Explaining subsistence change in southern New Zealand using foraging theory models
Abstract

New Zealand provides one of the earliest examples of foraging theory applications to archaeological situations. Since this landmark study, significant developments over the last twenty years has led to an increasing number of thorough analyses examining the effects of resource depression on human foraging. In particular, foraging theory analyses have become better at documenting resource depression and integrating butchery/transport studies into these analyses. Using the faunal data from the Shag River Mouth site, I illustrate how these methodological advances have resulted in a more comprehensive understanding of the processes of subsistence change in southern New Zealand.

Keywords
New Zealand; foraging theory; subsistence change
Introduction

Although foraging theory models were originally designed for application in an ecological time frame, a growing number of archaeological studies demonstrate that these models are productive for understanding subsistence change over a larger time scale (e.g., Broughton 1999; Butler 2001; Cannon 2000; Grayson and Cannon 1999; Janetski 1997; Simms 1987; Szuter and Bayham 1996; for a review of anthropological and archaeological applications, see Winterhalder and Smith 2000). Not only have these models have been important in explaining subsistence change, but they also elucidate the dynamic relationship between humans as predators and their prey. In particular, through the concept of resource depression, the decline in the encounter rates of prey resulting from human foraging practices (Charnov et al. 1976), these models examine the impact of human foraging on prey abundances and consequently on human subsistence patterns.

One of the earliest archaeological applications of foraging theory to demonstrate the effects of resource depression comes from New Zealand. Anderson (1981) used the prey and patch choice models of MacArthur and Pianka (1966) and MacArthur (1972) to study shellfish collecting at Palliser Bay on the southern end of the North Island. Anderson assumed that net caloric returns from shellfish were mainly based on size. Many archaeological studies since support this relationship between prey size and net returns (e.g., Broughton 1999; Hames and Vickers 1982; Schmitt and Lupo 1995). Using the foraging models, Anderson predicted that if size was an indication of net returns, then individuals larger than the mean size across all species should be harvested. Indeed, Anderson found that foragers were utilizing shellfish based on size starting with the larger species. As these larger taxa were ‘overexploited’, foragers harvested smaller individuals as well as smaller taxa. After a hiatus in the settlement of the area, the shellfish populations appear to rebound, increasing in size. After the area was reoccupied by humans, the pattern of declining size in the shellfish exploited is repeated. Thus, the effect of human predation was a decline in the abundance of large shellfish species, as well as a reduction in the average size of shellfish taxa exploited.

As an early use of foraging theory models, Anderson’s Palliser Bay research on shellfish clearly demonstrates how the models could be used to understand the effects of human foraging on prey populations, and their subsequent effect on human subsistence patterns. Since then, explicit use of foraging theory to explain subsistence change in New Zealand have been lacking.
However, the interpretations of changes in vertebrate taxa in southern New Zealand appear to be influenced by foraging theory. In this region, resource depletion, particularly of moas and seals has been an important explanation of subsistence change. The remains of moas, an order of large, wingless birds, fill many early middens from archaeological sites in the South Island of New Zealand. Within 200-500 years after human colonization, moas were extinct (Anderson 1989). The abundance of moa remains from archaeological contexts has led some to propose that moas are a prime example of overkill (e.g., Martin 1984). While the exact cause of moa extinction can be debated, it is clear that moas were once an important dietary resource, and that their decline is linked to human foraging practices. Their extinction, along with decline of other taxa such as seals, led to dramatic changes in resource exploitation. Specifically, a shift in exploitation is described from moas and seals to smaller taxa, such as other birds and fish (Anderson 1983; Anderson and McGlone 1989).

This interpretation of changes in vertebrate exploitation in southern New Zealand can easily be translated into a foraging theory context. Within foraging theory models, resource depletion is termed resource depression, or the decline in encounter rates with prey due to human foraging behaviors (Charnov et al. 1979). So, within southern New Zealand, initial subsistence practices focused on large-bodied prey such as moas and seals. With the resource depression of moas and seals, human foragers expanded their exploitation patterns to focus on smaller taxa. This translation of subsistence change is similar to that of Anderson’s shellfish study where prey size is a proxy to net returns, and human predation leads to a shift in the size of the prey exploited.

Since Anderson’s study, there have been significant methodological advances in applying foraging theory models to archaeological data that have allowed archaeologists to better articulate the finer details of the models in a quantitative manner. In this paper, I examine two specific developments. First, over the past twenty years a significant amount of research has focused on documenting the effects of resource depression, providing insight into the process of subsistence change. Second, foraging theory models are being used to explain changes in butchery and transport decisions. In both cases, ethnoarchaeological studies have helped integrate archaeological data into the foraging theory analyses by documenting the variables that affect foraging decision, and identifying potential proxy variables. In addition, archaeological research has greatly improved quantitative measures of documenting change, as well as assessing
alternative explanations. My research takes advantage of these advances to create a more
detailed, and empirically derived picture of subsistence change in southern New Zealand.

I analyzed the vertebrate faunal assemblage from the Shag River Mouth site using foraging theory models to generate predictions about subsistence change resulting from declining abundances of moas and seal. The Shag Mouth site is located on the east coast of the South Island of New Zealand, and has a long history of excavations (Figure 1; Anderson and Smith 1996a). I chose to analyze the faunal sample from the 1988 High Dune excavations because it produced a large dataset from a well-stratified, well-dated, and well-documented excavation (Anderson et al. 1996). The deeply stratified sequence at the Shag River Mouth site also provides an opportunity to examine subsistence change across time at a single locality.

**Documenting the effects of resource depression**

Resource depression is the decline in encounter rates of prey due to the foraging behavior of predators (Charnov et al. 1976). The effects of resource depression can be documented by measuring changes in foraging efficiency and diet breadth (Broughton 1999; Grayson and Cannon 1997). Since the prey choice model predicts that high-ranked prey are always pursued upon encounter, they are particularly susceptible to resource depression (Bayham 1979; Broughton 1994a, 1994b, 1997, 1999). As discussed above, body size is often used as an alternative measure for net returns. Since moas and seals are the largest bodied vertebrates in New Zealand, they can be assumed to be high-ranked prey. As encounter rates with these high-ranked resources decline, they contribute less to the diet. With less focus on higher return prey, foraging efficiency, or the net return per unit of time, declines. If high-ranked prey abundances and foraging efficiency decline significantly, then the mean foraging return rate may drop to the point where adding lower ranked taxa to the diet becomes profitable, thus diet breadth, or the number of resources exploited, may expand.

Before the effects of resource depression can be assessed, an important assumption of the prey choice model must be addressed. The model assumes that prey are distributed homogeneously across space so that each prey type has an equal chance of encounter (Stephens and Krebs 1986). However, in reality, prey distribution is often clumped so that encounter is non-random. In such cases, patches must be defined that create more homogeneous distributions
or random encounter rates. The predictions of the prey choice model can then be applied to each patch separately. Often it is difficult to define patches that represent different environments because many taxa crosscut environmental zones (Broughton 1999; Cannon 2000). As an alternative, researchers have created patches based on hunt types and prey characteristics (Smith 1991; Stiner et al. 2000). However, for the Shag Mouth assemblage, I was able to divide the vertebrate taxa into three analytical patches based on location: coastal, inland and offshore (Nagaoka 2000). The coastal patch is comprised of taxa such as seals, seabirds, and inshore fish that can be exploited from along the shore. The inland patch contains taxa such as moas, pigeons, quails, and ducks that inhabit the region interior of the coast. The offshore patch is comprised of mainly fish species that are taken off the coast, probably via canoes. The effects of resource depression are examined for each patch separately.

Given that moas and seals are high-ranked taxa within their respective patches, the prey choice model predicts that foraging efficiency and diet breadth should change with the decline of these large-bodied, high-ranked taxa. Most measures of foraging efficiency examine the relationship between high-ranked and low-ranked taxa. For example, Anderson’s shellfish data examines shifts in the relative abundance of different sized shellfish as a measure of the change in the relationship between high- and low-ranked prey. However, Anderson’s comparisons of his samples across time were qualitative because they consisted of examining the shape of frequency distributions. More recent studies use indices that summarize the relative abundance of high- and low-ranked taxa in one value for each sample. These values can then be plotted and their relationship to changes across time can be tested statistically.

Two types of indices have been used: an evenness index (Nagaoka 2001) and an index of the proportion of a high- to low-ranked taxon (e.g., Bayham 1979; Broughton 1994a, 1994b, 1997, 1999; Cannon 2000; Janetski 1997; Nagaoka 2000). The evenness index measures the proportional abundance of each taxon (Magurran 1988). The greater the index value, the more even the distribution is across taxa. At Shag Mouth, within the inland patch, the low evenness values for the lower layers show that the distribution across taxa was very uneven (Figure 2). Foraging within the inland patch appears to have specialized on moas during this early period. Over time, the assemblage becomes more evenly distributed across taxa indicating that foraging...
has become more generalized. This shift in evenness suggests that moas are comprising an increasingly smaller proportion of the inland sample, and thus foraging efficiency is declining.

The evenness index is not commonly used to measure foraging efficiency because the rank order of prey in terms of expected net returns is not taken into account (Nagaoka 2001). Instead, the index describes the shape of the frequency distribution when taxa are ordered from most abundant to least abundant. It is thus possible that evenness may not change, even though the relative abundance of high- and low-ranked prey abundances are changing dramatically. Given this limitation, the index is most useful when high-ranked taxa are also the most abundant taxa, as was the situation with the Shag Mouth sample (Nagaoka 2001).

A more commonly used measure is an index that compares the proportion of a high-ranked/large-bodied taxon to a low-ranked/small-bodied one, \( \frac{\Sigma \text{high-ranked}}{\Sigma (\text{high-ranked} + \text{low-ranked})} \). In North America, the most commonly used index to measure changing foraging efficiency is the artiodactyl index, which compares the relative abundance of artiodactyls to the comparatively smaller leporids (Bayham 1979; Broughton 1994a, 1994b, 1999; Cannon 2000 Janetski 1997). The larger the index value, the greater the proportion of the large-bodied taxon in the sample, and thus the higher the foraging efficiency.

To document changes in foraging efficiency in the inland patch at Shag Mouth, moas, as the high-ranked taxon, are compared to the New Zealand quail (\( \text{Coturnix novaeseelandiae} \)), a significantly smaller bird species (\( \frac{\Sigma \text{moas}}{\Sigma (\text{moas} + \text{quails})} \)). The moa-quail index declines significantly over time, indicating that moas are contributing less to the inland sample (Figure 3). Thus both measures of foraging efficiency, the evenness index and the moa-quail index, suggest that early exploitation of resources within the patch specialized on moas with smaller-bodied and thus lower-ranked taxa comprising a larger part of the diet later on. Thus, like the evenness index, the moa-quail index shows that foraging efficiency appears to have declined significantly as the encounter rate with moas declined.

The assumption behind the indices used to document changes in foraging efficiency is that the changes are due to resource depression. However, to determine if resource depression is causing these changes, other alternative explanations must be ruled out. It must be demonstrated that 1) the decline in high-ranked prey abundances are due to human foraging rather than natural environmental change; 2) the advent of technological improvements such as mass capture
techniques has not led to an increase in the capture rate of the low-ranked taxon; and 3) the
decline in foraging efficiency is not linked to increases in the abundance of lower ranked prey
(Broughton 1999; Grayson and Cannon 1999). There is little question that moa decline and
extinction was due not to causes, such as climate change, but to human action through habitat
alteration and predation (Anderson 1989a). There is also no evidence for technological advances
in quail harvesting such as mass capture techniques. According to ethnographic accounts, Maori
captured quail individually by placing snares amongst the grass along tracks formed by the quails
(Anderson 1994:169; Best 1942:237). Thus, only the third explanation requires more careful
examination.

Quail population abundances may have increased during the prehistoric era due to the
creation of more open habitat resulting from widespread deforestation (McGlone 1983). Pollen
analysis has documented an increase in open habitat around the Shag Mouth site during the
period when the site was occupied (Boyd et al. 1996). To determine if quail abundances
increased due to the creation of new habitat, an index similar to the moa-quail index is used to
compare the proportion of quail in the Shag Mouth assemblage is compared to that of a forest
bird, the New Zealand Pigeon ($\Sigma$ quail/$\Sigma$ (quail + pigeon)). The quail-pigeon index increases
slightly, but the change is not statistically significant (Figure 4). Thus, while more favorable
habitat for quails appears to have been created around the site, these changes did not have a
significant impact on the proportion of pigeons and quails within the entire inland patch. Thus,
with the alternative explanations ruled out, it appears that the changes seen in the foraging
efficiency measures are due to resource depression of moas.

Given this decline in foraging efficiency within the inland patch, diet breadth may also
increase. Diet breadth can be measured using richness (Broughton and Grayson 1993; Nagaoka
2001) and by a regression analysis of sample size and richness (Grayson and Delpech 1998;
Nagaoka 2000). Richness measures the number of taxa (NTAXA) exploited. Within the inland
sample, richness increases significantly (Figure 5), and is not correlated with sample size, a
problem which often plagues this measure (Grayson 1984). The regression analysis shows that
the regression line for samples from the upper layers have a steeper slope and a larger Y-axis
intercept than for the samples from the lower layers (Figure 6). The statistically significant
differences between the regression lines indicate that taxa are being added at a greater rate in the
later period. Both measures of diet breadth support the prediction that foraging efficiency has declined significantly so that diet breadth within the inland patch expands to include more low-ranked taxa.

The analysis of the coastal patch data, which is presented elsewhere, also shows a significant decline in foraging efficiency and an increase in diet breadth that appears to be due to resource depression of seals (Nagaoka 2000, 2001). A consequence of the resource depression occurring in the coastal and inland patches is that time allocation across patches shifts. The offshore may have been the patch with the lowest net return rate since it does not appear to have been utilized significantly until late during the occupation of the site. The marginal value theorem (MVT) predicts that if a patch is not used initially, it will be added only after the mean foraging return rate for the other patches declines below the expected return rate of the offshore patch (Charnov 1976). In addition, the MVT predicts that patch residence time will increase as the mean foraging return rate across all patches declines. To determine if this shift in the use of the offshore patch is linked to changes in resource depression in the other two patches, changes in the proportion of high-ranked patch-specific taxa should measure this shift in patch use as foraging efficiency declines (Broughton 1999). For example, barracouta, the most abundant species taken within the offshore patch, is compared to moas from the inland patch ($\frac{\Sigma \text{barracouta}}{\Sigma (\text{barracouta} + \text{moa})}$). The decline in the index indicates that barracouta exploitation in the offshore patch is increasing significantly relative to moas in the inland patch (Figure 7). The index comparing barracouta to seals also shows a similar trend (Nagaoka 2000). Thus, it appears that as foraging efficiency declines within the inland and coastal patches, more foraging effort is being spent in the low-ranked offshore patch. Indeed over time, it appears that the resource depression occurred in the offshore patch as well. The size of barracouta declines

In sum, my research supports the basic interpretation of a shift in the size of prey exploited from larger to smaller prey due to the effects of human predation, which is seen in the decline of foraging efficiency. However, my analysis expands on this interpretation much further. In addition to the significant decline in foraging efficiency, there is an increase in the number of resources exploited to include more low-ranked, i.e., smaller taxa. Also, different patterns of resource use emerge from the three patches. Within the inland patch, foragers specialized on moas until late in the sequence. While in the coastal patch, resource exploitation was more
generalized across several taxa. Only after the foraging efficiency in the other two patches declined did exploitation of resources in the offshore patch become important. Late in the occupation, offshore patch use increased with barracouta becoming the most common resource exploited out of all three patches.

**Explaining changes in butchery and transport patterns**

Over the last twenty years, studies of butchery and transport decisions have become better integrated into general dietary studies through the use of foraging theory models. Simple models of transport decisions predict that the kind and number of skeletal elements transported back to a central place depend upon the net returns or ‘utility’ of those elements and the distance to the home base (Binford 1978). In general, the model assumes that foragers will process large animals in the field and discard parts of the carcass in order to create more transportable units (O’Connell et al. 1988, 1990), which reduces transport costs while maximizing net returns per load (Bettinger et al. 1997; Bird and Bliege-Bird 1997; Metcalfe and Barlowe 1988). Those elements that are transported will tend to be of higher return or utility. For vertebrates, utility is specified for skeletal elements in terms of meat, marrow, and grease (Binford 1978, 1981). Elements are ranked in terms of their utility, and decisions about body part transport are made based on this ranking.

More recently, explanations of changes in butchery and transport decisions have been explicitly linked with foraging theory models, in particular the patch choice models. Instead of examining the exploitation of prey types within and across patches (Charnov 1976), the scale at which the patch choice models are applied is shifted down to treat individual prey items that have already been harvested as patches (Broughton 1999). When the scale shifts from prey types to individual prey items, patch choice models examine how much time a forager spends extracting resources from large prey items before moving on to the next one. When the patch choice models are applied in this way, the assumption is that the prey captured must be large enough so that the animal must be processed to transport. For such large animals, if transport costs are not changing significantly over time, then the MVT predicts that as encounter rates of prey and overall foraging efficiency decline, the amount of time a forager spends extracting resources from a carcass should increase (Broughton 1994, 1999; Charnov 1976). In other
words, foragers will use each prey item more intensively. Thus, foragers should exploit an increasing proportion of each individual animal, starting with the high return portions of the animal and adding more and more lower ranked portions as encounter rates decline. By using the MVT to examine changes in transport decisions over time, changes in skeletal element representation are linked to declines in foraging efficiency that result from resource depression.

The MVT models assume that foragers are consuming their prey at the point of capture, therefore transport costs are not a factor. However, when prey abundances near the site decline to the point where foragers need to go farther afield to obtain these resources, transport costs will be incurred, and will increase as distance increases (Hames and Vickers 1982; Hamilton and Watt 1970). Central place foraging models were designed to handle situations were predators forage out from a ‘home base’ and return their prey to that base for consumption (Cannon 2000; Smith 1991). From these models we can predict that as transport costs increase due to increasing distance to prey, foragers will become more selective not only about what is pursued, but also about what portions of those prey items are returned to the central place. That is, they will tend to forage for larger, higher return items in order to maximize their returns per trip (Orians and Pearson 1979; Schoener 1979). If distance to prey capture is increasing within a patch, then the proportion of each animal returned may decrease, focusing on the parts of the animal that provide higher return rates. These predictions differ from the MVT in that although changes in foraging efficiency are a factor, increasing distance to harvest determines what is transported.

The kinds of elements transported will depend on their rank based on their net returns. Traditionally, elemental net returns have been measured using utility indices the reflect the amount of meat, marrow, and grease associated with each skeletal element (Binford 1981). The relationship between skeletal element representation of an assemblage and nutritional value is examined graphically by plotting utility and %MAU against each other in a graph on an assemblage-by-assemblage basis. As with the foraging efficiency indices described above, Broughton (1999) created a simpler means of measuring changes in utility by creating an index that incorporates both a measure of utility and skeletal part frequency. Mean utility measures the average returns or utility per element for each stratigraphic layer or temporal unit (Broughton 1999). Each layer or sample is represented by a single number, which can then be plotted to examine changes in mean utility amongst samples. The larger the value for the mean utility, the
greater the proportion of higher-ranked elements were being transported. The relationship of mean utility for each sample across time can then be tested statistically.

For the Shag Mouth assemblage, as the largest vertebrate taxa, moas and seals are likely to have been butchered before transport. Two different patterns of transport emerge for the two taxa. The mean utility of moa elements returned to the site increases significantly (Figure 8). Higher utility elements are comprising a larger portion of the elements transported over time, indicating that foragers are becoming more selective about the moa portions returned to the site. A decline in the number of tracheal rings and gizzard stones found at the site, also support the notion that foragers were becoming more selective, field processing moas in such a way as to discard low return portions and transport increasingly higher return elements. The changes in moa skeletal element representation suggest that resource depression of moas occurred locally at first, causing foragers to hunt further from the site. With increasing distance to hunting areas, transport costs increased resulting in more field processing and increasingly selective transport of moa portions.

The pattern of transport for seals is much different. As is shown in Figure 9, the mean utility for seal elements decreases significantly over time. The range of elements transported back to the site expands to include a greater proportion of low utility elements over time. As the encounter rates with seals decline, foragers appear to be less selective, intensifying their use of each individual. The increase in the range of elements transported back to the site indicates that increasing transport costs are not a factor in transport decisions. Instead, it appears that unlike for moas, the use of seals is becoming more intensive rather than selective. More of each individual seal is being returned to the site as overall foraging efficiency declines.

While transport distance is a significant variable in decisions about body part transport, ethnoarchaeological research has identified several other variables such as prey body size, carrying party size, and processing time can also influence transport decisions and must be examined (e.g., Bartram 1993; Metcalfe and Barlowe 1992; O'Connell et al. 1988, 1990). For the Shag Mouth analysis, I examined two alternative explanations for the skeletal element patterns documented: 1) differential preservation of elements that is correlated with survivorship (Lyman 1994); and 2) the advent of efficient transport mechanisms that would have significantly lowered transport costs (O’Connell and Marshall 1989; Smith 1991; Winterhalder, 1981). It is
possible that the pattern of moa and seal elemental transport is an artifact of preservation, where only the densest elements (i.e., those that are least affected by taphonomic factors) are represented. If bone density is a factor in elemental abundance, then density should covary with a measure of elemental survivorship (Lyman 1994). For seals, bone density is not correlated with percent survivorship of elements in any layer. Thus, differential preservation does not appear to be affecting relative skeletal abundances of seals. Bone density studies are lacking for moas or any related species, thus differential preservation cannot be ruled out as a factor in moa element representation.

The use of efficient transport mechanisms such as snowmobiles and cars can greatly reduce transport costs so that they are nearly negligible. Canoes are commonly used for short trips and extended voyages in New Zealand and across Polynesia (Best 1925). The rise in importance of the offshore patch during the latter part of the Shag Mouth occupation demonstrates that canoes were important for obtaining resources. It is possible that canoes were used to transport seal carcasses from rookeries located farther down the coast. Thus, while changes in transport costs were not a factor in seal use, it is unknown whether only local populations were exploited or if an efficient transport vehicle such as canoes was used to exploit populations up and down the coast.

In addition to using the patch choice models to examine skeletal element transport, we can also use them to examine how intensively individual prey items are being used. In particular, using the MVT, we can reduce the scale of analysis one more level to treat individual skeletal elements as patches. When skeletal elements are treated as patches, the prediction from the MVT is that with declining foraging efficiency, time allocation for each element may increase, i.e., each element may be used more intensively (Broughton 1999). Intensive use of individual skeletal elements may be represented by activities such as the extraction of marrow or grease from bones, which requires that bones be broken to obtain these resources. Grease extraction in particular can be a relatively low return endeavor because of the costs of extraction. If marrow and grease extraction increases over time, then there should be a corresponding increase in bone fragmentation. Fragmentation can be measured by comparing the number of bone fragments to the number of elements represented (Lyman 1984, 1994). The ratio of the two measures should increase as fragmentation increases. As Figures 10 and 11 show, fragmentation of both moa and
seal long bones changes little over time. Thus, foraging efficiency does not appear to have declined enough to make bone breakage for marrow or grease extraction profitable.

(don’t like this ending) Foraging theory models are able to integrate the explanations about changes in processing patterns with dietary information by linking these changes to resource depression. As high-ranked prey abundances, individual seals are being used more intensively with a broader range of elements being transported over time. Transport costs are not a factor in transport decisions, however, it is unclear whether this is because only local populations are being exploited or if canoes are being used, negating transport costs to more distant regions. The pattern of moa elements returned to the site is much different. Instead of more intensive use, even in the face of declining moa numbers, foragers become more selective about what moa parts are transported over time. The overriding factor in this case is increasing transport costs. Resource depression is still important, but it occurs locally around the site first. Foragers begin traveling to areas farther from the site to areas with encounter rates greater than near the site. With increasing distance to harvest, foragers return less and less focusing on higher return portions. Over time, these more distant regions are affected by resource depression as well. If occupation at the site continued, it is likely that encounter rates in the further reaches would have declined significantly that it would have been more profitable to hunt local moas and start using them more intensively (Broughton 1999).

Conclusions

Foraging theory models provide a rigorous, explicit, and predictive framework with which to study changes in human behavior. The challenge has been to translate the application of these models from their ecological contexts to archaeological situations. Much research over the past twenty years has focused on the developing the methodology required to do this. As presented in this analysis, the methodology has become more rigorous quantitatively with the development of multiple measures of foraging efficiency and diet breadth that can be tested for their statistical significance. In addition, archaeologists have become better at understanding the intricacies of utilizing the models, identifying and evaluating alternative interpretations, and extending the application of these models into new areas of research, such as the butchery studies, or more recently into non-foraging societies (e.g., Cannon 2000; Gremillion 1996). These advances have
allowed for the application of foraging theory models in a wide variety of contexts. In some regions, foraging theory models are used extensively to address questions of subsistence change (see Grayson and Cannon 1997 and Zeanah and Simms 1997 for a review of research in the region). Since foraging theory studies strive to be rigorous and explicit, they can produce results that are comparable and thus cumulative. With such a database, regional and cross-regional studies can be conducted.

In New Zealand, foraging theory models have the potential to be just as productive. As the Shag Mouth analysis has demonstrated, these models consist of a rigorous methodology coupled with explanatory mechanisms that provide a broader understanding of how and why subsistence patterns change. However, Shag Mouth is just one site. And since studies have shown that environmental variability can produce different patterns of resource use (e.g., Cannon 2000), the patterns of change seen at Shag Mouth may not be representative of all sites in southern New Zealand. Similar studies from multiple sites in the region are required to understand regional variability in subsistence practices. Only until a regional database is developed can we begin to fully understand the impact human foraging had on the New Zealand landscape, and the consequences of these changes on human cultural practices. (kind of skimpy; looks like I just lost steam, which I did.)