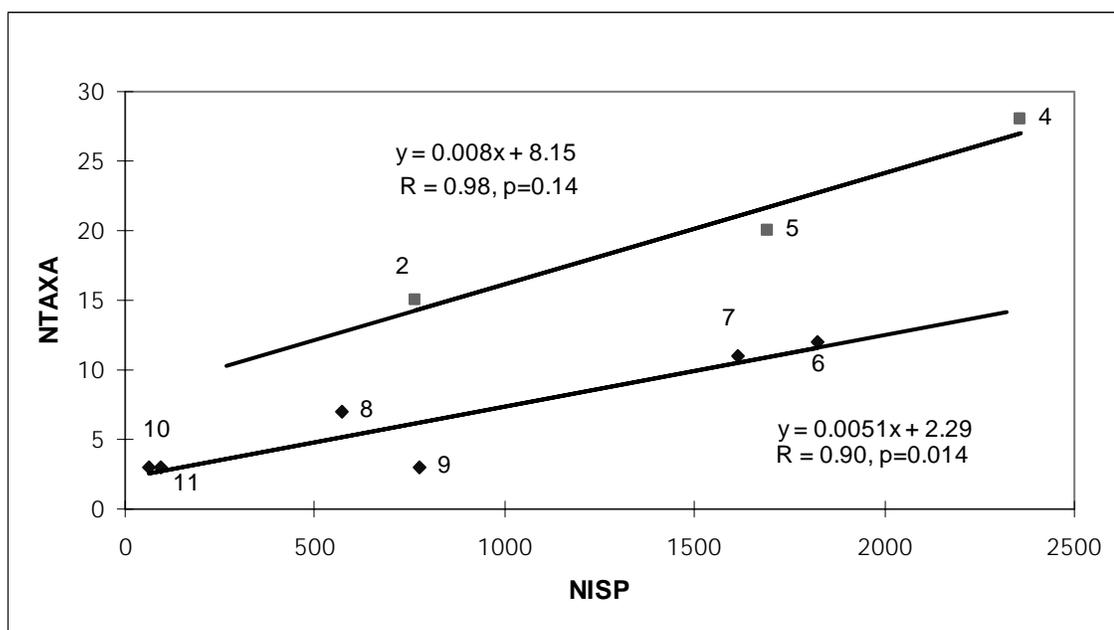
Figure 4.10. The NISP-NTAXA relationships with moa phalanges and tarsometarsi removed.
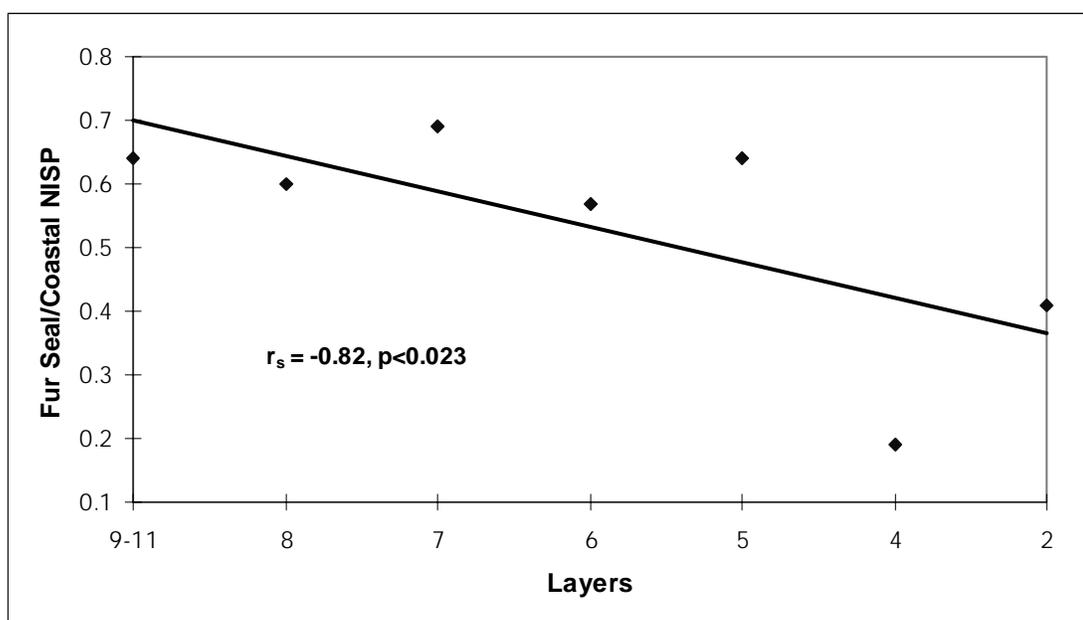
Figure 4.11. The relative abundance of New Zealand fur seal in the coastal sample.
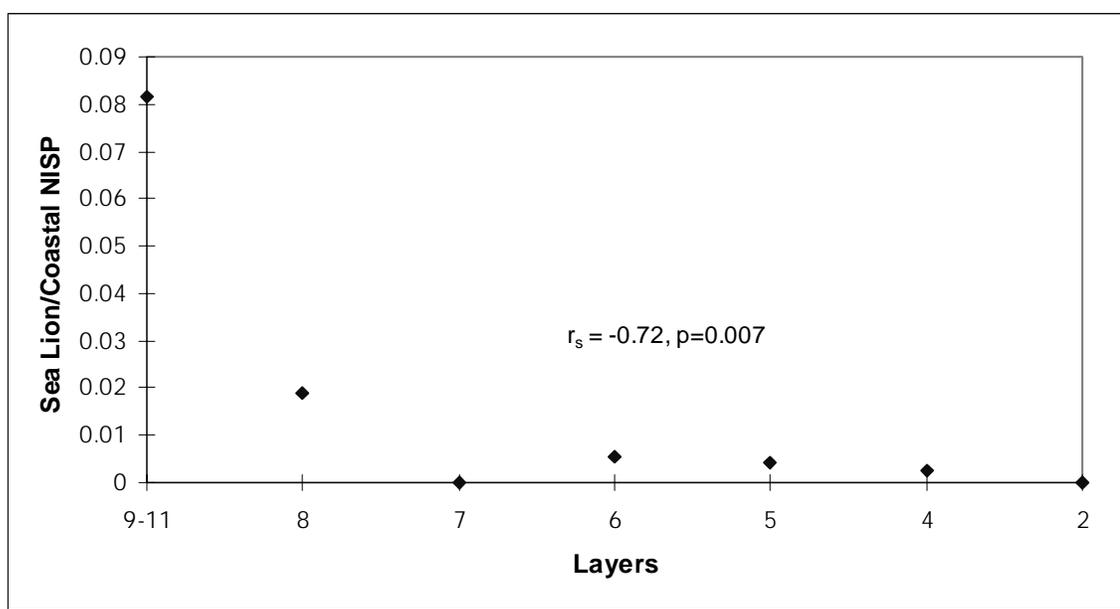
Figure 4.12. The relative abundance of Hooker's sea lion in the coastal sample.
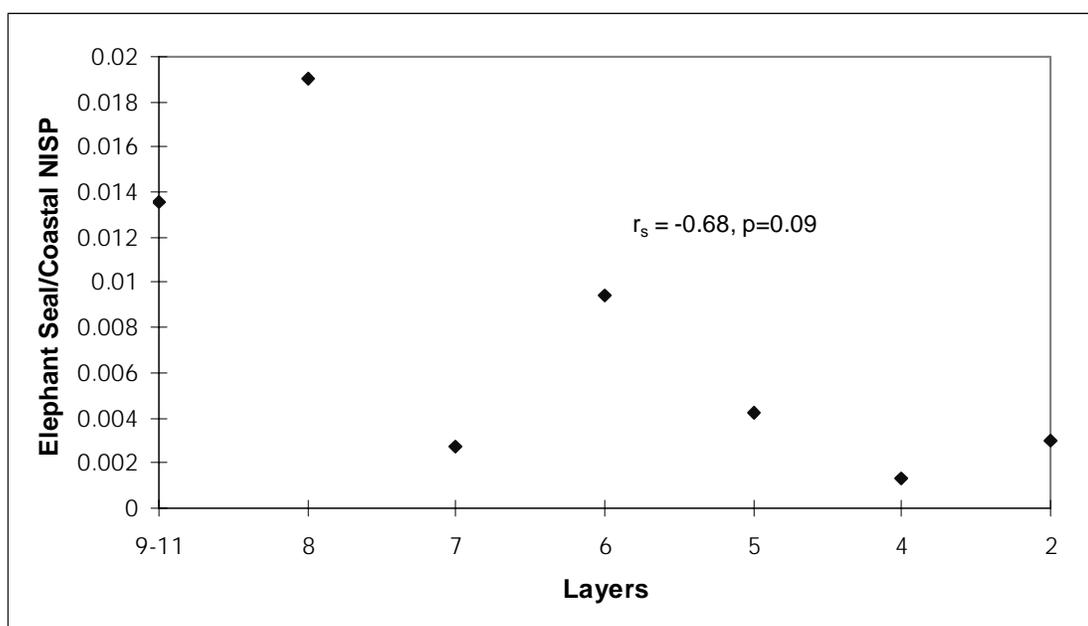
Figure 4.13. The relative abundance of elephant seal in the coastal sample.
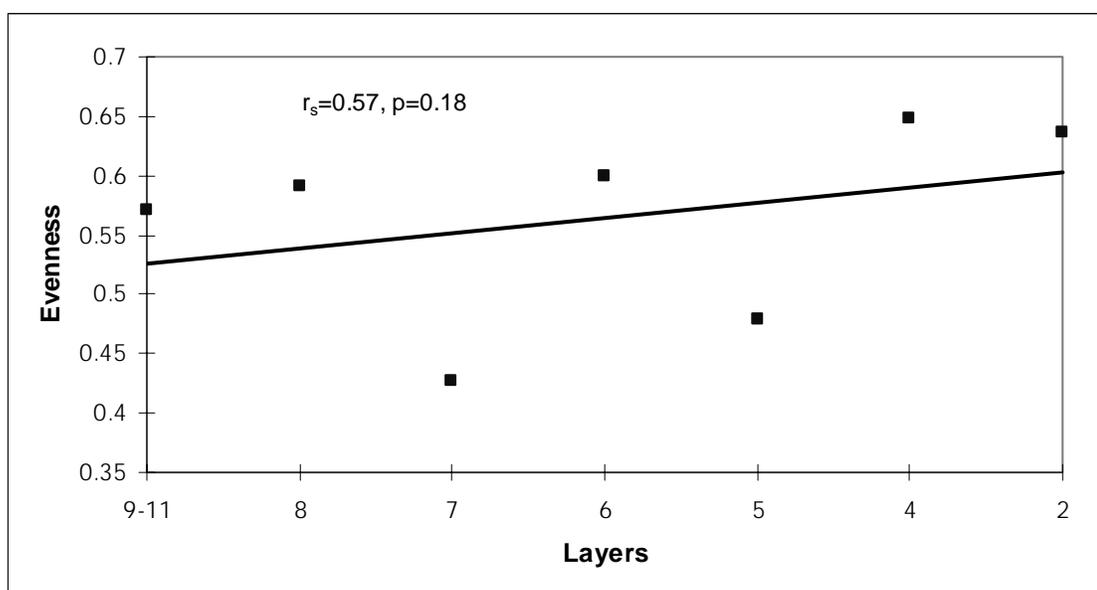
Figure 4.14. Plot of evenness for the coastal patch across layers.
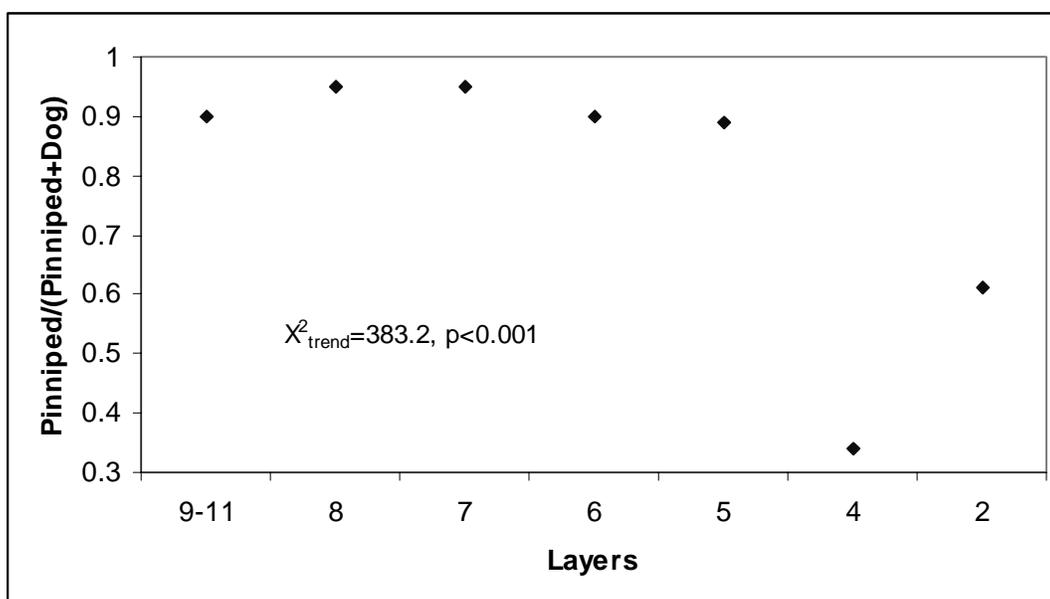
Figure 4.15. The pinniped-dog index of the coastal patch by layers.

The figure shows a scatter plot with a fitted trend line. The y-axis is labeled "Pinniped/(Pinniped+Wrasse)" ranging from 0.6 to 1. The x-axis is labeled "Layers" with values 9-11, 8, 7, 6, 5, 4, 2. The plot contains the annotation $X^2_{trend}=151.4$, $p<0.001$.
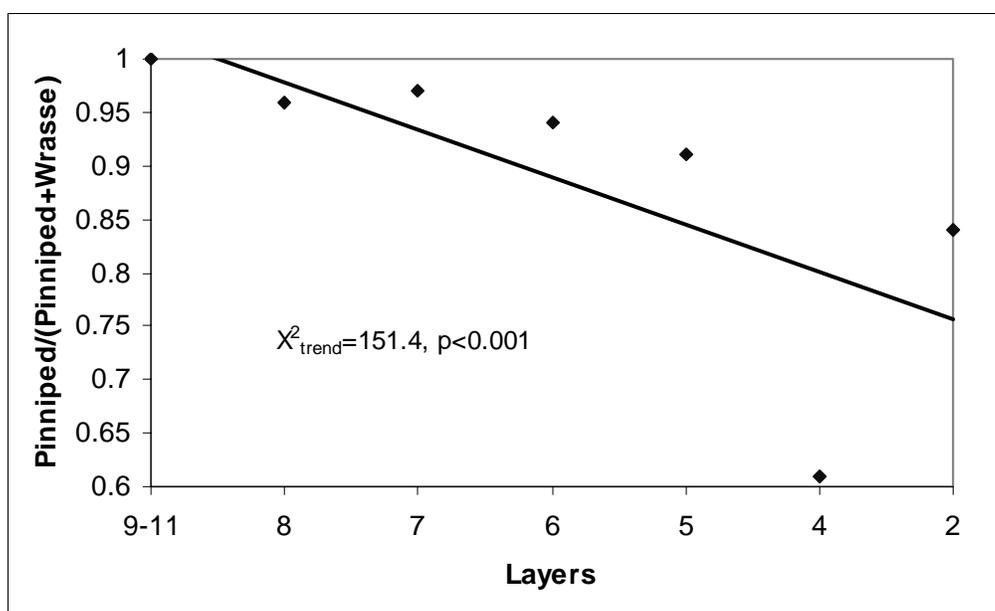
Figure 4.16. The pinniped-wrasse index of the coastal patch by layers.
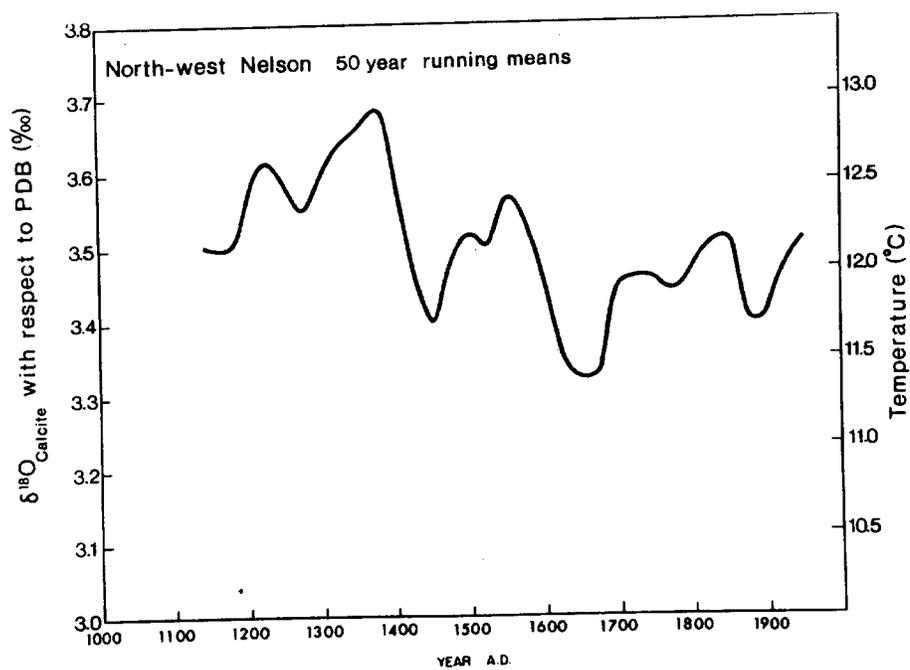
Figure 4.17. Speleothem paleotemperature curve (from Wilson *et al.* 1979)
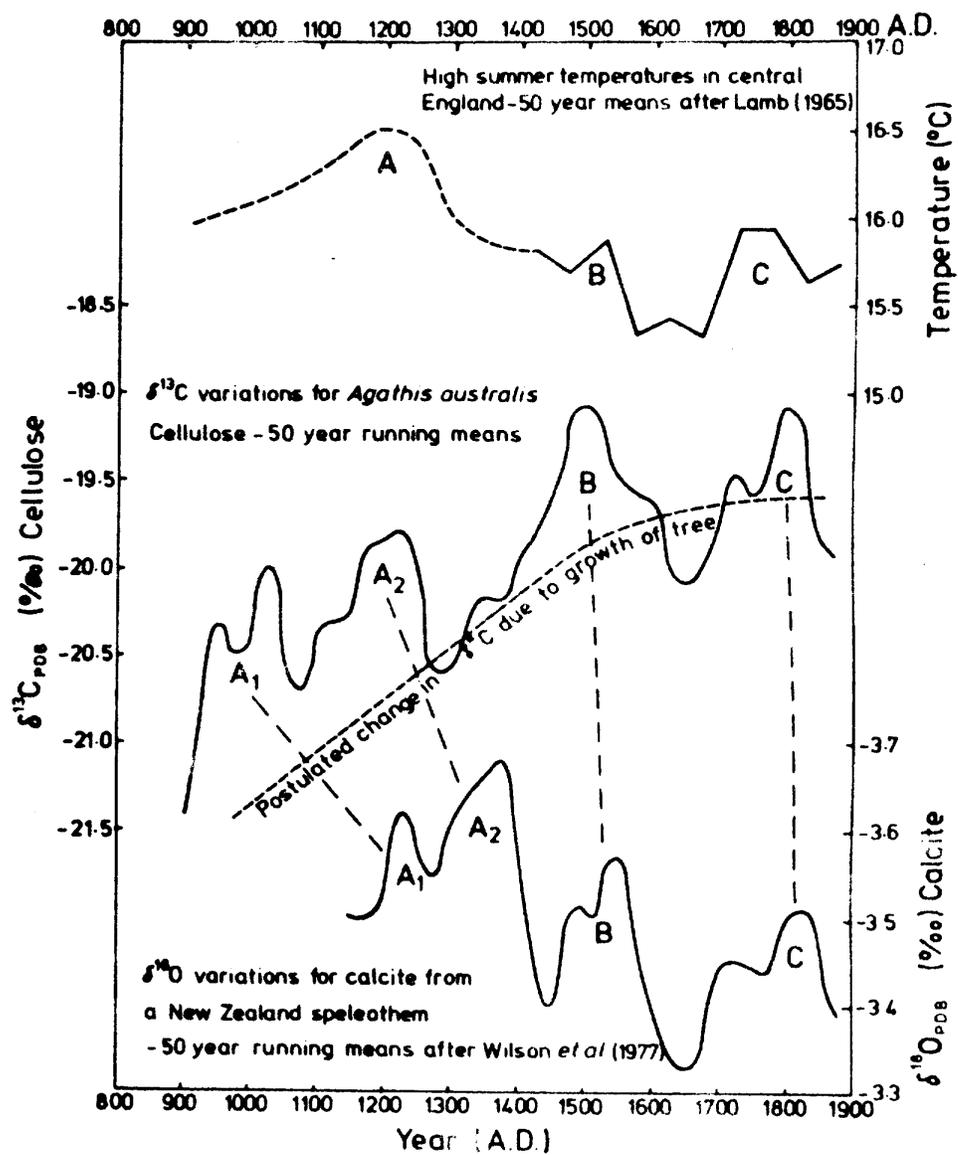
Figure 4.18. Speleothem data corrected using kauri tree ring data (from Grinsted and Wilson 1979).
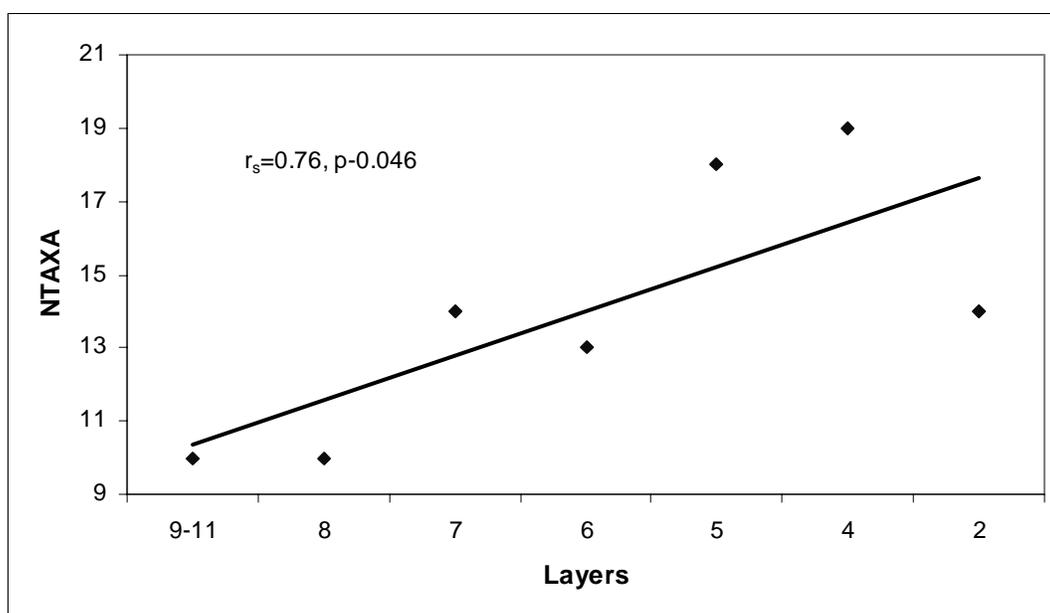
Figure 4.19. NTAXA values for the coastal patch by layer.
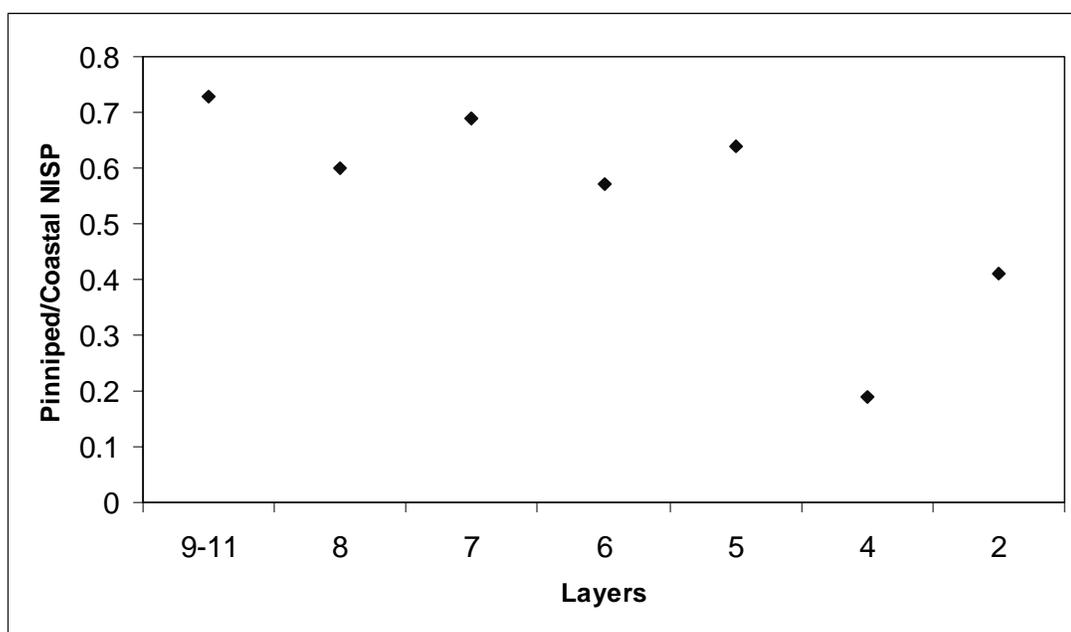
Figure 4.20. The proportion of pinnipeds in the coastal sample.
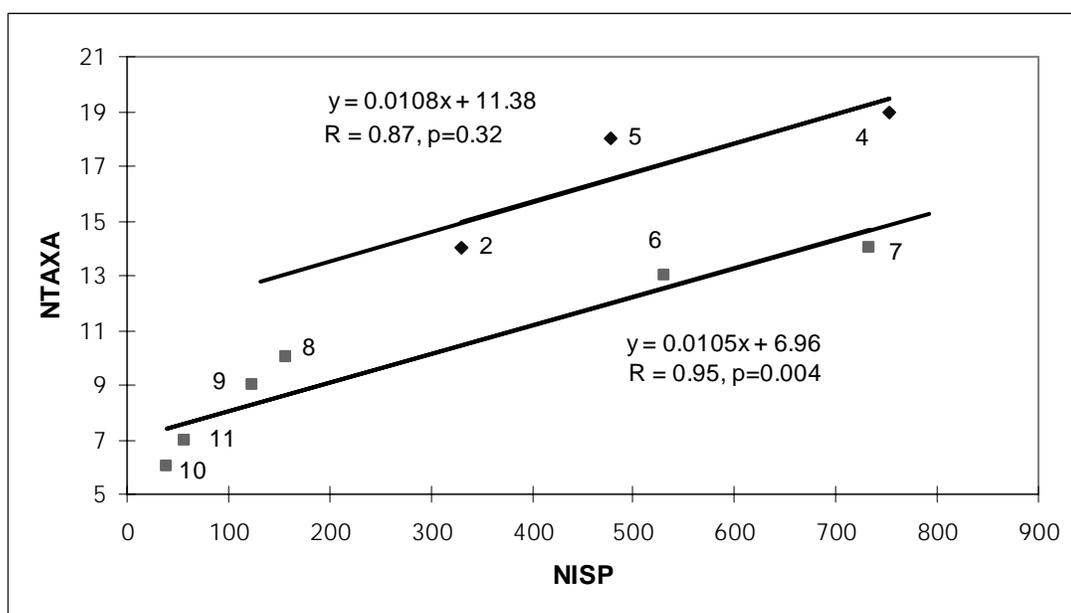
Figure 4.21. The relationship between NISP and NTAXA for the upper and lower layers of the coastal patch sample.
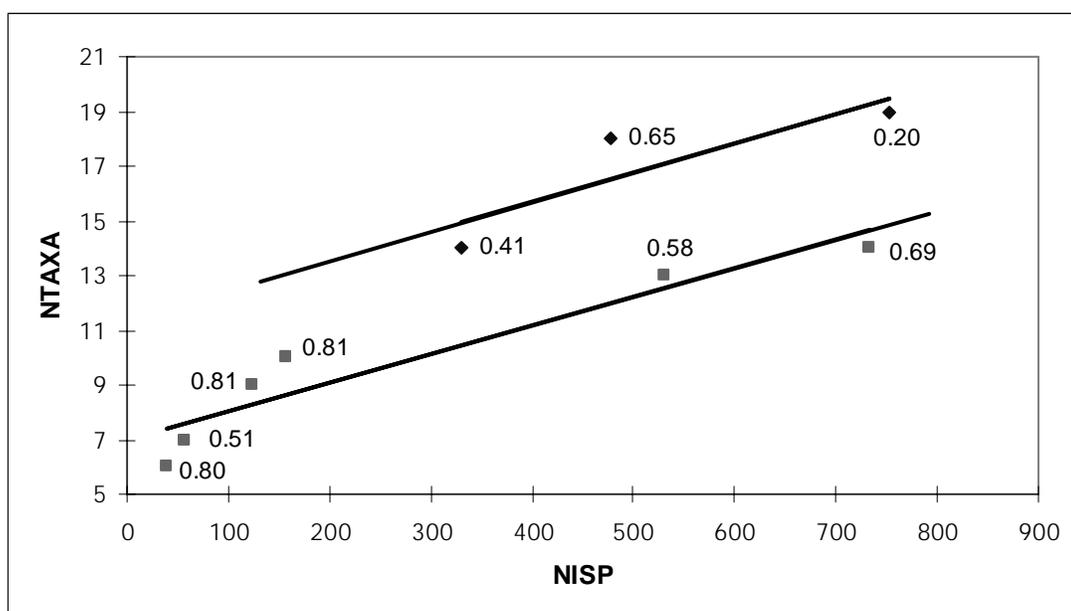
Figure 4.22. The NISP-NTAXA relationship with the proportion of pinnipeds.
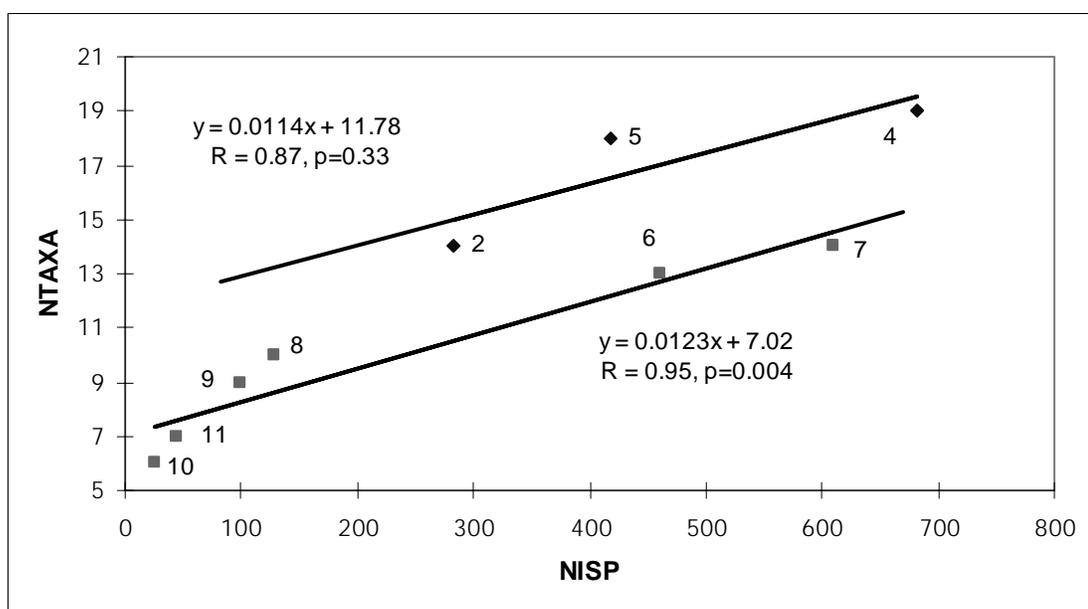
Figure 4.23. The NISP-NTAXA relationships with otariid and dog vertebrae and podials removed.
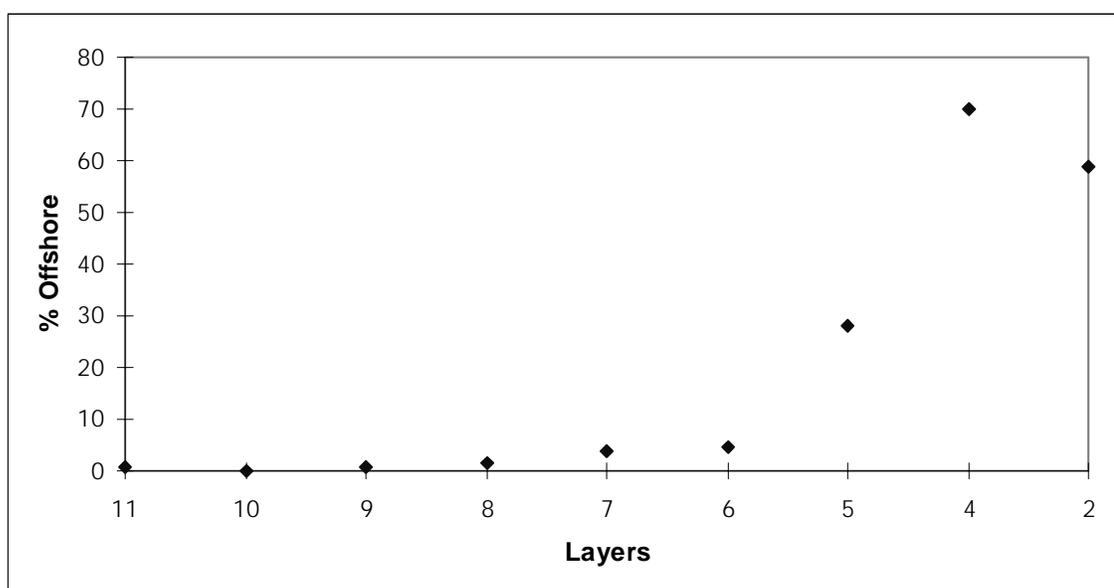
Figure 4.24. The relative abundance of resources from the offshore patch by layer.
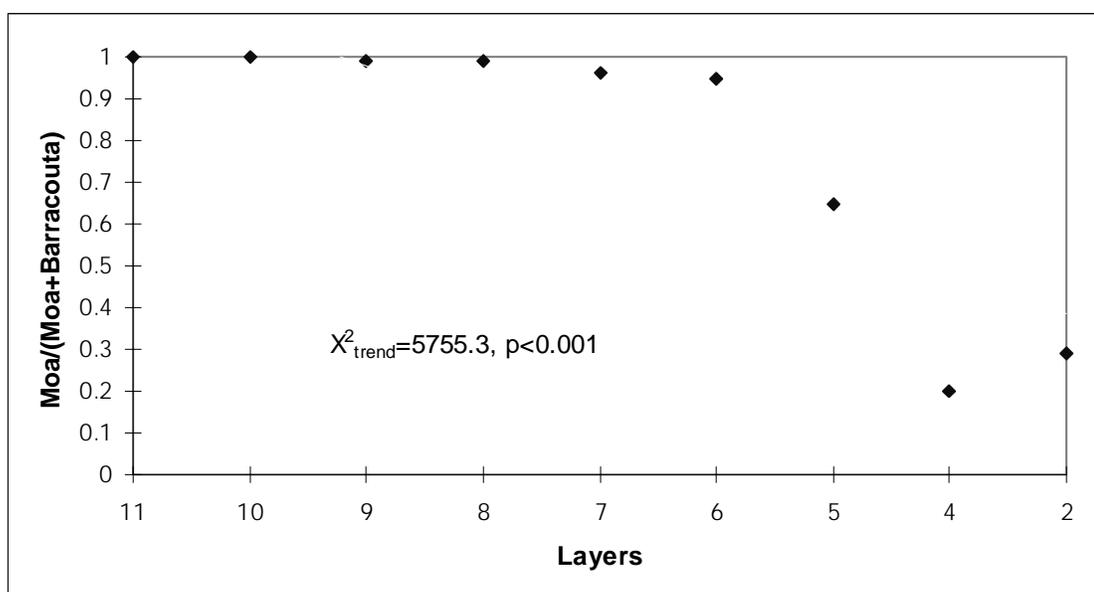
Figure 4.25. The moa-barracouta index by layer.
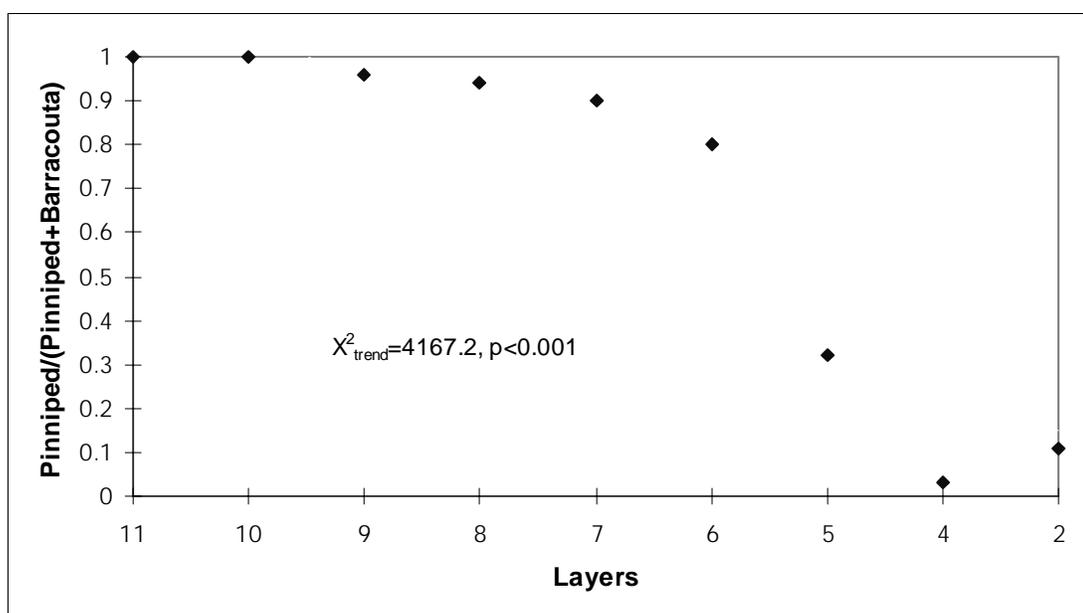
Figure 4.26. The pinniped-barracouta index by layer.
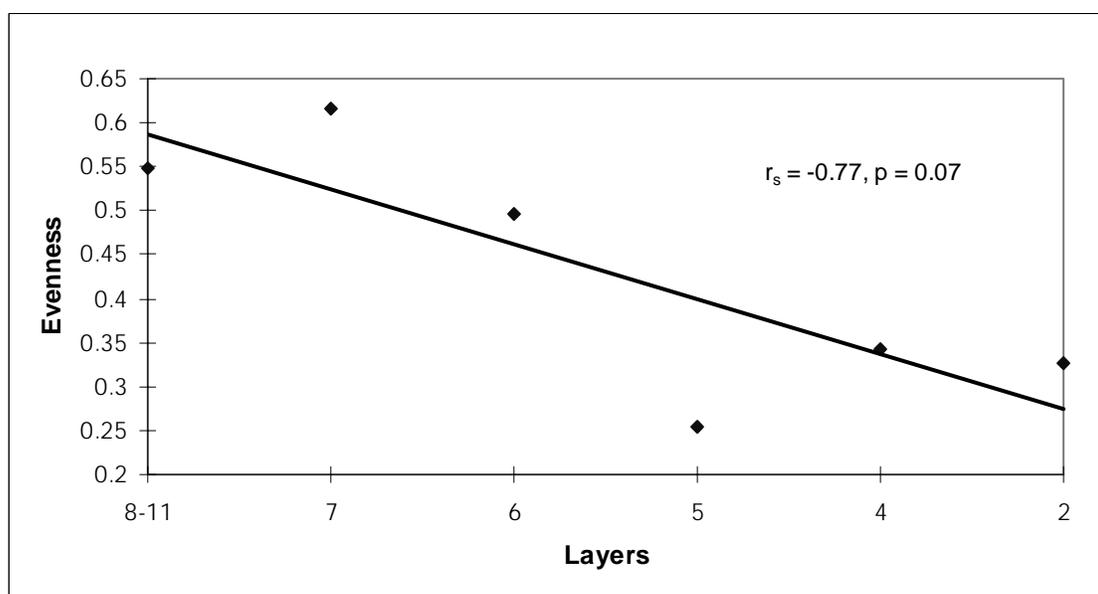
Figure 4.27. Plot of evenness values for the offshore patch by layer.

Table 4.1. Numbers of identified specimens for the inland patch by layer.

Taxon	Layers									Total
	2	4	5	6	7	8	9	10	11	
Moa	540	1394	1398	1781	1537	559	771	89	60	8129
NZ Quail	161	470	199	13	50	5	2		1	901
NZ Pigeon	30	127	29	4	10	2		1		203
Fairy Prion	1	153	1		1					156
Red/Yellow Crowned Parakeet	12	42	36	1	9	1				101
Fluttering Shearwater	2	42		1						45
Tui	6	24	3	3		1	1			38
NZ Pipit		8	5	13	2	2			2	32
Diving Petrel	1	19	1	2						23
Grey Duck	6	12	4		1	2				25
Black-fronted Tern		17	5	2	1					25
NZ Dotterel		15	1		2					18
Weka	2	5	2							9
Saddleback	1	2	1		1					5
Grey Teal	2	2	1							5
Brown Teal		5								5
NZ Snipe	1	3								4
SI Pied Oysteratcher	1	3								4
NZ Robin		4								4
Laughing Owl			1	1	1					3
Paradise Shelduck	1							2		3
Bellbird		1		1						2
Piopio		1	1							2
Freshwater Eel		2								2
Black-billed Gull			1	1						2
SI Kokako		1								1
Banded Rail		1								1
NZ Scaup		1								1
NZ Swan		1								1
Wrybill		1								1
NZ Falcon				1						1
Kaka				1						1
Auckland Island Merganser sp.				1						1
Inland Total	767	2356	1692	1823	1615	572	774	92	63	10872

Table 4.2. Numbers of identified specimens for the coastal patch by layer.

Taxon	Layers									Total
	2	4	5	6	7	8	9	10	11	
NZ Fur Seal	136	144	305	301	504	95	92	24	25	1626
Dog	87	291	39	35	25	5	5	4	10	501
Blue Penguin	17	36	56	70	121	30	5	2	5	342
Blue Cod	39	70	2	55	31	4	2			203
Wrasses	26	94	30	19	13	4				186
Black Cods	3	51	9		15		1			79
Stewart Island Shag	5	10	7	5	4	7	8	1	10	57
Spotted Shag	6	7	4	13	6			1	2	39
Hooker's Sea Lion		2	2	3		3	6	8	4	28
Yellow-eyed Penguin		1	4	8	2	6	2		1	24
Black-backed Gull		5	1	9	3					18
Shore Plover	4	14								18
Scorpionfish	3	13	2							18
Elephant Seal	1	1	2	5	2	3	3			17
Sea Perch		4	8							12
Red-billed Gull		2	3	5						10
Blue Moki	1			3	3					7
Fiordland-crested Penguin		4			2					6
NZ Dotterel		3	1							4
Little Pied Shag	1	1			1					3
Erect-crested Penguin			2			1				3
Rock Cod	2									2
Mullet			1							1
Coastal Total	331	753	478	531	732	158	124	40	57	3204

Table 4.3. Number of identified specimens for the offshore patch by layer.

Taxon	\multicolumn{9}{c}{Layers}	Total
	2	4	5	6	7	8	9	10	11	
Barracouta	1305	5751	757	90	67	8	5			7983
Red cod	103	990	41	7	5	1			1	1148
Albatross	125	413	18	11	8	1				576
Ling	27	92	19	2						140
Trumpeter	2	10	6	5	11					34
Hapuku	4	13	1							18
Gemfish		5								5
Tarakihi		2								2
Warehou	2									2
Offshore Total	1568	7276	842	115	91	10	5	0	1	9908

Table 4.4. The five most abundant taxa (NISP) for each layer in the inland patch. Percentages for each taxon are presented in parentheses.

				Layers			
Rank	9-11	8	7	6	5	4	2
1	Moa (99.0)	Moa (97.7)	Moa (95.2)	Moa (97.7)	Moa (82.6)	Moa (59.2)	Moa (70.4)
2	NZ Quail (0.3)	NZ Quail (0.9)	NZ Quail (3.1)	NZ Quail/ NZ Pipit (0.7)	NZ Quail (11.8)	NZ Quail (20.0)	NZ Quail (21.0)
3	NZ Pipit/ Paradise Shelduck (0.2)	NZ Pigeon/NZ Pipit/Grey Duck (0.4)	NZ Pigeon (0.6)	NZ Pigeon (0.2)	Parakeets (2.1)	Fairy Prion (6.5)	NZ Pigeon (3.9)
4	NZ Pigeon/Tui (0.1)		Parakeets (0.6)	Tui (0.2)	NZ Pigeon (1.7)	NZ Pigeon (5.4)	Parakeets (1.6)
5			NZ Pipit/NZ Dotterel (0.1)		NZ Pipit/Black -fronted Tern (0.3)	Parakeets/ Fluttering Shearwater (1.8)	Grey Duck/Tui (0.8)
Total %	100.0	99.8	99.7	99.5	98.8	94.7	98.4

Table 4.5. Number of identified specimens (NISP) and minimum number of elements
(MNE) for moa leg elements.

Layer	NISP	MNE
2	50	21
4	199	68
5	81	49
6	165	82
7	74	42
8	15	13
9	26	13
10	7	4
11	3	3

Table 4.6. Number of moa skeletal elements (NISP) from the upper and lower layers.

Element	Upper Layers	Lower Layers
Skull/Mandible	23	25
Vertebrae	280	357
Sternum	26	**18
Ribs	188	251
Innominate	48	**32
Femur	16	26
Tibiotarsus	204	**163
Tarsometatarsus	**22	45
Fibula	40	**24
Phlanges	**203	396

**significantly underrepresented (p<0.05)

Table 4.7. The five most abundant taxa (NISP) for each layer in the coastal patch. Percentages for each taxon are presented in parentheses.

Rank	9-11	8	7	Layers 6	5	4	2
1	Fur Seal (63.8)	Fur Seal (60.1)	Fur Seal (68.9)	Fur Seal (56.7)	Fur Seal (63.8)	Dog (38.6)	Fur Seal (41.1)
2	Stewart Island Shag (8.6)	Blue Penguin (19.0)	Blue Penguin (16.5)	Blue Penguin (13.2)	Blue Penguin (13.2)	Fur Seal (19.1)	Dog (26.3)
3	Dog (8.6)	Stewart Island Shag (4.4)	Blue Cod (4.2)	Blue Cod (10.4)	Dog (8.2)	Wrasses (12.5)	Blue Cod (11.8)
4	Hooker's Sea Lion (8.1)	Yellow-eyed Penguin (3.8)	Dog (3.4)	Dog (6.6)	Wrasses (6.3)	Blue Cod (9.3)	Wrasses (7.9)
5	Blue Penguin (5.4)	Dog (3.2)	Black Cods (2.0)	Wrasses (3.6)	Black Cods (1.9)	Black Cod /Blue Penguin (6.8)	Blue Penguin (5.1)
Total %	94.5	90.5	95.0	90.5	91.9	97.9	92.2

Table 4.8. Number of identified specimens (NISP) and minimum number of elements (MNE) for otariid skeletal elements.

Layer	NISP	MNE
2	96	67
4	128	68
5	242	163
6	209	138
7	347	239
8	63	44
9	81	44
10	16	13
11	25	16

Table 4.9. Number of otariid and dog skeletal elements (NISP) from the upper and lower layers.

Element	Upper Layers	Lower Layers
Skull/Mandible	62	140
Vertebrae	**76	185
Ribs	66	153
Scapula	21	33
Humerus	21	**14
Radius	27	31
Ulna	19	**4
Innominate	15	27
Femur	17	28
Tibia	11	20
Fibula	12	13
Metapodials	92	142
Podials	**25	84
Phlanges	148	260

**significantly underrepresented (p<0.05)