Section 7: Chronological change in fishing

INTRODUCTION

When archaeologists study prehistoric societies, they work in three dimensions. Two of these define the spatial domain, and the third is the time dimension. We can distinguish two broad categories of knowledge about prehistoric societies, which are associated with these two domains. The study of archaeological patterns across a landscape at one period of time is referred to as a synchronic study. This is where we examine and reconstruct the functioning of individual societies, tracing the daily round of activities, the annual cycle of subsistence economy relating to seasonal abundances, types of houses and social organisation, manufacture of tools, trading links with other communities, and so on. Synchronic studies are made as if we were riding aloft in a hot-air balloon, looking down on a landscape from above, observing and describing the functioning of one or more human communities.

As soon as we begin to examine the archaeological record from a side-on perspective, tracing changes through time rather than looking at one fixed point in time, much of the synchronic picture disappears and is replaced by a diachronic perspective. This opens up another whole branch of archaeological inquiry, where change is the operative word, and interactions between environment and human communities over long periods become a special focus of interest.

It is a major challenge in archaeology to weld together synchronic and diachronic pictures of past societies. Most archaeologists feel more comfortable working in one of these domains in preference to the other, but both are important. In this Section I am concerned with change – that is, the diachronic aspect of pre-European fishing in New Zealand. At the outset we should ask why should there be any changes at all? Perhaps homeostasis set in very early in the sequence, and people reached a cultural and economic equilibrium with the marine environment. This suggestion is far from the mark. It is well known that there were many and varied changes in pre-European New Zealand. Some of these occurred throughout the length and breadth of the landscape; others were local to particular regions. The general character of cultural change throughout New Zealand is well described by Janet Davidson in her book *The Prehistory of New Zealand* (Davidson 1984). An example of a well developed regional chronology of change can be found in a series of publications describing the prehistory of Palliser Bay (Leach & Leach 1979; Leach 1981). These and many other works chronicle the changing interplay between cultural and environmental forces. In some respects it is surprising that there was so much change, considering the very short time scale of the New Zealand pre-European period.

Two main aspects of change need to be considered in this Section. First are natural changes, whereby modifications occur in the external environment and result in an associated response by human communities. These would include changes in climate, sea conditions, and the abundance of different species. In the short period of New Zealand prehistory we might expect that such changes, occurring naturally, with no impetus from humans, would be relatively minor. It was mentioned in Section 4, however, that there is convincing evidence of significant change in the climate of New Zealand during the last 1,000 years; this will be reviewed shortly. These changes in climate would certainly have influenced land-based aspects of the economy, particularly the growing of imported tropical root crops like kūmara and taro, but the effects on the marine environment have yet to be thoroughly explored. Smith has found a more northerly distribution of some species of sea mammal during the pre-European period, and also evidence of more northerly breeding colonies than today, but rules out environmental causes in favour of hunting pressure (Smith 1985, 1989: 100, 104, 2005).

The second aspect is when change is brought about by human activities. There are two equally important parts to this – the first concerns humans themselves, who participate in various changes over a period of time. For example, they change aspects of their social organisation and culture. This can be observed in the archaeological record. New types of fishing technology may be developed, enabling more efficient capture of certain species. Social prohibitions may be placed on the taking of some types of fish, and these species will mysteriously disappear from later archaeological layers. People may discover new fishing grounds, resulting in a dramatic appearance or increase of a species. The second part arises from the fact that humans affect the environment they live in, and we certainly should expect to see changes as a result of people living in New Zealand during the pre-European period. Because of the short period of habitation in pre-European New Zealand, we might hypothesise that almost all of the observed changes in environment in New Zealand over the last 1,000 years will be due to humans, not to natural influences. To some, this may seem a somewhat unpalatable view, but many lines of evidence support it. In Palliser Bay, for example, archaeological research showed that deforestation by pre-European Māori led to significant changes in coastal ecology, ultimately affecting the very means of subsistence (Leach & Leach 1979: 254). Another example is moa extinction. Anderson concluded "Clearly there is still much to learn about moa extinction, but that it was caused, in various ways, by the human colonisation of New Zealand, can hardly be in any doubt" (Anderson 1989: 187).

What we have here is a complex web of cause and effect interactions involving humans and their natural environment. The interactions cause change; some of the changes take place in human culture and some take place in the natural world. Since fishing is the subject of this volume, the main source of information about any changes are fish bones in archaeological sites. We need to examine these remains for any signs of change in the composition of catches through time and/or in the size of fishes being caught.

In recent years there has been considerable interest in the idea that small prehistoric groups had a significant impact on their local marine environment over a period of time. This topic will be examined further in Section 9, but at this point we need to identify the extent, if any, of changes in fish catch composition and the sizes of fish caught at different periods.

In theory, it is a relatively simple matter to tie down the question of change in fish catch composition. We would simply document catches from as many archaeological sites as we can, organise them in a time frame, and then see if either local or New Zealand-wide changes can be observed. However, there are certain problems in doing this in New Zealand. Firstly, the shortness of the pre-European period has meant that there is greatly reduced confidence in traditional methods of dating archaeological sites. Although the radiocarbon dating method, for example, typically produces a plus or minus figure of 25-50 years, this is merely the laboratory statistical error, relating to the counting of nuclear events (the decay of ^{14}C atoms in a sample). There are many other sources of error involved in radiocarbon dating, which make it extremely difficult to organise layers and sites into a reliable chronology. In many cases, the sites were not dated when they were excavated and, unfortunately, there is no longer any material which is suitable for dating. In this respect the Radiocarbon Laboratory at the University of Waikato is pioneering research on dating archaeological fish bones (Higham & Petchey 2000: 273-275; Petchey 2000; Petchey & Higham 2000). In other cases, dates were obtained before we learned the importance of the factor called *inbuilt-age*, whereby a radiocarbon date can be several hundred years older than the true age of the human settlement the sample came from. In what follows, I have only been able to group sites at best into three broad categories of time (early prehistoric, late prehistoric, and protohistoric).

The second major problem in New Zealand is that very few archaeological sites contain stratified deposits which cover several centuries and contain significant economic debris at useful points in their history. Apart from fortified sites, which may span several hundred years but often contain few or no useful fish remains, most sites in New Zealand are essentially short-duration settlements. This means that it is very difficult to search for changes through time which affected individual communities, unless very careful attention has been given to dating sites which are horizontally rather than vertically stratified. A typical example of horizontal stratification is the series of midden sites at Black Rocks Point, Palliser Bay. Individual sites here are dated to time slots spanning almost the entire range of New Zealand prehistory. This is one place where we can certainly look carefully for possible changes in catch composition and fish sizes through time. However, this is a rare case.

Another thing we need to be constantly mindful of in New Zealand is the question of site function. A midden deposit at one locality may contain abundant evidence of barracouta fishing, and another nearby site, dating to say 200 years later, may contain numerous bones of tarakihi. It would be quite wrong to leap to the conclusion that we have evidence here of a major shift in focus in fishing activities over time. A more plausible interpretation is that both sites are seasonal fishing camps. The one with mainly barracouta would have been occupied during the summer when this species moves inshore, and the second during winter when tarakihi move inshore and can more easily be caught.

NATURAL ENVIRONMENTAL CHANGE

Before discussing observed changes in fish catches from archaeological sites at different periods of time, we need to consider the question of environmental change over the same period. After all, we could easily misinterpret observed changes by attributing them to differences in human behaviour or the product of intensive fishing, when actually the change might be due to natural events, such as climatic change. It is a truism that climate is constantly changing – year by year, and century by century. With a total chronology for New Zealand of 1,000 years at most, the important question here is, not whether change occurred, but whether the degree of change is significant. We need to answer two questions:

1: what quantifiable effect on the fishery does climate change have?

2: what quantifiable climate change has taken place during the last 1,000 years?

As far as the first question is concerned, there is excellent quantifiable information. Some of this has been described in Section 3. Coastal surface sea water temperatures closely follow coastal air temperature, with the air slightly cooler than the sea on average, and short-term fluctuations of air temperature are 3-4 times the standard deviation of surface sea temperatures. From studies of the subtropical convergence it has been found that there is a 5°C change between winter and summer, and this represents a seasonal shift of 11° of latitude. This is a considerable change, and is the reason why fish in New Zealand waters are so strongly seasonal in abundance (see Figure 22). Species tolerant of cold water move north in winter, and species intolerant of cold water move south in summer. So we can safely say that the dramatic changes in seasonal abundance of fish around New Zealand correspond to a 5°C change in surface sea water temperature.

A second important aspect of surface sea water temperature concerns recruitment. Once again, quantifiable information is available for some species, and data for snapper were given in Section 4. An increase of 2.5°C over the summer period corresponds with a ten-fold change in the abundance of one-year old fish (see Figure 40) and the relationship is exponential. At 17°C, the recruitment rate for one-year old snapper is close to zero. Once again, here is a rough yardstick against which to examine archaeological data – for snapper, a 2.5°C change represents the difference between abundance and nothing for a particular region.

One final point on this first question is that growth rates, of snapper for example, vary geographically. Fish from Tasman Bay and the west coast of the North Island grow faster and reach a larger average size than elsewhere (Paul & Tarring 1980; Annala *et al.* 2000: 412). We must therefore expect that growth rates may have changed in the face of any climate change.

Answering the second question (what quantifiable climate change has taken place) is a lot more difficult than the first, and controversial. Lockerbie (1959: 75) first drew attention to the importance that climate change would have had for pre-European Māori. He believed that it was of the order of 4-5°F (2.2-2.8°C), following Holloway's suggestion published by Golson (1957: 273, citing Raeside 1948 and Holloway 1954), and that the climate of Otago during the time of the moa-hunters about AD 1200 would have been comparable to that of the Bay of Plenty in the 1950s. This was a bold claim, hotly debated then, and little concrete archaeological evidence was gathered at the time to support or refute it.

Hendy & Wilson (1968) produced an uncalibrated palaeo-temperature curve from analysis of $\delta^{18}O$ isotope values on speleothems[1], which appeared to show the presence of climatic changes in New Zealand comparable to European events known as the Medieval Warm Period (sometimes called the Little

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[1] A speleothem is a secondary mineral deposit in a cave, such as a stalactite or stalagmite, formed by water action.

Climatic Optimum) and the Little Ice Age (Lamb 1965; Fagan 2000). This isotope curve was incorporated in a review of climatic change in New Zealand by H.M. Leach & Leach (1979), suggesting that there was reasonable agreement with evidence from glacial advances and retreats in the South Island (Figure 88). These two climatic events were found to be useful when interpreting the prehistory of Palliser Bay (B.F. Leach & Leach 1979; Leach 1981). The paper by H.M. Leach & Leach (1979) was roundly criticised by Burrows (1982), who suggested abandoning Euro-centric terms such as Little Ice Age in favour of developing a local framework. There is a danger of losing sight of the main objective here, which is to see if there are aspects of the climatic history over the last millennium that were of sufficient magnitude to have impacted on human culture and, in this particular case, on the fishery. Setting aside for a moment minor fluctuations in the climate curve, the two broad brush questions which we need to address here are these: During the early period of pre-European Māori occupation of New Zealand were climatic conditions especially favourable for the type of economic system which prevailed, and was there a period towards the end of the pre-European era when conditions worsened? There has been cautious acceptance by archaeologists of both these propositions (e.g., Davidson 1984: 37), but the details have been the subject of constant review.

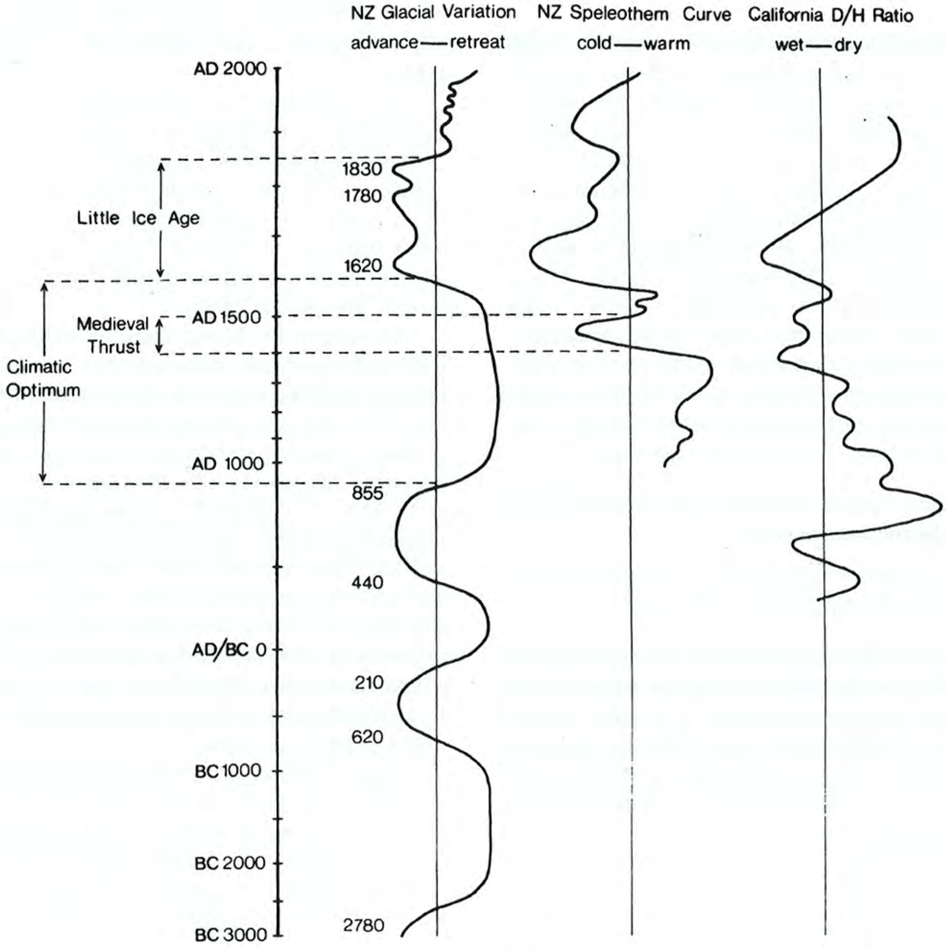

FIGURE 88

Comparison of Wilson's speleothem temperature curve with evidence of glacial advance and retreat, suggestive of a Little Ice Age and a Little Climatic Optimum in New Zealand. The D/H ratio is a proxy for rainfall. (from H.M. Leach & Leach 1979: 231).

Since Leach and Leach published the review referred to above (1979) there have been numerous scholarly publications confirming the existence of climatic fluctuations during the past millennium, using a range of different proxies for air temperature, rainfall, and surface sea water temperatures (one excellent review is by Jones *et al.* 1998), although it is generally agreed that southern hemisphere records are not as good as those in the northern hemisphere.

> Scaling of the hemispheric composite to the Northern Hemisphere temperature records suggests that the Little Ice Age temperatures were about 0.45-0.50°C colder than the mid-20th century warm period and that mean temperatures between 1000-1200 were only about 0.20°C warmer than the Little Ice Age. ... Similar conclusions can be derived from the sparser Southern Hemisphere data set of climate change over the last millennium. ... we believe that the term Medieval Warm Period still has value, as long as it is restricted to the northern hemisphere (there is insufficient documentation as to its existence in the Southern Hemisphere) (Crowley & Lowery 2000: 54).

Jones *et al.* (1998: 464, 469) conclude that there is less evidence of a distinctive event deserving the appellation of Medieval Warm Period, but that a Little Ice Age is clear globally:

> The coldest year (globally) of the millennium was 1601 with the coldest decade 1691-1700 and coldest century the seventeenth (Jones *et al.* 1998: 464).

They also cite evidence that the Little Ice Age may have had two phases, with some regions having the most severe conditions in the seventeenth century, while others were more greatly affected in the nineteenth century (Jones *et al.* 1998: 464, 469). The cause or causes of these observed changes in climate over the past millennium remain obscure, although solar irradiance and periods of more frequent volcanic eruptions are proposed. One phenomenon of special significance in the south Pacific region is the changing frequency of El Niño (warm events) and La Niña (cold events), and the possibility that such variations could cause longer-term low-frequency changes in climate (Mann *et al.* 2000; Jones *et al.* 2001). In particular, temperature fluctuations in New Zealand are in opposite phase to those in the tropical East Pacific (Folland & Salinger 1995: 1217).

There are now reasonable estimates of solar irradiation levels for the past 1200 years, based on a combination of ^{10}Be measurements of South Pole ice (Raisbeck *et al.* 1990) and the atmospheric ^{14}C record from tree rings (Bard *et al.* 1997) to produce a sequence of Total Solar Irradiance (Bard *et al.* 2000). The series has low frequency changes mirrored by speleothems and other proxies of climate (Mann *et al.* 2000; see also Figure 91 below).

Dendroclimatic studies, based on tree ring-width chronologies, have been notably poor in revealing historically recorded climate change, but a study using cubic smoothing splines produced good correlations for the period 1731-1862. Salinger *et al.* concluded:

> Warm season temperatures show considerable variability at the beginning of the record, followed by cool conditions in the 1760s and around 1790. Temperatures then increase somewhat up until the first decade of the 1800s, then cooling occurs until 1820, and warming to the mid-1830s. The period 1840 until the early 1860s is one of the coolest in the record (Salinger *et al.* 1994: 1142).

This conclusion is supported by historical records of glacial movements in New Zealand.

> Thus the cold temperatures recorded in the early part of the New Zealand temperature record appear to have been general for the preceding 100 years. The more expanded South Island glaciers and cold summers indicated by tree rings suggest New Zealand experienced the colder period of global climate which has been dubbed the 'Little Ice Age' as well, and that the early temperature records caught the end of this event (Salinger 1991: 49).

EARLIEST HISTORICAL INFORMATION IN NEW ZEALAND

In Europe, the Little Ice Age is generally thought to have lasted from about AD 1500 to 1800 (Barry 1978: 156). If New Zealand experienced similar conditions to Europe at this time, there should be some evidence of this in climate records kept by Captain Cook and his party, since he visited these shores in the period 1769-1777. Helen Leach carried out a detailed analysis of the day-to-day climatic records made by Cook and this revealed a pattern which, by today's standards, would certainly be described as unseasonable.

> The significant features of the weather in the summer of 1769-1770 were the short-lived anticyclones, the number of low pressure systems crossing the North Island, the possible passage of deep depressions close to the south of the South Island at

a time of year when they are normally far to the south of New Zealand, the prevailing disturbed west to southwesterly air stream, the apparent survival of active fronts as far north as Northland, and the occurrence of a tropical cyclone in late December when the normal cyclone season is late summer-early autumn (Maunder 1971: 221). Cook's general impression of Marlborough Sounds' weather was such that on April 25, 1773 he wrote "For the Eight days past we have not had a single shower of rain, a circumstance that I believe is very uncommon here especially at this time of the year" (Cook 1969: 127). There is certainly no trace in his records of the "large, slow moving, deep warm-type anticyclones stagnating over New Zealand and the adjacent seas" (Hill 1971: 1, 6) which bring about long dry spells and characterise a hot, settled summer (H.M. Leach & Leach 1979: 233).

By itself this is not necessarily convincing, but there are also other records in the journals of Cook and his companions that suggest colder conditions in the mid to late eighteenth century. It should be remembered that their visits to New Zealand were mainly in the summer months[2], and those were the weather conditions that they were most familiar with here. The many references to the presence of snow capped peaks are all during the summer months. For example in January 1770 Cook records:

> In the night had some Thunder Lightening and rain. At 5 AM saw for a few minutes the Top of the peaked Mountain above the Clowds, bearing NE; it is of a prodigious height and its top is cover'd with everlasting snow (Cook 1968: 232).

This peak was Mount Taranaki (Egmont). Snow occasionally covers its summit during summer, but would not today be described as everlasting. Cook further notes in February 1770:

> Over this land appear'd a prodegious high mountain the summit of which was coverd with snow (Cook 1968: 248).

This was Tapuae-o-Uenuku, in the inland Kaikoura range. Today it occasionally gets a small covering of snow in the summer, but it does not last for long. This mountain is mentioned by Cook and others in the party in several journals as a spectacular landmark for them at sea, visible from long distances, especially because it was always covered with snow (Banks 1963 (I): 464; Cook 1969: 252). A typical example is a comment by Banks, 12 February 1770:

> This morn the seamen all imagind that we had passd the mouth of the streights when to our surprize the great snowy hill which we had seen on the 7th appeard right ahead. At nigh[t] however we were abreast of the streights which was it not for the hill might be difficult to find in the Cloudy weather (Banks 1963 (I): 467).

Some of the observations of snow-clad peaks from out at sea during Cook's voyages may have been the seaward Kaikoura mountains (Figure 89), rather than Tapuae-o-Uenuku in the inland Kaikoura range. These are equally spectacular when covered in snow, and visible from great distances.

FIGURE 89

The snow-clad seaward Kaikoura mountains from out at sea, a view which was familiar during Captain Cook's visit to New Zealand. Photo courtesy of Rob Suisted, image #20348OP37.

There are similar records by Cook of Tapuae-o-Uenuku being covered in snow in October and November 1773 (Cook 1969: 284, 580). Furneaux made a most interesting observation after rounding Cape Jackson and entering Queen Charlotte Sound on the way to Ship Cove in April 1773: "As we sailed up the Sound saw the Tops of high mountains covered with Snow, which remains there all the year" (Furneaux 1969: 737). It is uncertain which mountains Furneaux was observing here. Was this Tapuae-o-Uenuku or some of the hill peaks at the head of Queen Charlotte Sound? Snow in April in either area would be most unusual in today's conditions, and certainly would not remain all year.

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[2] The various vessels visited as follows: First voyage October 1769 to March 1770. Second voyage March to June 1773, November to December 1773, October to November 1774. Third voyage February 1777.

Forster, commenting on the vegetation on the hills above Ship Cove had this to say on 12 November 1773:

> The higher we came, the more similarity found we with *Dusky-Bay* in regard to the plants, that grew there near the waters-Edge, which plainly proves, that the Summits of the hills in this Cove, have the same Climate with the low Country in *Dusky-Bay* (Forster 1982: 421).

From the summit of the hill he obtained a commanding view and commented that "The hills beyond the bottom of the Sound were covered with Snow (Forster 1982: 422). It is uncertain which southward peaks can be seen from this height, but it may have been Tapuae-o-Uenuku. Unfortunately, modern visibility is generally too poor to be able to reproduce these sightings. Three-dimensional terrain software might enable the peaks to be identified with greater certainty.

The final piece of historical information relevant to this matter is a comment made by Dieffenbach in August 1839, while exploring the hills behind Ship Cove, just as Forster had done 66 years earlier. He climbed two peaks. The first, to the south-west of the anchorage, was clear of forest on the top and was estimated by trigonometry to be 900 ft high (274 m). The second peak was wooded on the top, bearing north-west from the anchorage, and estimated to be 2093 ft (638 m) by measuring the temperature at which water boiled at the top. It is not easy to be certain of the identity of either of these two peaks from Dieffenbach's information. The taller of the two would probably be Mt Furneaux, which is the highest peak in this general vicinity at 823 m (2700 ft). Dieffenbach records:

> There was snow on the summit, and the thermometer stood at 41° Fahrenheit (Dieffenbach 1843 (I): 29).

High peaks in the Marlborough Sounds do occasionally get a light dusting of snow in the winter which might stay for a few hours, but this is very rare.

It is reasonable to conclude that historical information for New Zealand in the period of AD 1769 to 1839 provides consistent evidence for believing that summer weather conditions were considerably cooler and less settled than during the early twentieth century.

RECENT SPELEOTHEM EVIDENCE IN NEW ZEALAND

Considerable research has been carried out on speleothems to extract climatic data in the Holocene since the Wilson curve first appeared (Figure 88). Two of these studies are of special relevance to the last thousand years. They are illustrated in Figure 90, and are parts of much larger time sequences (Williams *et al.* 2004, 2005). For the portion illustrated here, covering the period AD 1000 to 2000, the time sequence was obtained by interpolation using four radiocarbon dates for the Paturau curve and three for the Waitomo curve. The differences between the two curves are partly a consequence of differences in the resolution of dating and isotope analysis. The Paturau curve is more closely dated and sampled than the Waitomo one, so it is considered more reliable at this state of research on the samples. This is the reason that the two curves do not appear to be completely synchronous. For example, the most negative $\delta^{18}O$ value (coldest conditions) appears at around AD 1680 in the Waitomo curve and at about AD 1620 in the Paturau curve, but they probably occurred at the same time, so the 60 years apparent difference may not be real. "Both probably represent the influence of the Little Ice Age that may have been more strongly felt in Paturau than at Waitomo" (Williams 2005: pers. comm.).

Despite the difference in detail between these two curves, they provide further compelling evidence that there was a period of warmer climate in New Zealand during the earlier part of the last 1000 years, followed by a period of colder climate later in the sequence. In a recent publication on these speleothems, Williams *et al.* comment as follows:

> A marked positive $\delta^{18}O_c$ excursion characterized the late Holocene between 0.71 and 0.57 ka, and it coincided with a positive $\delta^{13}C_c$ excursion at 0.66 ka. This suggests that the interval was warm and dry, so reduced precipitation may be partly responsible for the relatively high $\delta^{18}O_c$ values. This warm peak is a little later than the equivalent in western North Island..., but both could represent a delayed southern counterpart of the Medieval Warm Period of western Europe, although Hughes and Diaz... and Jones et al. ... found little evidence to support its global occurrence. Nevertheless, in Tasmania, Cook et al. ... identified a period of particularly warm summers from 1.1 to 0.5 ka from the tree-ring record. Temperatures subsequently cooled rapidly, judging by falling $\delta^{18}O_c$ values, to a trough at about 0.4 ka that appears to correspond with the Little Ice Age in Europe..., although this end of our record is based only on two speleothems, so detail is less secure than elsewhere in the composite series (Williams *et al.* 2005: 314).

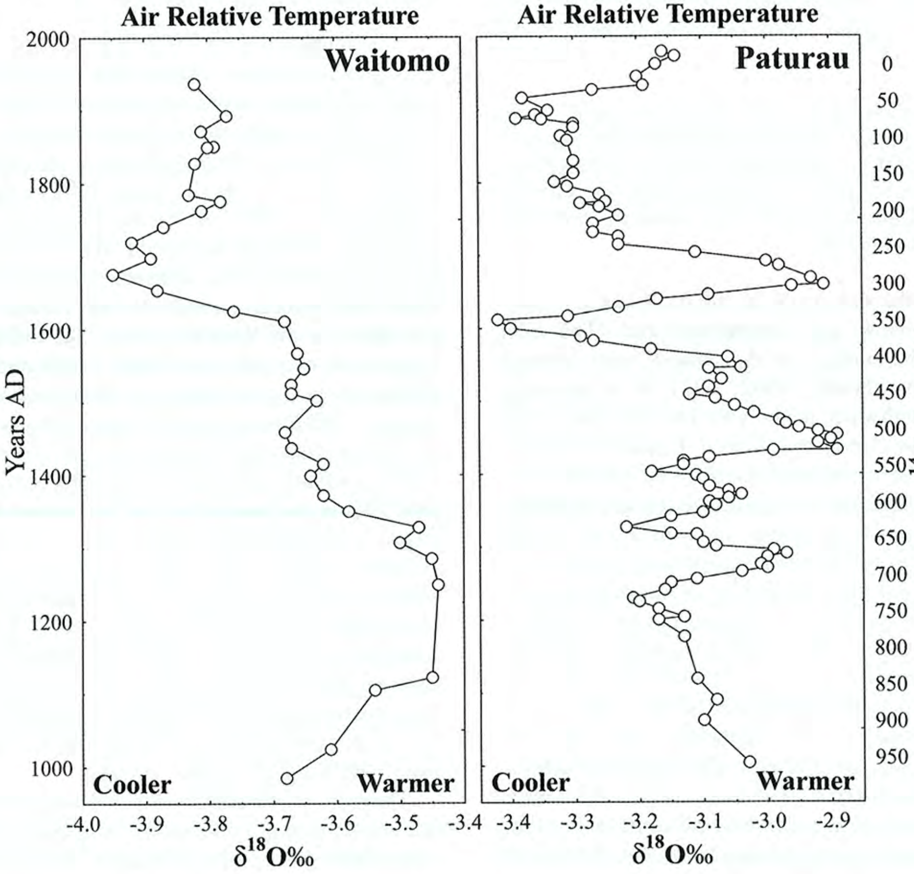

FIGURE 90

Two speleothem temperature curves from Waitomo (west central North Island) and Paturau (northwest South Island), more convincing evidence of a Little Ice Age and a Little Climatic Optimum in New Zealand (courtesy of Paul Williams).

This research is continuing, with refinements in dating these two speleothems, as well as additional curves from Hawkes Bay and Fiordland (Williams 2005: pers. comm.). The results are eagerly awaited.

ARCHAEOLOGICAL ISOTOPE EVIDENCE IN NEW ZEALAND

Another useful line of evidence about environmental change in New Zealand over the past 1000 years relates to surface sea water temperatures. This is of direct relevance to pre-European fishing. This research was prompted by the discovery of an unusual faunal collection at an archaeological site (R26/291) near Raumati on the south-west coast of the North Island. The fish remains were largely kahawai and red cod, with low occurrence of snapper and other species that would be expected on this open sandy beach area (Davidson & Leach 2000; Leach *et al.* 2000a). The Raumati assemblage was in considerable contrast with the fish remains from the nearby Foxton site (59 km to the north), which were almost entirely snapper (80%, see Davidson *et al.* 2001: 80). The Raumati site would be described by most archaeologists simply as a shellfish dump, because at first sight it appeared to be composed entirely of shellfish, and in particular of tuatua (*Paphies* spp.). Collection of large quantities of the midden during a salvage operation enabled careful laboratory analysis, which revealed considerable diversity in the fauna, contrary to first impressions. Not only were the fish remains unusual for the area, but it was found that the tuatua included significant quantities of the sub-tidal species *Paphies donacina* (24%, see Leach *et al.* 2000a: 8), which are very rare in archaeological sites. The more common species, *Paphies subtriangulata*, is inter-tidal and easily gathered at low tide. *Paphies donacina*, on the other hand, only occurs in deeper water beyond tidal range and is normally only gathered when washed up on the beach after storms. The presence of this species therefore suggested that extended stormy weather prevailed when the site was occupied by pre-European Māori. Moreover, the Foxton site, which also contained large quantities of tuatua, was found to contain no specimens of *Paphies donacina* (Leach *et al.* 2001a: 16).

In short, there was a notable contrast between these two nearby archaeological sites. Radiocarbon dating showed that the Foxton site was occupied from about AD 1200 to 1450, and the Raumati site from about AD 1450 to 1680 (Leach *et al.* 2000a: 32); that is, the former falls in the period of the supposed Medieval Warm Period in Europe, and the latter in the period of the Little Ice Age. They therefore offered an excellent opportunity to search for clues about possible changes in surface sea water temperature by analysing the oxygen isotopes $^{16}O/^{18}O$ in shellfish using mass spectrometry.

Tuatua is an ideal species for examining $\delta^{18}O$ as a proxy for surface sea water temperature because it lives in open coastal waters and is not subject to exposure to the high temperatures that can occur in estuaries. The species lives for about 4 years, and a grab sample of 10 valves from any one layer in an archaeological site should therefore cover a period of a minimum of 4 years and a maximum of about 40. After careful cleaning, each sample of 10 left valves was powdered and then randomly split repeatedly until a suitable sized sample was obtained for oxygen isotope analysis. It could therefore reasonably be assumed that the final sample is representative of a period of about 4 to 40 years. This is a somewhat unusual way to obtain a palaeotemperature measurement. Most research aims to obtain results for as fine a division of time as possible. In archaeological research this is most often because of its use in seasonal dating. However, in this case I was deliberately trying to obtain a mean temperature integrated over several years to smooth out short term fluctuations. Because most of the growth of shellfish is during summer, this mean integrated temperature does not equate to a mean annual value, but is biased towards summer. This is a point noted for a number of proxy measurements, including coral and tree-ring data (Jones *et al.* 1998: 464, 468).

The results of this analysis are illustrated in Figure 91.

The Foxton site is in the vicinity of the Manawatu River and tuatua living on the coast nearby can be expected to have had some fresh water mixed in their marine environment. The Raumati site, on the other hand, has no river nearby. This difference was confirmed by $\delta^{13}C$ values on tuatua at the two sites, with Foxton showing some fresh water dilution, which was corrected for in calculating surface sea water temperatures. Hendy, who carried out the analysis commented:

> I note that there is a significant difference in age, and I would expect temperature differences of several degrees between 1200 and 1550 AD (Hendy 2000: pers. comm.).

He recommended a correction, dw, of 0.15 for the Foxton series in the calculation:

$$T°C = 16.9 - 4.2*(dc-dw) + 0.13*(dc-dw)^2,$$ where dw=0.15

The estimated mean integrated sea water temperatures in which the shells lived at these two sites are presented in Table 14.

Cat. N.°	Provenance	$\delta^{18}O$	$\delta^{13}C$	Raw °C	Corrected °C
AK995	Raumati Bag 4	1.38	1.41	11.4	11.4
AK994	Raumati Bag 2	1.24	1.38	11.9	11.9
AJ631	Foxton Period 3 (Late)	0.77	1.11	13.7	14.3
AK992	Foxton Period 2 (Early)	0.71	1.19	14.0	14.6
AK993	Foxton Period 1 (Early?)	0.72	1.23	13.9	14.5

TABLE 14

$^{16}O/^{18}O$ Analysis of Tuatua Samples from Two Archaeological Sites.

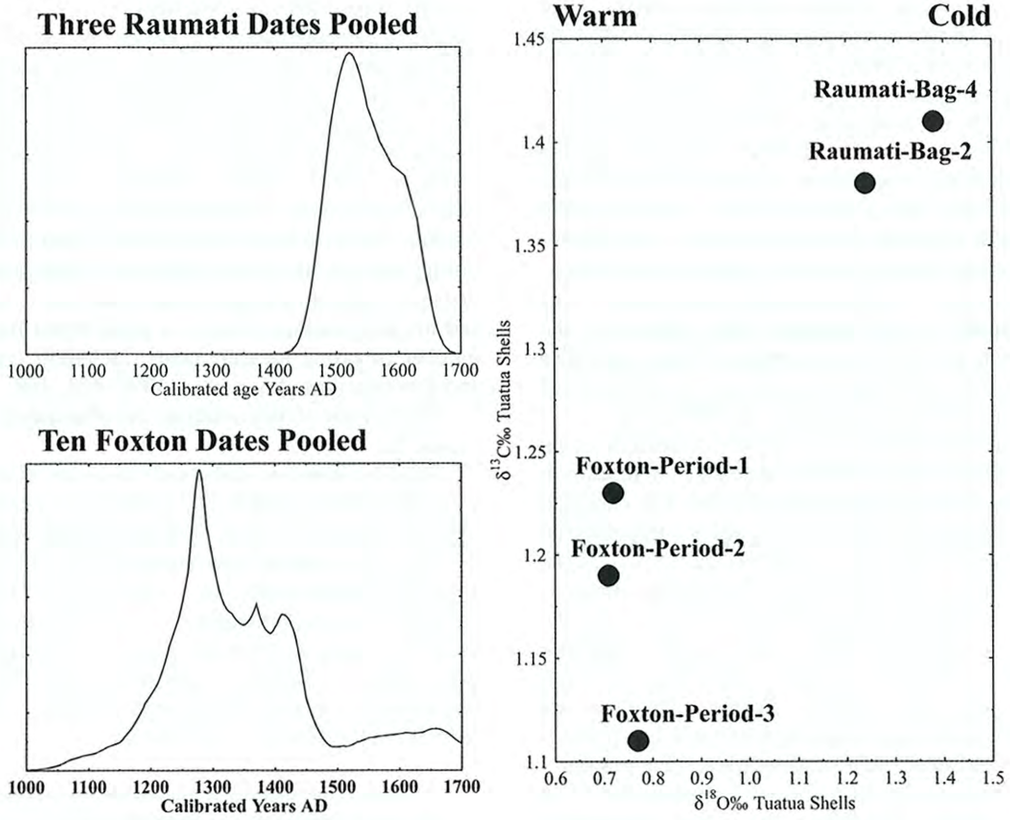

FIGURE 91

Carbon $\delta^{13}C$ and Oxygen $\delta^{18}O$ isotope results for shell samples from archaeological sites at Foxton and Raumati, together with the pooled radiocarbon dates (from Leach *et al.* 2000a: 32, 35).

The mean integrated sea water temperature at Raumati is estimated to have been 11.7° C, whereas at Foxton, some 300 years earlier, the estimated value is 14.3° C. That is, there has been a decrease of 2.6° C.

Further information has been obtained from a series of shell middens, investigated during salvage work at Site R25/13 at Pukenamu near Te Horo, 17 km north of the Raumati site. At the time of the investigation, the site appeared as a series of shell midden scatters about the slopes of a low, largely unconsolidated, dune system. The surface of much of the area under investigation had already been modified by bulldozer activity. Six discrete midden areas (A to F) were recorded. Intact midden was sampled at Areas B and C. Area F consisted of 11 small patches of midden; most of these were sampled. Four radiocarbon dates were obtained from three middens (Area B, upper and lower layers, Area C, and Midden 3 in Area F). Midden 3 was the oldest, closest to Foxton in age; the two layers of Midden B were close to Raumati, and Area C returned a date of late prehistoric or early historic age. Mean integrated sea temperatures were obtained for six shell samples from these dated contexts. These additional analyses are consistent with the results obtained from Foxton and Raumati.

These archaeological proxies for surface sea water temperatures are plotted out in Figure 92, along with the three speleothem curves discussed above, and the solar irradiance curve (after Mann *et al.* 2005, raw data available from IGBP PAGES/World data center for Paleoclimatology Date Contribution Series # 2005-035).

Clearly this is a promising field of research, and shows once again how valuable these midden dumps are for environmental research.

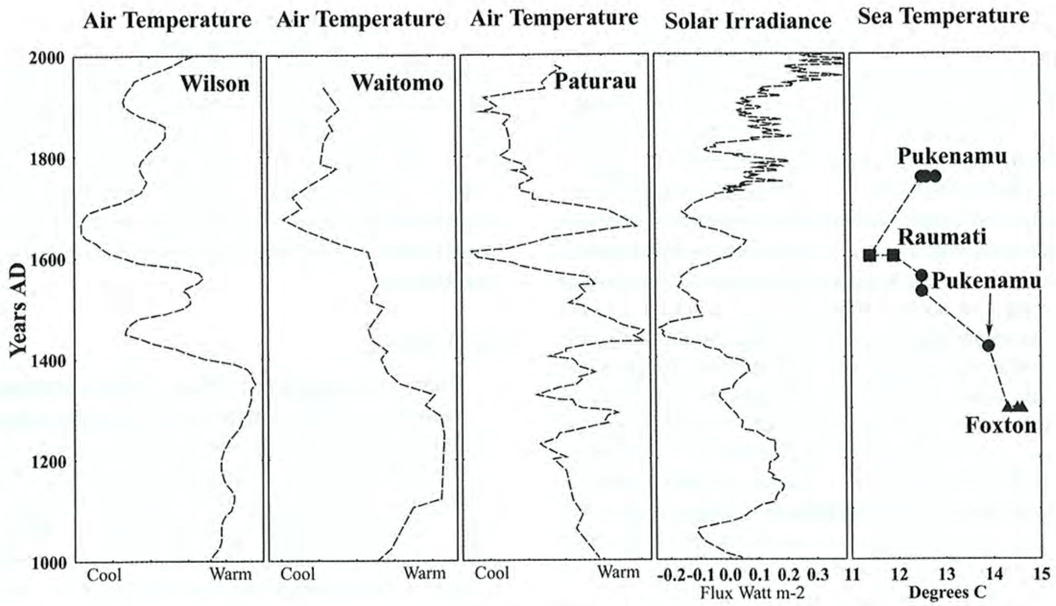

FIGURE 92

Integrated annual surface sea water temperature values for the Horowhenua coastline from analysis of $\delta^{18}O$ in archaeological specimens of tuatua at different periods of time (right), compared with several assessments of air temperature and solar irradiance over the same period. See text for details.

OTHER ARCHAEOLOGICAL CLUES IN NEW ZEALAND

As mentioned above, there was a notable difference in the occurrence of snapper in the two sites at Foxton and Raumati. Snapper at the Foxton site ranged from 88 to 96% of total MNI in the deepest part of the site (early prehistoric), and contributed 73% in upper deposits, dating to the middle prehistoric (Davidson *et al.* 2001: 81). In contrast, the Raumati site has less than 5% snapper, and dates to late prehistoric times. This contrast is very surprising considering that the coastline in both places is so similar. These are not the only archaeological sites where early deposits show high abundance of snapper and later ones show low abundance. This has recently been noted in Tasman Bay by Barber who comments:

> For twelfth- to fourteenth-century AD central New Zealand assemblages, including Tasman Bay, snapper is generally dominant at over 50 percent of the catch. By contrast, snapper at most shares dominance in archaeological fish collections from later sites of Tasman Bay and eastern Golden Bay. More generally, snapper is relegated to minor species rank below red cod (especially) and barracouta in these later sites. The exact cause or causes of this change in the catch are not conclusively resolved to date (Barber 2003: 442).

In Tasman Bay, early deposits such as Rotokura Layer 4 and Anapai have abundant snapper (78% and 69% respectively), whereas late sites have hardly any snapper (3% and 1% in two sites at Awaroa Inlet and 3% at Appleby). Only one of three late sites at Tata Beach in eastern Golden Bay, immediately to the north-west of Tasman Bay, contained any snapper (1%). The possibility that the various sites in Tasman Bay were occupied at different seasons does not provide a satisfactory explanation for the changes in proportions of snapper. Tasman Bay is a spawning ground for snapper with a resident population available year round. The Horowhenua coast receives its snapper from spawning grounds further north around Taranaki, and there is some seasonal movement of young snapper southwards during summer; however, older snapper are resident year round. Again, seasonal changes could not account for the observed dramatic changes in abundance.

The simplest explanation for such a dramatic change in snapper abundance from one end of the prehistoric period to the other in Tasman and Golden Bays is that the species died out locally as cooler conditions began to prevail during the Little Ice Age. The estimated drop in mean integrated surface sea water temperature over the 300 year time interval between Foxton and Raumati is 2.6ºC. Although this is consistent with Hendy's anticipated result (cited above), it is well above suggested air temperature changes over the same period derived from speleothem research. However, even though air and sea water temperatures are correlated (discussed in Section 3), subtle changes in climate can cause movement in current circulation patterns, which in turn can result in much larger changes in local sea water temperature. A period of stronger westerly winds, which would be experienced during the Little Ice Age, would bring colder water in to the west coast of New Zealand and could easily account for considerable lowering of surface sea water temperatures, well above changes in air temperature experienced on the land. Even so, this apparent change in temperature is much larger than fluctuations during the last 335 years in waters around New Caledonia. Stable isotope research on corals has shown these to be of the order of 0.5-0.8ºC (Quinn *et al.* 1998).

In any event, a drop in water temperature of 2.6ºC would result in snapper reproduction ceasing (Paul 2005: pers. comm.). A population of increasingly large fish might survive for 30-50 years, but they would then die out or move north. The present-day Tasman Bay snapper population is genetically isolated from breeding populations further north (Bernal-Ramírez *et al.* 2003: 567) and in cold years spawning success is poor to nil. Bearing in mind the exponential relationship between recruitment rate and temperature (see Figure 40), this population is especially vulnerable to changes in surface sea water temperatures. A lowering of annual temperature of 2.6° C would mean that conditions in Cook Strait would be approximating those more typical of central and southern South Island waters, where spawning of snapper does not occur and adults are very rare. The snapper population in Tasman Bay exhibits low genetic diversity (Hauser *et al.* 2002: 11745). The reason for this is unclear, although fishing pressure during the historic era will have contributed. One further possibility is 'founder effect' – re-seeding of the area by a small immigrant group from further north following the Little Ice Age.

The situation at places like Foxton and Raumati along the Horowhenua coastline is slightly different to Tasman Bay, as there is no known spawning or nursery in this area. It is suspected that snapper here derive from the population around Cape Egmont, and that they move south during the summer when the sea warms up, and probably retreat northwards in the winter. The onset of the Little Ice Age would certainly curtail any southward movement and once again, over a period of 30-50 years of sustained lower temperatures, snapper would die out. An interesting feature of such a process is that the average size of snapper would increase over time before they died out completely. This would be easy to detect from size-frequency analysis of archaeological catches (see below).

DISCUSSION

There is compelling evidence from a number of sources that the climate in New Zealand has changed significantly during the last 1,000 years and, in particular, that there was a period of cooler conditions comparable to the European Little Ice Age. Although evidence of a Medieval Warm Period (or Little Climatic Optimum) is not as clear, it does seem certain that conditions in New Zealand before the Little Ice Age were at least as mild as those prevailing during the period immediately following it, before the onset of the recent episode of rapid global warming.

Evidence from historic records left by Captain Cook and his companions is consistent with this view, as are speleothem records, estimates of surface sea water temperatures from archaeological shellfish at different periods, and the changing abundance in archaeological sites of snapper, a species especially sensitive to water temperature.

These changes had far-reaching implications for pre-European Māori. Some of these have been traced in publications relating to the inhabitants of the Cook Strait region; in particular the virtual collapse of kūmara horticulture and Harris Line evidence of starvation during the onset of the Little Ice Age (Leach & Leach 1979: 256; Davidson & Leach 2001: 117 ff., 2002: 268 ff.). The remainder of this present Section traces changes in fish catches with this climatic chronology now firmly in mind.

BROAD CHANGES IN CATCH COMPOSITION

In order to consider any possible changes through time on a broad front, we need to group the information from sites into some suitable time slots. There are formidable problems in doing this, but one must be tough minded and try to forge ahead despite this. In Appendix 1, I have listed the

126 sites for which we have reasonable fishing information, and the 36 fish families identified in assemblages from these sites. A time period has been assigned to each site. Most of these follow the discussion about chronology in Leach & Boocock (1993), where broad trends in fishing were considered, using 84 sites for which information was available at that time. This has been swelled by further research since 1993; other age assessments are provided by Anderson (1997). The categories into which I have grouped the sites are:

1. *Early Prehistoric.* Before AD 1500, loosely corresponding to what is referred to as the Archaic Period, or New Zealand East Polynesian Culture.
2. *Late Prehistoric.* After AD 1500 and before AD 1769, loosely corresponding to what is referred to as Classic Māori culture.
3. *Protohistoric.* After AD 1769 and before AD 1840. Māori settlements during early European times.

Appendix 1 also provides the MNI of 36 fish families in each of these sites. This is given as a matrix of figures at the end of the appendix. There are many ways in which this basic matrix of data could be examined to see if there are any significant changes through time in New Zealand as a whole, and there are problems with each technique. Several difficulties need to be kept in mind. For example, there can be wild fluctuations in relative abundance of different fish types at the same period in sites near to each other in one region. These reflect changing abundance of different fish seasonally; the sites involved are specialised fishing camps, rather than year-round settlements. Moreover, some assemblages are very small and these should be give less weight than large samples in working out aggregated percentages.

With these sorts of problems in mind I carried out a range of different analyses of the data to see if there were any believable overall trends. I rejected as unreliable all values relating to elasmobranchs, and teleostomi not identified to family. I tried rejecting all assemblages with an MNI of less than 40 and then 50, and then 100. I calculated simple means, and then used a weighted mean technique where the mean percentages for any one family were weighted in favour of large assemblages compared to small assemblages. This approach initially sounds quite sensible but unfortunately, some of the largest assemblages are from sites which appear to be functionally specialised. They may therefore disguise broader trends by swamping the analysis if they are given too much weight. In carrying out this study I became conscious of the possibility of circular argument, where one might reject results which do not conform to some *a-priori* notion about what the trends should look like.

In the end I chose a fairly simple approach. The matrix in Appendix 1 was split into three parts, one for each age group. The percentage matrices were calculated for each in turn, after first extracting data relating to elasmobranchs and unidentified teleostomi and rejecting any sites with an MNI of less than 40. The simple unweighted mean percentage for each family was then calculated for each of the three matrices. The results for the 15 most abundant fish types are given in Figure 93. In theory, the weighted mean method should always be preferred, though in practice the choice of samples with which to calculate it is a crucial matter. We will shortly see that this type of broad-brush study is fundamentally flawed, because the mix of samples making up the major groupings is not appropriate, and neither weighted nor unweighted means would alleviate this problem. I have chosen the simple unweighted means in this case to illustrate just how misleading it can be when unlike samples are combined into major groups.

At first glance, Figure 93 does indeed show some interesting fluctuations over time, but whether these can be considered as major New Zealand-wide changes in fishing is another matter. The bottom bar graph shows the pattern for the Early Prehistoric, and it is evident that of the five most important fish types, snapper dominates, with 27%. This falls to 10% in the Middle period. Further inspection of the data which make up this trend shows that in the Early Prehistoric, the mean snapper catch is 50% in the North Island, but only 5% in the South Island. The particular mix of sites from each island is what makes up the overall mean of 27% snapper for the Early Prehistoric. This is not a very satisfactory situation (the mean is a poor representative of the range of values, which are effectively bi-modal). Similarly, the lower figure of 10% for the Middle Period snapper is made up of North Island sites averaging 26% and South Island sites averaging 0.5%. This shows just how easy it would be to misinterpret apparent trends of this kind completely.

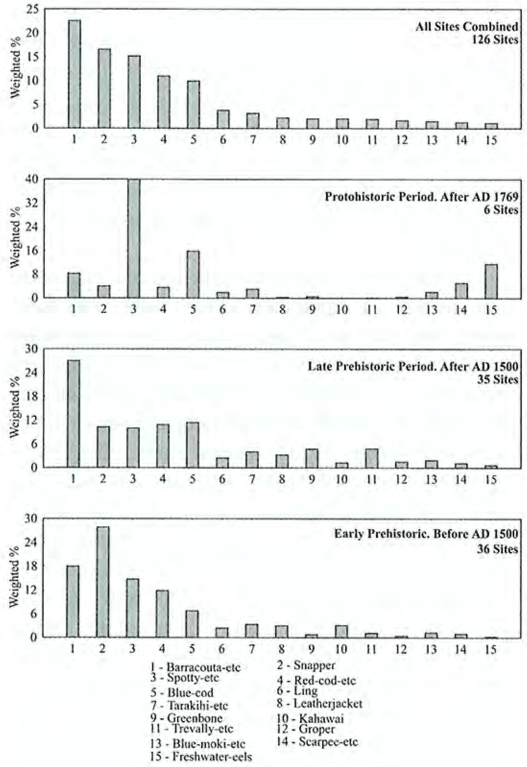

FIGURE 93

The relative abundance of different fish types for three periods. At the top is the overall abundance when all 126 sites are combined. The percentage values are simple unweighted means, giving equal emphasis to all assemblages with an MNI greater than 40. Such an analysis is not considered very useful. The alternative of examining change through time for small regional units is preferable.

We might also note from the foregoing that snapper appears to fall in popularity in both islands: in the North Island from 50% to 26%, and in the South Island from 5% to 0.5%. Could this be a 'real' trend? In my view, the search for major trends like this should be tackled from the bottom up, not from the top down. In this present analysis I have started off by painting a picture with a very broad brush (New Zealand wide), and then adopted a slightly smaller brush by looking at the two islands separately. Although it is tempting to think that in doing so we have now hit on a significant trend, I am instinctively sceptical about this approach. If snapper catches declined through time on a broad scale, then I would expect to see this manifest itself at a very local level, such as in a study of catches through time on Motutapu Island in the Hauraki Gulf. I would then expect to see the same change in a similar study in Tasman Bay in the South Island, and so on. Only a series of confirmed local trends like this would begin to suggest a change affecting New Zealand as a whole. This reflects my general approach in archaeology of trying to understand individual functioning communities first, and then working outwards from this strong base-line.

The same form of statistical scenario can be put together for barracouta fishing. Figure 93 shows what appears to be a large change from the Early to Middle Period of 18% to 27% of the catch. Once again, we can break this down into North and South Islands. In the North Island, there is a rise from 2.2% to 5.2%, and in the South Island from 34% to 49%. One could easily calculate the standard error of these percentage differences to test for 'statistical' significance in the trends. However, I do not think this is wise. It might inadvertently lend weight to the idea that statistical testing was the most suitable way of confirming or rejecting a theory of change here, and I do not think this is an appropriate test at all. Once again, I suggest that there is no substitute for careful study of the chronological sequence of changes affecting small localised pre-European communities in New Zealand.

At this point, it is necessary to depart from the main discussion into a small diversion for the sake of clarity about a small statistical matter with considerable implications.

At the Waitangi Tribunal hearing of the Ngai Tahu claim against the Crown, the issue of possible changes through time in pre-European Māori fish catches assumed an almost pantomime character, with claims and counter claims. Did barracouta fishing increase or decrease in importance for the Ngai Tahu? "Dr Leach argued for a 10 percent decrease while Professor Anderson favoured a 10 percent increase – Professor Anderson concluded that there is no apparent change in the taking of barracouta over time"; "Dr Bathgate's tables do not support his [own] view" (Bathgate 1992: 58, 57); finally, Dr Habib commented that "It would appear that there was some conflict between the archaeological evidence and the biological evidence" (Bathgate 1992: 77). The problem here arose from the variable use of numerical information, and it is likely to arise whenever one tries to pool information from several prehistoric communities to reach an average. In the specific example just cited there were two reasons for the different conclusions reached – firstly, the databases used by myself and Anderson, although similar, were not quite the same. Secondly, and more importantly, we each used a different numerical technique to estimate mean proportions. Anderson calculated an average of individual percentages without taking into account differing sample sizes at each archaeological site. The method I used was a weighted mean technique, which does take into account different sample sizes (Snedecor & Cochran 1967: 521). This latter technique is identical to the sum of MNI for one species divided by the sum of the total MNIs across all sites. An argument might be advanced in favour of either one of these methods of working out average proportions, depending on some basic assumptions. There are at least four alternative ways to calculate the mean proportion of a series of mean values, together with an associated standard error:

Method 1. The weighted mean [Snedecor & Cochran (1967: 521), and the standard error of proportion (Snedecor & Cochran 1967: 210)].
Method 2. The weighted mean with minimum variance (Leach 1972: 115).
Method 3. The simple mean and standard error of the mean.
Method 4. The simple mean and standard error of the mean proportions (Manly 1989 pers. comm.). The standard error is calculated thus:

$$\mathrm{sqrt}((\Sigma((SE\text{-}P_i)^2))/N^2),$$

where $SE\text{-}P_i..P_n$ are the series of standard errors of proportions.

There is further discussion on the vexed question of barracouta statistics by Anderson (1981) and Leach (1989a, 1989b).

This high profile incident showed how careful archaeologists need to be to get their basic statistical techniques squeaky clean when presenting findings to the general public, especially in a forum when there can be financial outcomes. Some observers of this incident may have begun to feel doubtful of the value of quantification in archaeology, and that would be a pity. The unfortunate reality is that very few archaeologists are sufficiently aware that every form of quantification involves a systematic error, and that this always needs to be taken into account. This is something discussed in some detail in Section 8, where I describe the pioneering research relating to diet by Wilfred Shawcross. In the specific example about barracouta, it is not appropriate to work out a mean percentage value of barracouta abundance from values taken from several archaeological sites without taking into account the different sample sizes, and therefore the different systematic errors in each. More generally, the use of percentages in archaeology is greatly abused because very few researchers appear to know how to calculate an error associated with the percentage. Incidentally, a percentage is really exactly the same thing as a proportion, just scaled so that the total is 100.0 in preference to 1.0. Calculating the confidence limits of a percentage is therefore the same thing as calculating the confidence limits of a proportion (also known as the standard error of a proportion), and is as follows (Snedecor & Cochran 1967: 210-211; Leach & de Souza 1979: 32):

$$C = K * (P * (1.0 - P) / N)^{0.5} + 1 / 2N$$

C is the confidence limit, P is the proportion, N the sample size, and K is a constant related to the chosen probability level (= 1.96 for 95% confidence, following the distribution of Student's t). The factor 1/2N is added as a correction for continuity, which is important for small samples. For example, If N=128 and there are 7 items with some characteristic, then P=0.054688, and C=0.0433. So the 95% confidence range can be expressed as 5.47% ± 4.33%. For small samples, the distribution of Student's t must be consulted to adjust the value of C accordingly. For example if N=35, C will be 2.02, not 1.96.

This method of calculating the ± value associated with any percentage is followed throughout this volume, and appears in a number of Tables in this Section. It is also referred to in Method 1 and Method 4 above. Any of these four methods which are outlined is satisfactory; what is not satisfactory is ignoring the systematic errors associated with percentages. I have dealt with this matter at some length because of its fundamental importance.

Returning to the main subject – another aspect of fishing behaviour which can usefully be examined over long periods is catch diversity. Some groups of fishermen grow very knowledgeable about catching particular species and become specialised in their endeavours. That is, their catch diversity is low, focused on a few species. High diversity is when people catch a large number of fish types, though in variable proportions. Extreme pressure on marine resources, following sustained periods of intensive fishing, usually results in a reduction in natural diversity, which will be reflected in fish catches. In other words, on a New Zealand-wide scale, significant human impact on marine resources should show up as reduced diversity over time.

In order to examine this possibility I extracted the most reliable information from Appendix 1 by ignoring assemblages with MNI of less than 100 fish and calculated a well-known measure of diversity known as Shannon's H statistic (Shannon 1948; Peet 1975) for the remaining 56 sites. These are plotted out in Figure 94. The mean values were: Early Prehistoric 1.36, Late Prehistoric 1.35 and Protohistoric 1.63. It is clear from Figure 94 that there is wide variation at each period and no obvious trend over time. The number of fish families caught ranged from 3-10 in the first two periods and 7-8 in the last.

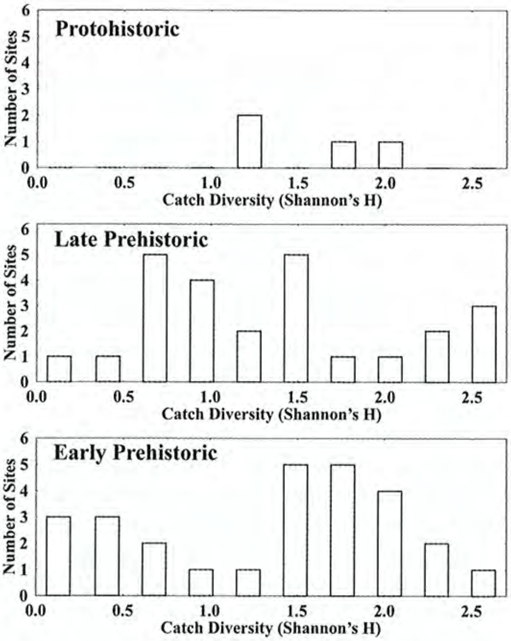

FIGURE 94

The diversity of fish catches varies a great deal from one archaeological site to another, but does not show any significant trend over time.

Once again, this type of analysis reveals a weakness in the New Zealand-wide approach in seeking to understand trends over time. It is difficult to discover something meaningful by simply adding up diversity in catch from one region to another, just as it is with relative abundance. In my opinion, it is much more sensible to study catch diversity for an individual functioning human community in one location and examine how this changes through time. At best, these wide-ranging across-region types of analyses might point to some anomaly which deserves closer attention. A case in point concerns freshwater eels.

It may have been noticed in Figure 93 that there is apparently a notable rise in freshwater eel numbers in the Protohistoric period from a small proportion in both earlier periods. Is this 'real'? The first thing which must be said is that the bar chart for the Protohistoric period combines information from very few sites; but it is basically all the archaeological evidence we have of any quality for this period. Nevertheless, it can hardly be considered a good sample of Māori fishing in the Protohistoric era up to AD 1840, and much more knowledge is needed in the future. As far as freshwater eel is concerned, there is a dearth of information in archaeological sites of any period. As Marshall has pointed out, the common dogma invoked to explain this is that eel bones are soft and easily decay in archaeological sites (Marshall 1987: 56). This is manifestly untrue, as there are numerous archaeological sites throughout the world with abundant eel remains (Wheeler & Jones 1989: 164). For example, in one early mesolithic site on the north coast of Spain sixty percent of a sample of 7,000 fish bones were of freshwater eel (Roselló & Brinkhuizen 1994: 403). Closer to home, eel bones occur in abundance in some sites in the Pacific too (see below).

The actual role of freshwater eels in the economy of the Māori is hard to extricate from the wealth of anecdotal evidence and myths and traditions about eels. So strong are Protohistoric stories about eels and their importance in Māori society that it would be understandable if one found it hard to imagine anything different prevailing in the past. The important point here is where do we draw the line? How far back in the past are our present-day enculturated views relevant? Some would say this depends on the strength with which a present-day piece of culture is held. There is no doubt that eels were *very* important to some Māori groups in the Protohistoric era. Does the strength of this aspect of recent Māori custom mean that the same custom prevailed for 100 years backwards in the past, or 200 years, or 500 years, or 1000 years? How should one answer this question? My answer is simply that such questions are *only* answerable using archaeological techniques. Moreover, in my view the strength with which a custom is held is no guide at all to how long it has prevailed. Christian beliefs are held with great strength by many Polynesian peoples, yet historical records attest that equally strong non-Christian views were supplanted very rapidly when Europeans came into the Pacific world.

Archaeological evidence of freshwater eels in early New Zealand provides an interesting object lesson about changing customs. We also need to see this issue in the context of the wider Pacific, to which Māori ultimately trace their ancestry. Throughout the Pacific, eels pervade stories and legends about fabulous characters who can transform themselves from human to animal form and back again. Many of these stories are thinly disguised sexual metaphors, where the eel is an embodiment of the penis. Stories abound of eels talking to people, visiting houses (usually at night), impregnating women, and escaping unseen. In some islands in the Pacific it is considered absolutely disgusting even to contemplate eating an eel. For some people, the eel is an object of totemic importance. Pacific islanders distinguish between different kinds of eel, of course, and in some societies it is considered acceptable to eat moray eels but not freshwater eels; in other groups both are forbidden. Nowhere are eels ignored; in short, they are *special*. In case we begin to think there is something odd about Pacific Islanders, it might be mentioned that the English are fond of eels for food and the Scots abhor them.

Archaeological evidence from the Pacific shows that some groups ate eels in abundance during the prehistoric period and others avoided them. On the Polynesian outlier of Kapingamarangi, for example, eels are common in archaeological sites (Leach & Ward 1981: 59), whereas on the nearby island of Nukuoro, occupied by closely related Polynesian people, there are no eel bones in the sites (Leach & Davidson 1988: 14-15; Davidson & Leach 1996: 187). There are no significant environmental differences between the two islands; they are both atolls and eels are common in both lagoons. It is just that the Kapingamarangi people consider eels to be good food and the Nukuoro people consider them disgusting. On the Polynesian outlier of Tikopia, eel bones are common in the early archaeological horizons and then disappear from the archaeological record from about A.D. 1700 onwards (Kirch & Yen 1982: 292). In modern-day Tikopian society the eel is regarded with disgust, and it is thought that if a person ate one they would die (Firth 1967: 555).

I believe that the Oceanic setting is always relevant to New Zealand prehistory but is sometimes lost sight of. It has been suggested that the lack of eel bones in New Zealand archaeological sites is a matter of differential survival; that the bones are small, fragile, and easily break down. Nothing could be further from the truth. Eel bones are dense and strong and certainly do not have any physico-chemical properties which might make them more susceptible to decay than the bones of other fish. The fact that eel bones are very common in some sites in the Pacific and not others is perfectly in keeping with what we know of the highly variable, but always special, customs relating to eels. In short, the lack of eel bones in New Zealand sites is bound to reflect food avoidance behaviour towards eels for much of the pre-European period. The fact that in the nineteenth century, New Zealand Māori mass harvested eels at Lake Onoke (Saunders 1965) and traded them throughout the North Island, and that eels were greatly prized as a delicacy at this time, suggests to me that Māori custom and beliefs concerning eels were undergoing rapid change, like so many other aspects of Māori society during the tempestuous period of early European contact.

In this respect, an interesting observation was made by Brunner during his sojourn on the West Coast of the South Island in 1846-48. He found that Māori were required to perform spiritual cleansing when dealing with eels. This suggests that they considered them potentially dangerous to handle. Perhaps we have here an example of a custom making an historical transition from the sacred to the profane. The passage in Brunner's journal is instructive.

> There is a particular *tapu* existing among the natives relating to the eel. You must wash your hands before going to catch them, and also on returning, and the bait must be prepared some distance from the house. There must be a distinct fire for cooking the eel, for which you must have a special tinder-box; your hands and mouth must be washed both before and after partaking of them, and should it be necessary to drink from the same stream from which the eels are caught, you must have two vessels of water, the one to drink from, the other to dip from the stream. Whether this relates to particular places or not, I am not able to say, but I found it strictly adhered to at Okitika and Okarita and at the former place I had to walk half a mile for water, with a stream running within a few yards of our station (Brunner 1959: 274-275).

Taylor, who edited Brunner's journal for publication, observed in a footnote at this point: "Hokitika and Okarito, which he had not visited at this stage. In the *Nelson Examiner* this eel-*tapu* passage is placed much later, on 12 February 1848, when returning up the Grey River" (Taylor 1959: 275). Brunner must have thought this matter of some importance when he found the custom to be more widespread, after he had travelled further south, and inserted the passage in the entry for the 19th April 1847, where he had first come across it. This is a classic description of ritual associated with food avoidance behaviour. In some respects it is similar to the Roman Catholic custom of avoiding red meat on Friday, but permitting it in some circumstances, such as when food is very scarce. Elsdon Best was obviously puzzled about this practice amongst some Māori, for he remarked:

> A peculiar note comes from a South Island source [not identified by Best] to the effect that when about to set an eel-pot a Maori would wash his hands. "If this act be neglected," says our informant, "then no eels will enter the pot." This may be so, but I cannot say that such a precaution ever came under my own observation. These punctilious eel-trappers must have died out before my time, or possibly the usage did not extend to the North Island... When exploring Westland in 1847, Brunner noted this superstitious practice among eel-fishers [citing Hamilton 1908: 69 as his source of information] (Best 1977: 188-189).

Hamilton did not specify which manuscript he consulted for Brunner's observation. Unfortunately, we are now so far removed from the primary historical observations that we may never fully understand what was happening to Māori customs relating to eels after 1769. However, there are three pieces of evidence which, when put side by side, present an intriguing picture:

1: Pre-European archaeological evidence suggests eels were very infrequently caught and eaten.
2: There are clear signs, at least amongst some South Island Māori in the early historic period, that taking eels for food was considered extremely dangerous, and special precautions were required to ensure personal safety.
3: From the nineteenth century onwards eels were subjected to mass harvesting by Māori in several parts of the North and South Islands, and distributed as an important trade item.

It seems hard to avoid the conclusion that the utilisation of freshwater eels as food was a relatively recent activity and that when the first Polynesian immigrants arrived in New Zealand, they brought with them a strong belief that eels were sacred and should not be eaten.

Where have eel bones been found in New Zealand? They have been identified in only 20 of the 126 sites studied. The details are provided in Table 15.

In this Table I note the sites where I can verify the identifications to be correct. Some of the others may possibly be marine eels; I have not personally checked these identifications. It will be noticed that a number of the sites are in the Chatham Islands. We should not expect that food avoidance customs would necessarily be the same among Māori and Moriori. However, the figures are also fairly low in the Chatham Islands. When these figures are plotted out (Figure 95) there do seem to be signs of an increase over time, but the number of data points is pitifully small.

It should be noted that both the simple and weighted means are provided in Table 15, as discussed above. The two values are substantially different in each case. The weighted mean gives greater credence to large samples, and is therefore more representative of the entire series. However, it also reveals a weakness inherent in combining values from different archaeological sites separated by considerable distances. The communities which were responsible for the deposits may have had quite different approaches to gathering food. Combining them together statistically will not fairly represent any one of them. Once again, this shows that in examining changes through time it is preferable to give far greater attention to individual regional sequences.

Another interesting aspect about eel exploitation is an initial indication that only very small eels were being taken at some of these sites. The mass eel harvesting described in nineteenth century records involved an abundance of large fat females attempting to migrate out to sea for spawning. This does not seem to be indicated in the few bones we have from archaeological sites. I have started a modern comparative collection, with 88 specimens so far, measuring up to 1200 mm long, and extracted their cranial bones. Comparison of these with the relatively large archaeological collections from Parewanui and the Washpool suggests that only very small eels are represented in those sites. Such eels are more often

Eel MNI	Total MNI	%			Archaeological Site
Protohistoric	**Period (eels present in 1 of 8 sites)**				
29	54	53.7	±	14.5	*Parewanui Midden, Bulls, Manawatu
Simple Mean		**53.7%**	**±**	**14.5**	
Late Prehistoric (eels present in 10 of 63 sites)					
1	5	20.0	±	53.8	Northland Harbour Board, Whangarei
24	159	15.1	±	5.9	*Kahiti South, Hansons Bay, Chatham Is
6	95	6.3	±	5.5	*Kahiti North, Hansons Bay, Chatham Is
1	17	5.9	±	14.9	*Ohinemamao, Petre Bay, Chatham Island
1	25	4.0	±	10.1	Raupa N53/37, T13/13, Hauraki Plains
1	35	2.9	±	7.1	Aotea N64/25, North Island west coast
1	4197	0.33	±	0.19	*Waihora, Chatham Islands
2	1206	0.17	±	0.27	*Mana Island North Settlement R26/141
1	884	0.11	±	0.28	*CHA, Chatham Islands
4	4978	0.08	±	0.09	*CHB, Chatham Islands
Simple Mean		**5.5%**			
Weighted Mean	**0.47%**	**±**	**0.13**		
Early Prehistoric (eels present in 9 of 55 sites)					
1	14	7.1	±	18.2	*Riverton, Southland
37	771	4.8	±	1.6	*Washpool Site, Palliser Bay
3	278	1.1	±	1.4	*Hot Water Beach, Coromandel
1	94	1.1	±	2.6	*Wakapatu, Western Southland
1	401	0.25	±	0.61	Sunde Site soft shore midden, Motutapu
1	585	0.17	±	0.42	*Rotokura, Tasman Bay
1	584	0.17	±	0.42	Sunde Site Oyster lens, Motutapu
1	2134	0.05	±	0.12	*Shag River Mouth, Otago
1	2425	0.04	±	0.10	Houhora, Northland
Simple Mean		**1.6%**			
Weighted Mean		**0.65%**	**±**	**0.19**	

TABLE 15

Eel Bones in New Zealand Archaeological Sites.
Asterisked items (*) indicate identifications confirmed by myself.

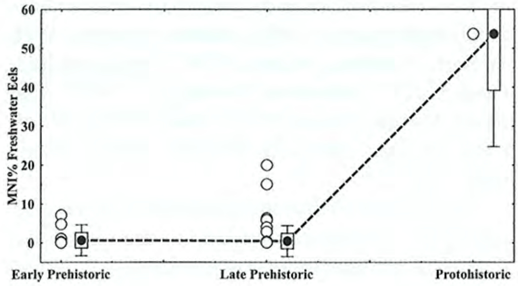

FIGURE 95

Eel bones are found in very few New Zealand archaeological sites, occurring in only 20 of 126 sites studied. There appears to be an increase in exploitation of eels over time.

seen in small, fast-flowing streams. The bones are certainly not from the very large mature eels involved in the spawning migration. There is obviously a great deal still be to be learned about eel exploitation in early New Zealand, but the signs so far suggest that mass harvesting of large eels was a very late phenomenon.

In this section on New Zealand-wide changes in fishing I have skirted around the issue to some extent, because I believe New Zealand prehistory is so rich regionally that trying to paint a picture with too broad a brush risks obscuring rather than revealing. I will return to the subject of possible broad changes in catch composition at various points in the following discussion where I consider evidence from individual archaeological sites in more detail.

LOCAL CHANGES IN CATCH COMPOSITION

Studies of pre-European Māori society have suggested that many groups were highly mobile. This is especially so for people living in the South Island, where the tropical root crops imported by the first settlers could not grow, but it also characterises many groups in the North Island. In place of a sedentary society with permanent villages, a picture has emerged of groups moving from one 'transient village' to another (Anderson & Smith 1996a), and only infrequently settling in a 'permanent' village for any length of time. This is partly because kūmara gardens required long fallow periods, in the absence of fertiliser (Leach 1976), so even in an area with good resources, combining land for gardens, nearby forest, and access to the sea, it may still have been necessary to up stakes and move away periodically to fresh pastures.

For this reason, and possibly others, very few sites in New Zealand had long sustained periods of occupation which allowed the build-up of numerous occupation layers. It is these kinds of sites more than any other which facilitate the study of change in human society. This is the reason we have such detailed knowledge of the development of urban society in the Middle East; sites like Jericho, although complex to excavate, have evidence of continuous occupation. Some sites in New Zealand, such as some major northern fortified *pā*, were occupied or reoccupied over long periods. However, where economic debris was present in abundance, archaeologists interested primarily in the structural history of a site have often failed to collect adequate samples of economic debris for analysis. In other cases, the people inhabiting these settlements appear to have processed marine food at specialised seasonal camps in coastal areas, using the *pā* as a base. The specialised camps of course do leave the evidence required for studies of economic change, but they often contain only a few stratigraphic layers representing a very short period of time. The next time the same area was visited, a new midden was made in a slightly different place. This type of problem is not unique to New Zealand by any means, but it is especially frustrating when one is attempting to trace the impact which a community may have had on an area of coastline, or to put together a picture of changing focus on different species of fish over a long period. Recent excavations at a large site at Shag River Mouth produced abundant economic evidence, numerous artefacts, and other settlement debris; but the site appears to have been occupied for only a short period (20-50 years according to Anderson *et al.* 1996: 67), and this frustrates any attempt to understand cultural or economic change affecting a single community.

Consequently, we are fortunate in New Zealand to find any sites with significant stratigraphy deposited over a long period of time, which contain sufficient economic debris to detect changes in fish catch composition. However, there are a few notable ones, and some comments about each are presented below.

LONG BEACH

This site is immediately north of Dunedin, just outside the entrance to Otago Harbour. It is a long bay showing seaward shoreline development. Older archaeological deposits are found at the rear of the present beach and sand dune formation. In one area a site was located and excavated which had been occupied both early and late in the sequence. It is not suggested that there was continuous occupation, but cultural debris from lower layers had clear Archaic affinities and Classic Māori artefacts were present in upper layers. Fish bone was abundant in all layers in the site, and has been studied in detail, first by Fyfe (1982), and later in the Archaeozoology Laboratory at the Museum of New Zealand (Leach & Boocock 1993).

Long Beach has the greatest amount of fish bone of any site so far excavated in New Zealand. Table 16 lists the remains securely dated to early and late contexts. This explains why the figures given in Appendix 1 are not quite the same as those presented here. The total MNI for the site was 5770, of which 5456 could reliably be allocated to a specific time period. Only seven other sites in New Zealand have produced fish MNI above 1,000 individuals: CHB, Chatham Islands, 4978; Waihora, Chatham Islands, 4197; Purakanui Inlet, Otago, 2745; Houhora, Northland, 2425; Shag River Mouth, Otago, 2134; Mana Island North, Cook Strait, 1206; and Breaksea Sound, Fiordland, 1153.

Eight types of fish are represented in the early period at Long Beach and nine in the late period. Only five of these are in any great abundance, showing that the people inhabiting this area were fairly specialised in their exploitation of marine fish. No freshwater eels are present, even though there is a swampy area inland of the site which is a favoured environment for eels. Some fish types show consi-

Family	Early	Late	Total	Early %	Late%
Barracouta, etc.	3831	550	4381	83.0% ± 1.1	65.6% ± 3.3
Red cod, etc.	583	177	760	12.6% ± 1.0	21.1% ± 2.8
Ling	182	38	220	3.9% ± 0.6	4.5% ± 1.5
Groper	10	47	57	0.2% ± 0.1	5.6% ± 1.6
Spotty, etc.	6	12	18	0.13% ± 0.1	1.4% ± 0.9
Maori chief	3	4	7	0.06% ± 0.08	0.48% ± 0.5
Blue moki, etc.	1	5	5	0.02% ± 0.05	0.60% ± 0.6
Blue cod	0	5	5	0.00% ± 0.01	0.60% ± 0.6
Tarakihi, etc.	0	1	1	0.00% ± 0.01	0.12% ± 0.3
Blue warehou	1	0	1	0.02% ± 0.05	0.00% ± 0.1
Totals	**4617**	**839**	**5456**		

TABLE 16
Long Beach Fish MNI and Percentages.

derable change in relative abundance over time (Figure 96). Barracouta shows a clear decline in importance. This is associated with a rise in red cod, groper, blue cod and labrids. The barracouta would have been taken by lure from canoes, and the lower abundance could be related to a decrease in opportunities to go to sea for this form of fishing. As discussed in Section 4, these fish move inshore during summer months in this area. Leach & Anderson (1979a) hypothesised that bad sea conditions later in the pre-European sequence led to greater focus on inshore species such as labrids. This may be the case at Long Beach, where there is a decrease in barracouta and an increase in labrids. These would have been taken off the rocky headlands on either side of Long Beach. It is interesting that groper is a significant component of fish catches later in the sequence. Groper are very poorly represented in the archaeological record throughout New Zealand; this is generally taken as an indication that deep water offshore fishing was not a common pursuit of pre-European Māori. Contrary to this view, groper could easily be caught off rocky headlands in the early historic period, before inshore resources generally were depleted by Europeans. The groper at Long Beach could well have been taken off the nearby rocky headlands rather than in deep offshore waters. The significant rise in the frequency of red cod can also be taken to indicate increased emphasis on fishing off the two adjacent headlands.

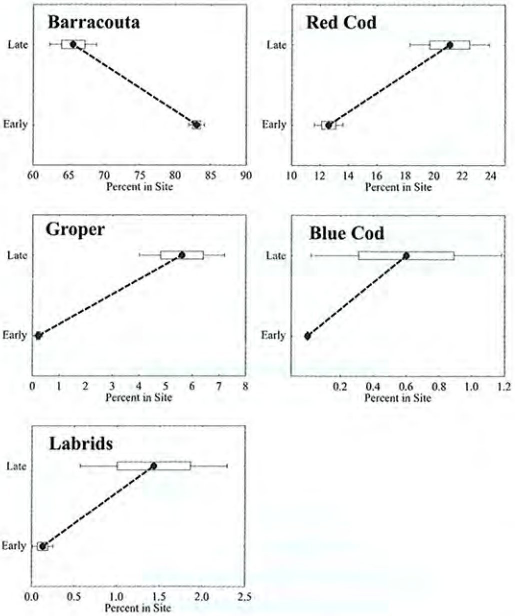

FIGURE 96
Changes over time in relative abundance of five fish types at Long Beach, Otago. All changes are significant at 95% confidence limits.

SHAG RIVER MOUTH

The Shag River Mouth site, situated on the sand spit at the mouth of the Shag River in north Otago, is one of the best known archaeological sites in southern New Zealand. It was first excavated during the 1870s, during the controversy about the relationship between moa-hunter and Māori, and has been the scene of numerous subsequent investigations. Between 1987 and 1989 a series of excavations was carried out under the direction of

Anderson, Allingham and Smith (Anderson *et al.* 1996). These centred in two main areas: a high dune towards the southern and landward end of the sand spit, and the northern and inner edge of the low-lying sand flat on the inner side of the dune, although extensive test pitting was carried out over much of the site. Cultural deposits were relatively shallow on the sand flat, but deep stratigraphy was encountered in the high dune, where seven distinct occupation layers were separated by layers of wind-blown sand.

Table 17 shows the relative abundance of fish families in the total catch from the dune excavation. A wider range of families is represented than at Long Beach, and several families besides barracouta and red cod were making a reasonable contribution to the catch. Even so, barracouta still dominate, at a level comparable to that in the late catch at Long Beach.

In spite of the apparently very short duration of settlement at this site, there are 10 intact stratigraphic layers in the excavated area known as SM/C: Dune. This provides an excellent opportunity to observe short term variability in catches. It needs to be noted that Layer 1 consisted of clean wind-deposited sand. Sparse weathered cultural material was recovered from two stained sand lenses within it, well above the main midden deposit (Anderson & Allingham 1996: 40). It is therefore a moot point whether Layer 1 should be included when examining the time series. Anderson and Smith suggest that there was a change in fishing strategy from a primary focus on baited hooks over rocky ground and reefs towards deliberate targeting of pelagic schools, notably barracouta (Anderson & Smith 1996b: 244). The former strategy is particularly evident in the catches of blue cod, wrasse and trumpeter. When the relative abundance of barracouta and blue cod is examined along with their standard errors (Figure 97) the supposed changes are not so easy to confirm. However, there certainly does seem to be a shift at Layer 5, continuing to Layer 2. Given the short-term nature of occupation at the site and the strong inshore movement of barracouta in Otago waters over summer, this stratigraphic sequence of changing dominance of barracouta could represent seasonal changes.

Family	Common Names	MNI	%	SE
Gempylidae	Barracouta, etc.	1354	63.45	± 2.07
Moridae	Red cod, etc.	339	15.89	± 1.57
Mugiloididae	Blue cod	155	7.26	± 1.12
Labridae	Spotty, etc.	116	5.44	± 0.99
Ophidiidae	Ling	57	2.67	± 0.71
Nototheniidae	Maori chief	46	2.16	± 0.64
Latrididae	Blue moki, etc.	30	1.41	± 0.52
Scorpaenidae	Scarpee, etc.	20	0.94	± 0.43
Percichthyidae	Groper	11	0.52	± 0.33
Cheilodactylidae	Tarakihi, etc.	2	0.09	± 0.15
Anguillidae	Freshwater eels	1	0.05	± 0.12
Sparidae	Snapper	1	0.05	± 0.12
Centrolophidae	Blue warehou	1	0.05	± 0.12
Mugilidae	Yelloweyed mullet, etc.	1	0.05	± 0.12
Totals		**2,134**	**100**	-- --

TABLE 17

Fish MNI at Shag River Mouth, Dune Excavation (all provenances combines) (SE, standard error).

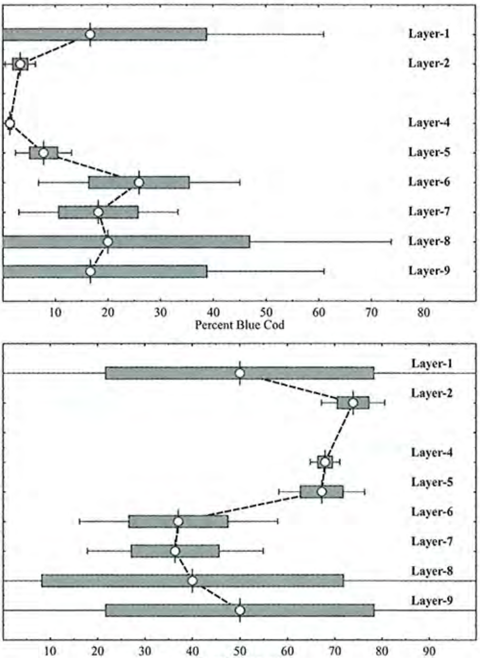

FIGURE 97

Changes over time in relative abundance of blue cod and barracouta at Shag River Mouth, Otago.

BLACK ROCKS

Black Rocks is a headland near Cape Palliser in the southernmost part of the North Island. The area consists of a sandy flat below steep cliffs. Large rocks extend out to sea for about 300 m. This rocky promontory has dense seaweed in pla-

Family	**BR3 (MNI=188)**	**BR4 (MNI=682)**	**BR2 (MNI=55)**
Spotty, etc.	60.64 ± 7.25	40.76 ± 3.76	38.18 ± 14.01
Greenbone	5.85 ± 3.62	11.00 ± 2.42	32.73 ± 13.56
Blue cod	4.26 ± 3.15	5.28 ± 1.75	14.55 ± 10.42
Tarakihi, etc.	4.79 ± 3.32	8.06 ± 2.12	0.00 ± 0.91
Barracouta, etc.	2.13 ± 2.33	8.21 ± 2.13	1.82 ± 4.51
Blue moki, etc.	3.19 ± 2.78	4.25 ± 1.59	3.64 ± 5.96
Kahawai	6.91 ± 3.89	2.93 ± 1.34	0.00 ± 0.91
Scarpee, etc.	0.53 ± 1.31	6.01 ± 1.86	1.82 ± 4.51
Conger eel	2.13 ± 2.33	2.20 ± 1.17	3.64 ± 5.96
Groper	3.19 ± 2.78	1.91 ± 1.10	1.82 ± 4.51
Red cod, etc	1.60 ± 2.06	4.55 ± 1.64	0.00 ± 0.91
Snapper	3.19 ± 2.78	1.47 ± 0.98	0.00 ± 0.91
Marble fish	0.53 ± 1.31	1.47 ± 0.98	1.82 ± 4.51
Ling	1.06 ± 1.73	0.00 ± 0.07	0.00 ± 0.91
Hoki	0.00 ± 0.27	1.03 ± 0.83	0.00 ± 0.91
Trevally, etc	0.00 ± 0.27	0.59 ± 0.65	0.00 ± 0.91
Red gurnard	0.00 ± 0.27	0.15 ± 0.36	0.00 ± 0.91
Maori chief	0.00 ± 0.27	0.15 ± 0.36	0.00 ± 0.91

TABLE 18

Black Rocks Fish MNI and Percentages.

ces and is rich in marine food. There are a number of middens scattered over the flat, four of which were excavated by Anderson (1973, 1979). Three yielded quantities of fish bone. The MNI and percentages are provided in Table 18, after figures for elasmobranchs and unidentified teleostomi were extracted. There are no signs of permanent habitation on Black Rocks Point itself, and the middens are believed to be specialised food processing camps occupied by people from one of the nearby valleys where villages were located.

As with Long Beach, some notable trends through time can be detected in these figures. The three sites form a chronological sequence, established by a combination of radiocarbon and conchiolin dating (Anderson 1973: fig. 19). The latter technique examines the amount of residual conchiolin in protein-rich shellfish species as a guide to their relative age. BR3 (the Black Midden) is the earliest site, closely followed by BR4 (the Crescent Midden). BR2 (the Pond Midden) is considerably later. The first two sites are Archaic in cultural affiliations; the Pond Midden dates to the period of Classic Māori culture. Figure 98 shows the changing proportions of four fish types over time. Not all the observed changes have such clear statistical significance as at Long Beach, but they are interesting nevertheless. The contributions of both labrids and snapper to the fish catch appear to decline, while blue cod and greenbone rise in importance.

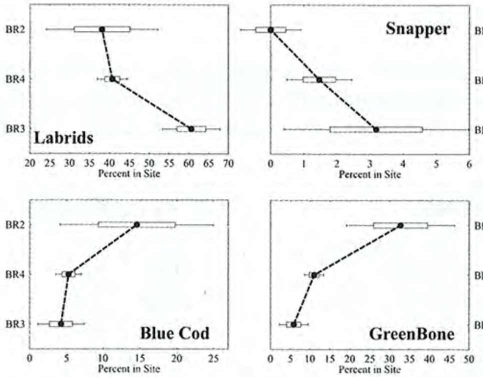

FIGURE 98

The changing character of fish catches at Black Rocks, Palliser Bay. There are signs here that labrids and snapper declined over time, and that blue cod and greenbone increased in importance. The 65% and 95% confidence limits are shown. Not all changes are statistically significant.

There are several possible ways of interpreting these changes. The smaller size of the BR2 assemblage makes it difficult to be sure that the observed trends are consistent and numerically significant. There is convincing evidence that Black Rocks was effectively abandoned for perhaps as much as 300 years between the end of occupation of BR4 and the beginning at BR2 (Leach & Anderson 1979b: 158). This conclusion has been reached on the basis of signs of coastal forest rejuvenation and the recovery of some marine stocks such as pāua (*Haliotis iris*). The four fish types can all be taken in shallow inshore water at Black Rocks, possibly all from amongst the rock-strewn areas within 100 m of the shore. The greenbone, a vegetarian fish, is extremely difficult to catch using a baited hook. Today, these fish are caught with a set net functioning as a gill net. They may have been taken by Māori using a form of hoop or dip net dragged carefully through kelp beds. If so, it is possible that their rise in abundance may be attributed to improved fishing technique. The apparent decline in labrids at Black Rocks is somewhat puzzling. These are the easiest of all fish in New Zealand to catch. It is possible that when people first arrived at Black Rocks, labrids were so numerous that it was hard to catch anything else. They are voracious feeders and, if present in any number, attack a baited hook ahead of other species. The apparent decline in the proportion of snapper is interesting, but the small numbers of fish make it difficult to confirm whether it is significant or not.

WASHPOOL

This site is also in Palliser Bay, at the mouth of the Makotukutuku River. It is situated on a stretch of virtually featureless sandy beach, which extends for several kilometres in each direction. There is a small rocky outcrop 500 m from the site, known as Shag Rock, but very little of this extends into the sea. Today most of this coastline is a high energy beach with unstable sands, but the presence of filter feeding shellfish in the Washpool midden suggests that the beach line was more stable when people first came to the area. Although there is evidence of crude shelters and pole structures, possibly for drying fish, it is not thought that the area excavated at the Washpool was actually the village itself. It is more likely that the village was close by, but has been destroyed by the road cutting to the river. Many lines of evidence suggest that the general area was permanently occupied, with houses close to the river mouth and also further inland in the Makotukutuku valley. Several human burials were found in the Washpool site, and also a dog burial.

The site contained several stratigraphic layers. Midden had been deposited regularly over a considerable length of time, spanning most of the pre-European period. The layers are grouped into three periods. Fish remains belonging to 20 families were present, with a combined MNI of 698 (Leach 1979a). The relative abundance of the catch at different periods is presented in Table 19 and illustrated in Figure 99, in which only the first 15 families are shown. Apart from some minor fluctuations, the

Family	**Level I (MNI=228)**	**Level II (MNI=121)**	**Level III (MNI=349)**
Freshwater eels	9.65 ± 4.05	4.13 ± 3.96	7.74 ± 2.95
Marblefish	0.44 ± 1.08	0.00 ± 0.41	0.29 ± 0.70
Kahawai	10.53 ± 4.20	5.79 ± 4.57	8.88 ± 3.13
Leatherjacket	0.44 ± 1.08	0.00 ± 0.41	0.29 ± 0.70
Elephantfish	0.00 ± 0.22	4.96 ± 4.28	1.72 ± 1.51
Trevally, etc.	2.19 ± 2.12	0.83 ± 2.03	1.72 ± 1.51
Tarakihi, etc.	21.49 ± 5.55	18.18 ± 7.29	20.34 ± 4.37
Conger eel	0.88 ± 1.43	0.83 ± 2.03	0.86 ± 1.11
Barracouta, etc.	4.82 ± 3.00	8.26 ± 5.32	6.02 ± 2.64
Spotty, etc.	17.98 ± 5.20	27.27 ± 8.35	21.20 ± 4.43
Blue moki, etc.	3.51 ± 2.61	0.83 ± 2.03	2.58 ± 1.81
Red cod, etc.	12.28 ± 4.48	14.05 ± 6.61	12.89 ± 3.66
Blue cod	3.95 ± 2.75	1.65 ± 2.69	3.15 ± 1.98
Greenbone	1.75 ± 1.92	0.83 ± 2.03	1.43 ± 1.39
Ling	0.44 ± 1.08	0.00 ± 0.41	0.29 ± 0.70
Groper	1.75 ± 1.92	1.65 ± 2.69	1.72 ± 1.51
Tuna, etc.	2.63 ± 2.30	4.13 ± 3.96	3.15 ± 1.98
Scarpee, etc.	0.44 ± 1.08	0.00 ± 0.41	0.29 ± 0.70
Snapper	2.63 ± 2.30	3.31 ± 3.60	2.87 ± 1.89
Red gurnard	2.19 ± 2.12	3.31 ± 3.60	2.58 ± 1.81

TABLE 19

Washpool Fish MNI and Percentages.

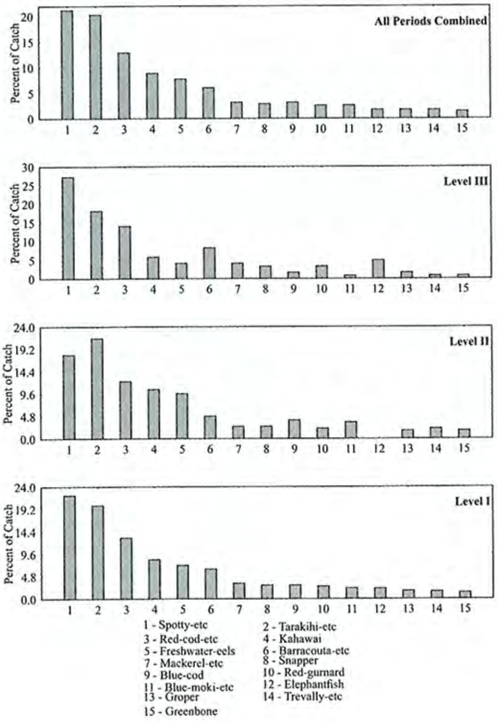

FIGURE 99

Fish catches from three different time periods at the Washpool Site, Palliser Bay. This illustrates considerable uniformity over a long period, but with some small changes between Levels I and II.

catches show remarkable uniformity over a very long period, although the catch pattern is significantly different statistically between Levels I and II (Leach 1979a: 121). The figures for labrids and tarakihi appear to show a change in relative dominance from Level I to Level II, and then back again at Level III. However, these changes by themselves are not numerically significant. Two factors probably combine to explain this uniformity in catch. One is that a large open beach area of the kind where the Washpool site is located would have experienced little or no impact from the small resident population, believed to be about 30 people (Leach & Leach 1979: 266). The second is that, unlike Black Rocks, this area does seem to have been permanently settled. Any seasonal changes in abundance would therefore be smoothed over by the continuous dumping of midden over long periods. The long period of build-up at this site is confirmed by Archaic artefacts in early levels and late radiocarbon dates for upper levels.

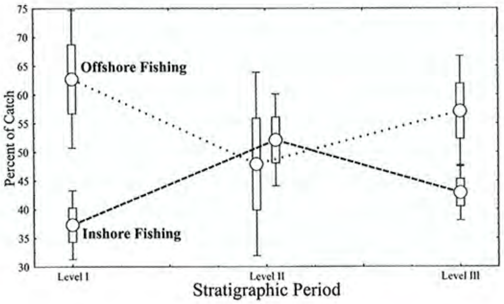

FIGURE 100

The balance between fish types taken inshore and offshore at the Washpool Site shows some tendency to change over time.

When the different fish types are grouped into those which are more easily taken in shallow inshore waters and those which probably required baited long line fishing from a canoe offshore (Figure 100) a modest change over time can be seen in favour of inshore activities (Leach 1979a: 122). This fits well with the pattern of environmental changes which have been reconstructed for Palliser Bay. It is suggested that generally stable conditions there gave way to poorer weather later in the pre-European sequence, which would have made canoe-based fishing more difficult.

MANA ISLAND

Mana Island (Te Mana o Kupe ki Aotearoa), lies about 4 km off Titahi Bay near the southwest tip of the North Island. It is about 2.5 km long and 1.25 km wide. Much of the island is bounded by cliffs but there is a sheltered landing in the southeast where the main stream system reaches the coast. The flat behind the beach here has always been the principal occupation area on the island. Cultural deposits extend for about 300 m along the beach ridge.

The nearby marine environment has extensive rough ground with vigorous seaweed beds, and is rich in shellfish and shallow water fish species. To the seaward of Mana Island is Cook Strait, which has very deep water. Canoe expeditions could easily reach the South Island from here.

Excavations were carried out in two parts of the beach ridge (Horwood 1991) and fish remains were abundant in both (Horwood *et al.* 1998). The larger northern excavation contained a relatively deep stratified deposit. The layers can be grouped as upper (predominantly or entirely an historically documented occupation by a group of Ngāti Toa in the first half of the nineteenth century) and lower, a considerably earlier pre-European occupation. The southern excavation contains material dating to the same period as the early horizons in the northern excavation and the two have been combined for the purpose of the present study. When the relative abundance of fish types is calculated (Table 20) and plotted out (Figures 101, 102) a surprising amount of change is revealed.

Family	Early Period MNI=719	Late Period MNI=997
Spotty, etc.	35.74 ± 3.57	26.68 ± 2.80
Snapper	25.87 ± 3.27	10.93 ± 1.99
Leatherjacket	10.71 ± 2.33	4.81 ± 1.38
Blue cod	6.82 ± 1.91	9.73 ± 1.89
Kahawai	6.26 ± 1.84	3.71 ± 1.22
Tarakihi, etc.	3.06 ± 1.33	3.51 ± 1.19
Blue moki, etc.	2.50 ± 1.21	8.83 ± 1.81
Trevally, etc.	2.23 ± 1.15	1.30 ± 0.75
Barracouta, etc.	1.81 ± 1.04	6.42 ± 1.57
Greenbone	1.39 ± 0.93	12.44 ± 2.10
Scarpee, etc.	0.97 ± 0.79	1.71 ± 0.85
Conger eel	0.70 ± 0.68	4.71 ± 1.37
Marblefish	0.56 ± 0.61	1.81 ± 0.88
Groper	0.56 ± 0.61	1.60 ± 0.83
Mackerel, etc.	0.28 ± 0.45	0.00 ± 0.05
Red cod, etc.	0.14 ± 0.34	0.50 ± 0.49
Ling	0.14 ± 0.34	0.50 ± 0.49
Red gurnard	0.14 ± 0.34	0.30 ± 0.39
John dory	0.14 ± 0.34	0.10 ± 0.25
Freshwater eels	0.00 ± 0.07	0.20 ± 0.33
Elephantfish	0.00 ± 0.07	0.20 ± 0.33

TABLE 20

Mana Island Fish MNI and Percentages.

The pattern of change evident in Figure 101 contrasts sharply with that at the Washpool (Figure 99), which showed considerable continuity. There is a far wider range of fishing opportunities at Mana Island than at the Washpool, and it is possible that some of this observed change reflects experimentation and the development of new or improved fishing skills over time. In Figure 102, four fish types are singled out to illustrate the extent of change indicated at Mana Island. Labrids decrease in abundance from 36% of the catch during the early occupation of the Island to 27% in the nineteenth century. Snapper also decrease significantly from 26% to 11%. By contrast, blue cod and greenbone increase, the latter from 2% to 12%. The pattern in Figure 102 is exactly the same as was observed at Black Rocks (Figure 98). These two sites are both near rocky broken ground on the northern edge of Cook Strait, and the strikingly similar patterns at the two sites must be significant. The changes illustrated in Figure 102 are not the only ones which are notable. Blue moki increases significantly from 3% to 9% over the same period.

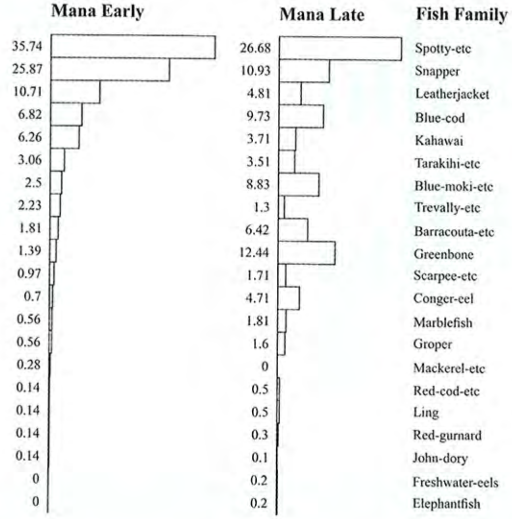

FIGURE 101

Changing relative abundance of fish types at Mana Island over time.

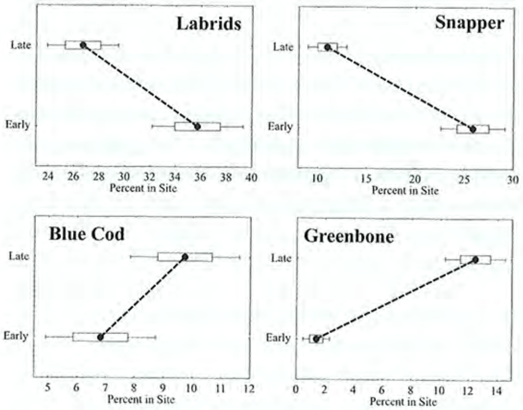

FIGURE 102

There are substantial changes in the abundance of several fish types at Mana Island over time. Labrids and snapper decrease while blue cod and greenbone increase.

As mentioned earlier, the only effective way of catching greenbone is by either setting a gill net in place for a length of time or dragging a hoop net carefully through weedy areas. The marked increase in abundance of these fish must indicate increased use of nets over time. This is probably also indicated by the increased catch of moki. These fish are very hard to catch in any number using a baited hook, but are easy to catch in abundance in weedy areas with a gill net. For a gill net to snare a fish, the mesh has to be relatively large and a certain sized mesh is especially made to catch a specific fish type. This type of fishing is practically unknown in the Pacific, and it is not at all clear from early historical records whether gill nets were used by Māori. Drag nets or seines do ensnare fish by the gills accidentally, but the catch is effected by dragging the net through the water and beaching it at a suitable place. These nets cannot be used in broken weedy areas, because they simply snag all the time. There are excellent historical records of hoop nets being dragged through weedy areas to capture marblefish (Buck 1926: 612 ff.). A few moki might have been caught by this method at Mana Island, but it seems more likely that set nets (gill nets) were being used. We may therefore have evidence of the development of this technique in New Zealand at both Black Rocks and Mana Island.

The increase in blue cod and decrease in labrids may possibly indicate that the people at Mana Island had become more adept at fishing in clear open waters than previously. There is also a small rise in groper, which may be a similar indication. The lower number of snapper in the more recent deposits at both Black Rocks and Mana Island is especially interesting. As was noted in Section 4 and discussed in detail above, where I considered environmental change, snapper recruitment is critically dependent on water temperature. The Little Ice Age would have had a more noticeable effect on snapper stocks in an area where they are not particularly abundant normally, as is the case in Cook Strait.

Finally, right at the bottom of Figure 101 is a small blip representing freshwater eels. None are present in the early period, but in the late part of the occupation there is an MNI of 2.

KOKOHUIA

The Kokohuia site is situated on a flat-topped promontory known as Waiarohia Point, between Opononi and Omapere in the Hokianga Harbour, Northland. It can be considered a general habitation site, with a range of features in different areas. The midden was recovered by Taylor (n.d.a, n.d.b). Radiocarbon dating suggests occupation between the fifteenth and seventeenth centuries AD, with a possible break in the middle of the sequence (Leach *et al.* 1997a). The midden remains can be split stratigraphically into two units, representing an earlier and later phase of occupation. How far apart these are in time is disputed. However, the two stratigraphic units provide a useful series with which to investigate any change.

The Hokianga Harbour is long and narrow with strong tidal movement. It extends inland for about 25 km and has numerous inlets, usually with extensive mud and sand flats, and areas of mangroves. The lower harbour and harbour mouth are productive recreational fishing grounds.

Family	**Early Period MNI=380**	**Late Period MNI=447**
Snapper	54.47 ± 5.14	48.32 ± 4.74
Spotty, etc.	13.16 ± 3.53	13.20 ± 3.25
Kahawai	8.42 ± 2.92	6.26 ± 2.36
Trevally, etc.	7.37 ± 2.76	8.50 ± 2.70
Red gurnard	6.58 ± 2.62	9.84 ± 2.87
Tarakihi, etc.	2.37 ± 1.66	2.46 ± 1.55
Leatherjacket	2.37 ± 1.66	2.24 ± 1.48
Blue moki, etc.	1.05 ± 1.16	1.79 ± 1.34
Barracouta, etc.	1.05 ± 1.16	0.89 ± 0.98
Yelloweyed mullet, etc.	1.05 ± 1.16	0.45 ± 0.73
Parore, etc.	0.79 ± 1.02	0.67 ± 0.87
Greenbone	0.53 ± 0.86	1.57 ± 1.26
Scarpee, etc.	0.26 ± 0.65	1.12 ± 1.09
Red cod, etc.	0.26 ± 0.65	0.89 ± 0.98
Flounder, etc.	0.26 ± 0.65	0.22 ± 0.55
Blue cod	0.00 ± 0.13	0.89 ± 0.98
Marblefish	0.00 ± 0.13	0.22 ± 0.55
Mackerel, etc.	0.00 ± 0.13	0.22 ± 0.55
Ling	0.00 ± 0.13	0.22 ± 0.55

TABLE 21

Kokohuia Fish MNI and Percentages.

Changes in relative abundance (Table 21) are plotted out in Figures 103 and 104. Figure 103 shows that the fish catches at the two periods are very similar. The most abundant fish by far is snapper, followed by labrids and kahawai. Statistical testing of the two series reveals only three fish types which might show changes (Figure 104). These are

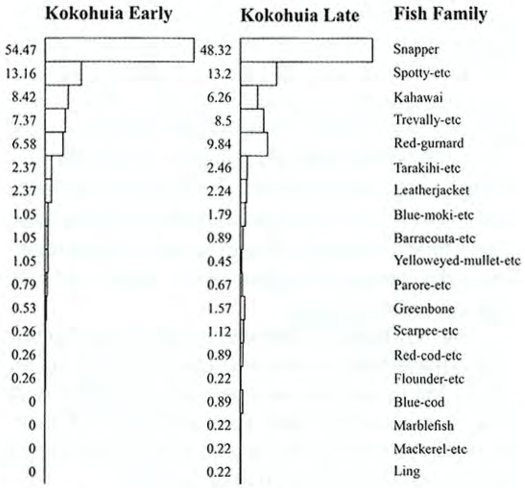

FIGURE 103

The relative abundance of fish types at Kokohuia shows very little change over time.

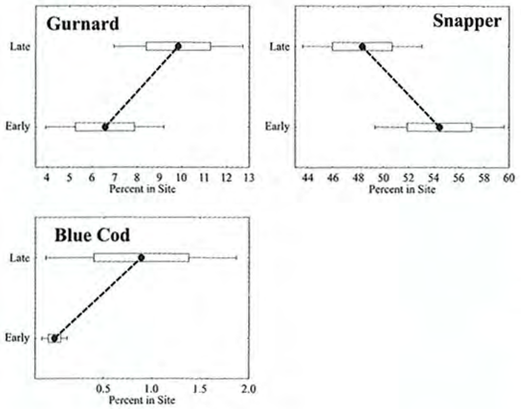

FIGURE 104

There are only three probable changes in the abundance of fish types at Kokohuia. These are significant at one but not two standard errors.

significant at one standard error, but not two. Gurnard appears to increase somewhat, along with blue cod, and snapper may have fallen in abundance.

DISCUSSION

Thus far I have examined the possibility that careful study of individual archaeological sites, or of several sites which show that there has been occupation in the same locality over a sustained period of time, might reveal changes in fish catch abundances. Few such sites exist, because of the mobile nature of pre-European Māori society; however, where they do, we have been able to see some interesting changes through time. I have summarised these in Table 22 and Figure 105. It must be remembered that these patterns arise from only a few sites which could be examined in this way, and the patterns may include important seasonal effects, which are difficult to factor out.

The Nett value in the right hand column of Table 22 is calculated from the Table giving +2 or -2 for rises or falls which have 95% confidence, and +1 or -1 for rises or falls with 68% confidence. Site codes are as follows:

LB= Long Beach Early to Late
BR34= BR3-BR4
BR32= BR3-BR2
BR42= BR4-BR2
WP12= Washpool I-II
WP13= Washpool I-III
WP23= Washpool II-III
MI= Mana Island Early to Late
KO= Kokohuia Early to late

Greenbone stands out as one fish which has increased in importance over time, at least in the Cook Strait area. This could well be a result of discovering effective means of capturing these fish. As mentioned above, the custom of gill-netting appears not to have been employed in the Pacific, possibly because of the extreme clarity of water in the tropics. The use of drag nets does have a respectable antiquity in the Pacific, and by the time of European contact in New Zealand was a spectacular activity. However, these types of nets cannot be used in weed-infested rocky areas where greenbone live. It

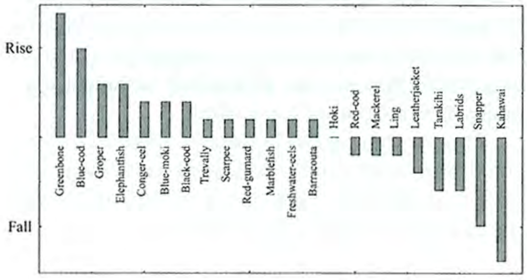

FIGURE 105

Fish types on the left hand side have risen in abundance over the pre-European period in New Zealand, while those on the right hand side have fallen. These patterns are observed in the few sites which have evidence of sustained or periodic occupation at one locality.

Species	Rise 95%	Rise 68%	Fall 95%	Fall 68%	Nett Rise-Fall
Greenbone	BR32,BR42,MI	BR34	--	--	7
Blue cod	LB	BR42,MI,KO	--	--	5
Groper	LB	MI	--	--	3
Elephantfish	WP12	WP13,MI	--	WP23	3
Conger eel	MI	--	--	--	2
Blue moki	MI	LB	--	WP12	2
Black cod	--	LB,BR32	--	--	2
Trevally	--	BR34	--	--	1
Scarpee	BR34	--	--	BR42	1
Red gurnard	--	KO	--	--	1
Marblefish	--	MI	--	--	1
Freshwater eels	--	WP23,MI	--	WP12	1
Barracouta	BR34,MI	--	LB	BR42	1
Hoki	--	BR34	--	BR42	0
Red cod	LB	--	BR42	2BR32	-1
Mackerel	--	--	--	MI	-1
Ling	--	--	--	BR34	-1
Leatherjacket	--	--	MI	--	-2
Tarakihi	--	BR34	BR32,BR42	--	-3
Labrids	LB	WP12	BR34,BR32,MI	--	-3
Snapper	--	--	MI	BR32,BR42,KO	-5
Kahawai	--	--	BR32,BR42	BR34,WP12,MI	-7

TABLE 22

Rise and Fall in Abundance of Fish at Different Archaeological Sites.

is therefore possible that gill-nets were developed in New Zealand somewhat later in the sequence. If this is so, it would also account for the apparent rise in importance of blue moki over time. These fish inhabit similar areas to greenbone and are difficult to catch on a baited hook. A few of these types of fish can be caught with hoop nets dragged slowly through weed, which is the technique Buck described for capturing marblefish (Buck 1926).

It is interesting that both blue cod and groper also show up as fishes which increased in importance over time. These fish are caught with baited hooks, and although blue cod can be caught in quite shallow water off the rocks, it is more likely that both these species were taken from canoes while fishing offshore in deeper waters over rough ground.

The species which falls most strongly is kahawai. This is a surprising find, but on the evidence available, it is apparently confined to the Cook Strait area. The pattern of seasonal movements of kahawai is very poorly understood, despite considerable research over the years by fisheries scientists. Māori in the early historic era used a specialised lure with pāua shell inlay for catching these fish. These artefacts are common in museum collections, although few kahawai bones are found in archaeological sites. Not one of these specialised lures has been found in a securely dated pre-European context. I have to admit that our knowledge of kahawai fishing in pre-European New Zealand is sadly deficient. It is possible that these fish were much more common in inshore surface waters in the Protohistoric period than in earlier times. This would account for the sudden efflorescence of these specialised lure hooks.

Snapper also falls in abundance. This is another surprising find, repeated at Black Rocks, Mana Island and Kokohuia. Although the extent of the fall in each case is not very great it is enough to cause one to wonder if the Little Ice Age is responsible. Snapper are not common in the Cook Strait region at any time, and the Little Ice Age would be sufficient to cause a noticeable lowering of recruitment within this species which might manifest itself in a more pronounced way in a marginal area such as this. Given the importance of snapper in Northern Māori economy it is a great pity that we have no information on abundance or size changes in this species for almost all of the North Island. This is an important area requiring further research.

Labrids also appear to decline in relative abundance, and this perhaps is easier to understand. These fish are so common that they are a very effective standby in times of hardship. It has been proposed that they can be a signal of adverse economic circumstances, such as marked deterioration in sea conditions or other kinds of environmental pressure (Leach & Anderson 1979a). Their high abundance in archaeological collections in Cook Strait and Fiordland is a good example. Some of the sites I have been able to study show an increase in labrids and others show a decrease, so there is only a marginal decline overall.

LOCAL CHANGES IN FISH SIZE

The next issue to be explored is whether there were any changes in the sizes of fish caught at different periods. At the outset it must be stressed that when we find evidence of changes in mean size of fish over time, it would be wrong to leap to the conclusion that this is due to impact on the marine resource by prehistoric people. Strong anecdotal evidence and a few passing references in published literature have suggested that fish sizes declined over archaeological time (Chaplin 1976: 133, 136; Desse-Berset 1993). The suggested causes of these observed changes are many and varied (climate change, growth rate, fishing pressure, etc.), but a common theme is the effects of commercialisation of the fishery in the industrialised era (Chaplin 1976: 130; Wheeler & Jones 1989: 166; Desse & Desse-Berset 1993: 345).

For New Zealand, to my knowledge there were no published size frequency histograms from archaeological sites for any species in a time sequence until 1994 (Leach & Boocock 1994), and this research actually showed an increase in mean size. It is not a simple matter to arrive at a trustworthy size frequency diagram of a prehistoric catch, but the background research on modern comparative material has now been completed for a few of the more common species in New Zealand (Table 23). This part of Section draws upon this work to examine the possibility that there were significant changes over time in New Zealand.

If the mean size of a fish catch can be shown to have changed in the course of time, either increasing or decreasing, there are several possible reasons. These are:

1: The change reflects a natural one in the marine environment
2: The change reflects human impact on the fish stock
3: The change reflects a change in fishing technology
4: The change reflects fishing in a different marine zone
5: The change reflects a change in fishing behaviour, such as size selection

Reasons 3, 4 and 5 should really be bracketed together in a grouping called 'cultural change', of which there are many forms. For example, modern fishing regulations in New Zealand prohibit the taking of fish below a certain size limit. Fishermen in small scale societies, such as in remote islands of the Pacific, have similar customs and, as in modern New Zealand, not everyone always follows them. Conflict between neighbouring groups and population pressure can appear and disappear over time. This can have the effect of limiting or extending the resource range a prehistoric group could utilise. A group could have access at one period to some particularly good fishing beds where large fish could be taken, but effectively be barred from using them at another period.

What this amounts to is that interpreting change in archaeology is almost never a straightforward matter. It is useful to see whether changes are widespread or confined to particular regions or periods of time. For example, if one found that mean snapper size fell through time in many archaeological sites in Northland where there was a high population, but remained relatively stable in most sites in Tasman Bay where there was much lower population, then one could reasonably suspect that we might be dealing with resource impact by humans in the north. Correctly interpreting change in archaeology usually requires a wide variety of evidence to be taken into account.

Of special interest is any archaeological evidence of human impact on resources over long periods. This is useful in helping to refine virgin biomass estimates in modern resource management modelling and can reveal subtle effects of humans harvesting the sea which are only manifest over hundreds or thousands of years. With this in mind, we should consider which species of fish might be particularly susceptible to human exploitation, and which are less likely to be so.

Species	Publication
Snapper	Leach & Boocock 1995
Barracouta	Leach *et al.* 1996a
Kahawai	Leach *et al.* 1996b
Blue cod	Leach *et al.* 1997b
Labrids	Leach *et al.* 1997d; Leach & Davidson 2001a
Red Cod	Leach *et al.* 2001b
Greenbone	In Process
Tarakihi	In Process
Freshwater eels	In Process
Albacore	In Process

TABLE 23

Fish Species whose Bones have been Studies Allometrically for Live Lenght and Weight estimates.

BARRACOUTA

Among the 35 families of fish which occur in New Zealand archaeological sites, there are very few species which might be adversely affected by intensive pre-European fishing. Of the species which are most abundant in archaeological sites, barracouta is not likely to have been much affected by the advent of Polynesians. As discussed in Section 4, barracouta is highly seasonal in its appearance in inshore shallow waters. Adults appear, in the south-eastern regions at least, during the summer to autumn months, and during winter to spring months in western parts of Foveaux Strait and along both east and west coasts north of about Banks Peninsula to nearly the top of the North Island (Figure 28). The current estimates (Annala 1994: 33-34) of MCY (Maximum Constant Yield) for barracouta are (tonne per annum):

Region	tonne per annum
BAR1: Auckland East	8,050
BAR4: Chathams	2,640
BAR5: Southland, Sub-Antarctic	9,500
BAR7: West Coast Nth and Sth Is	10,230

These figures are very large compared with other species taken by pre-European Māori. It is not possible that Māori could have had a significant impact on the resource. Any observable change can therefore be narrowed down to either a natural environmental factor such as climate change, or perhaps a cultural factor such as development of a new fishing technique.

The Barracouta catch at Long Beach is of special interest. The large number of bones recovered and kept by the archaeologists offered a unique opportunity in New Zealand for detailed research (the five standard cranial bones alone number 29,233, of which 15,558 were able to be measured for estimation of live fork length and weight). The only other archaeological site with a large number of barracouta bones available for study is Shag River (1,920 bones measured). The two assemblages will be discussed together.

The large number of measurements available meant that variations in estimates of fork length based on different parts of the anatomy could be investigated, and this was explored by Leach *et al.* (1999b) and Leach & Davidson (2001a). It was found that the spread of mean values in fork length, derived from different parts of the anatomy and from both whole and broken bones, is about 20 mm overall. This must be seen in perspective. The mean and standard deviation of the fork length of the Long Beach barracouta catch as a whole are 795 mm and 51 mm (Table 24). The variation observed amongst these different parts of the anatomy is therefore less than 3% of the mean, and less than half of the standard deviation.

The overall range in the Shag River Mouth barracouta remains by different parts of the anatomy is rather greater at about 45 mm, but the standard errors are considerably larger too, since a much smaller sample is available. The pairs of measurements do not form such tight clusters of mean fork length as in the case of Long Beach. Again, this is mainly due to smaller sample size.

There are several interesting features about the fish sizes at these two sites. Both archaeological catches show a strong dominance of very large and therefore old fishes. These catches can be compared with modern trawl data from southern New Zealand and the Chatham Islands (Figure 106). The modal peaks in both early and late archaeological periods are well above the largest modal peaks for Chatham Island surveys, and similar to the largest peak in Southern New Zealand surveys. Unfortunately, we do not have any information on the size frequency distribution of the fish that migrate to inshore shallow waters today for comparison with the pre-European data[3]. However, on the strength of what is presented here, it would appear that very old individuals were being preferentially caught. It is not easy to decide whether

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[3] Graham records large migrations of immature stages, up to 46 cm in length, entering Otago Harbour in early summer or autumn (Graham 1956: 312). This value is below the smallest specimen caught at Long Beach or Shag River Mouth.

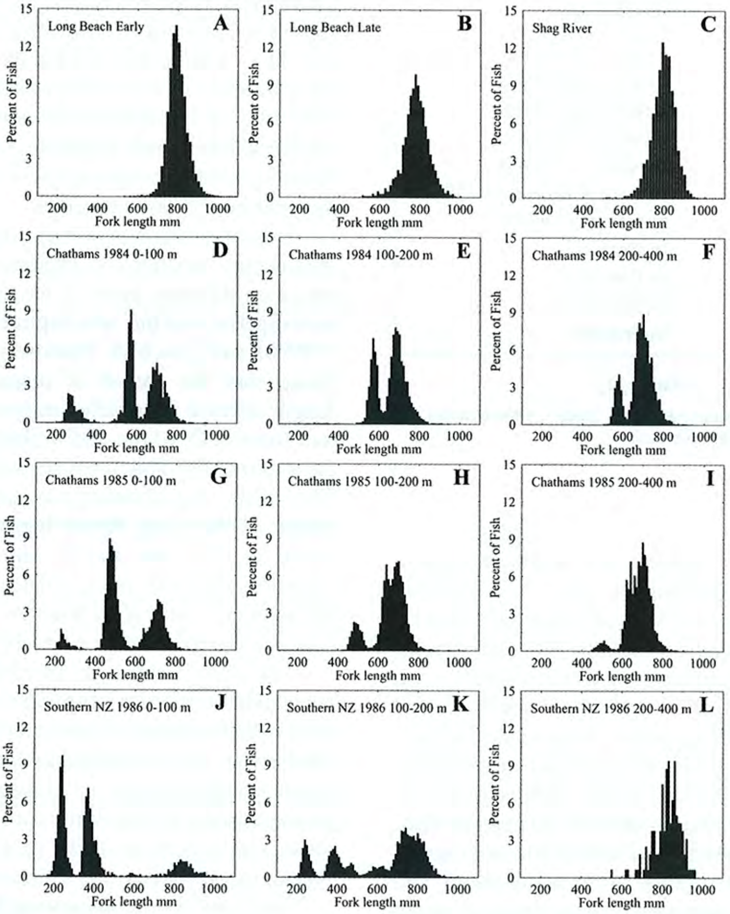

FIGURE 106

Pre-European barracouta catches compared with modern trawl data for the species.

this is because these were the only fish available for catching, or whether the technique for capturing the fish favoured only the largest individuals.

At Long Beach, two significant changes can be detected over time. The mean fork length decreased by 20 mm, and the standard deviation increased by 15.3 mm. The absolute size of these changes may not appear large, but they are both highly significant statistically. A broader range of somewhat smaller fish were being caught later in time. In view of the very large maximum constant yield for this species, it is hard to imagine that pre-European catches could have been responsible for this lowering in the mean size over time[4]. It is much

Provenance	N	Mean	SE	SD	SE
Long Beach					
Late Period	1586	778.4	± 1.6	63.2	± 1.1
Learly Period	13257	797.9	± 0.4	47.9	± 0.3
All Layers	15558	795.2	± 0.4	51.2	± 0.3
Shag River Mouth Dune					
Layer 1†	9	808.4	± 11.7	35.0	± 8.2
Layer 2	324	786.1	± 3.5	63.3	± 2.5
Layer 4	1194	796.6	± 1.6	53.8	± 1.1
Layer 5	214	792.9	± 3.2	46.6	± 2.3
Layer 6	16	800.8	± 11.9	47.8	± 8.4
Layer 7	15	819.3	± 11.6	45.0	± 8.2
Layer 8	3	830.8	± --	--	± --
Layer 9	1	902.0	± --	--	± --
All Layers	1920	794.6	± 1.2	54.6	± 0.9

† This layer may not be part of the main time series, as discussed earlier

TABLE 24

Fork Lengths of Archaeological Barracouta.

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[4] Leach *et al.* (1999b: 27) estimate that the total catch biomass was 10.6 and 3.4 tonne, at Long Beach and Shag River Mouth respectively.

more likely that we are observing a natural biological change over the period involved. Fluctuation in growth rate, caused by changes in sea water temperature, is a possible reason. This could be confirmed by aging and carrying out $^{16}O/^{18}O$ analysis on otoliths. Unfortunately, otoliths from barracouta are often unreadable for aging, as many as 59% being rejected from individuals over 80 cm (Hurst & Bagley 1987: 20).

The figures for mean fork length in the various layers in the dune at Shag River Mouth are plotted in Figure 107 (from Table 24). Although the standard errors are large and there is considerable overlap, there seems to be a trend towards decreasing size over time. It is very difficult to know how to interpret this. The apparent trend could be entirely due to chance, given the large size of the standard errors. However, it is certainly intriguing.

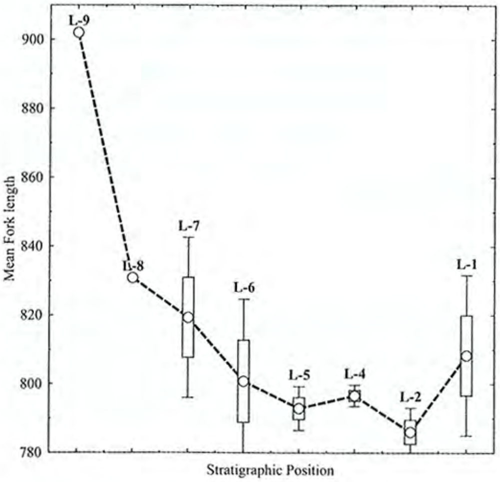

FIGURE 107

The mean fork length of barracouta catches from different stratigraphic layers in the sand dune sequence at Shag River Mouth. There are signs of decreasing size over time, but establishing statistical significance is made difficult by small sample size for some layers.

In the case of Long Beach, there is no such ambiguity – here the barracouta mean size decreases by 20 mm (Table 24) and is highly significant (Student's t = 11.89 with 14,841 degrees of freedom). Moreover, the standard deviation increases by 15.3 mm over time. This is again highly significant (standard error = 1.1 mm).

Barracouta grow very quickly for the first few years of their life, so it is possible to determine their age from fork length with reasonable accuracy. Hurst & Bagley (1987: 20) provide suitable mean and standard deviation figures, and those for ages three to ten years are plotted out over the top of the size-frequency diagrams of the Long Beach and Shag River barracouta fish catches in Figure 108 (left). It is clear from this that the fish being captured were all relatively old individuals. This is also apparent in Figure 106, where the modern research trawl data are shown.

It is possible to decompose a size-frequency diagram where there is a mixture of age components like this. A considerable amount has been published on the subject (Macdonald & Pitcher

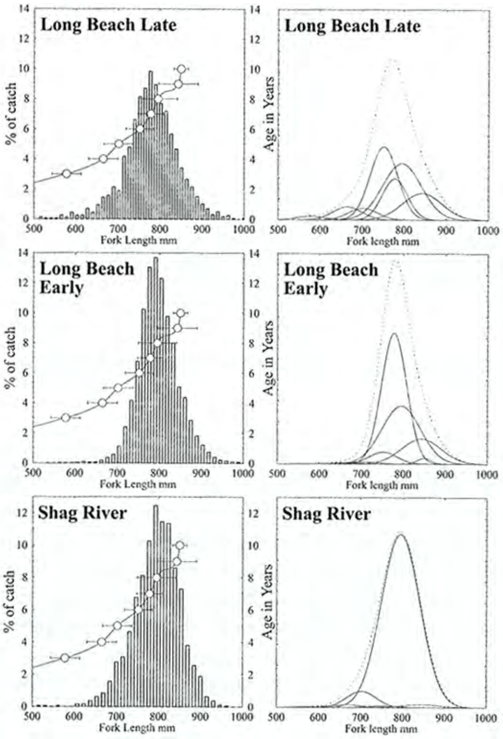

FIGURE 108

Size-frequency diagrams of barracouta catches at Long Beach and Shag River Mouth. Left: The modern age/length growth curve of barracouta is superimposed on each catch diagram. Right: Each catch is decomposed into its constituent age grades. The late catch from Long Beach shows a more even mix of fishes of four ages, whereas the earlier catches at both Long Beach and Shag River Mouth show much greater dominance of one age grade, with only one or two other ages in the mix. This is particularly marked at Shag River Mouth.

1979; Schnute & Fournier 1980; Everitt & Hand 1981; Titterington *et al.* 1985; Macdonald 1987; McLachlan & Basford 1988). Peter Macdonald at McMaster University in Canada has developed an algorithm which is now widely used for separating age grades of fish from trawl catch data. By using the MIX software iteratively until the χ^2 value is lowest, indicating the best fit, the proportions of the different age grades in the barracouta catches may be estimated. I used the MIX program (version 3.0) to separate out the age components in the catch diagram from Long Beach (early and late assemblages) and Shag River Mouth. The results are provided in Table 25 and Figure 108 (right).

Age in Years	Long Beach Early	Long Beach Late	Shag River Mouth
3	0.1	1.5	0.3
4	0.4	5.4	1,2
5	1.0	4.8	6.7
6	4.7	28.8	0.7
7	46.8	14.7	0.0†
8	31.8	30.9	95.2
9	14.1	14.9	1.7
10	1.1	0.0†	0.0†
Totals	**100.0**	**101.0**	**105.8**

† The MIX software produced some negative values within the range of the standard errors of the estimate, and this is the reason why totals do not add up exactly to 100%

TABLE 25

Percentage Age Composition of Archaeological Barracouta.

There are some interesting features in these age-frequency results. Two different time periods are represented at Long Beach: the early settlement can be referred to as Archaic or New Zealand East Polynesian in character, and the later as Classic Māori. Shag River Mouth is chronologically and culturally aligned with the early period at Long Beach. A narrow range of age grades is represented in both the early fish catches. Shag River Mouth is almost completely dominated by eight-year-old fish, with a minor number of five-year-olds. The early people at Long Beach caught barracouta from three age grades – mainly seven-year-olds, with a smaller number of eight-year-olds, and a few nine-year-old fish.

The late sample from Long Beach contrasts markedly with both these earlier barracouta catches. In this case, four different age grades are quite evenly represented. Six- and eight-year-old fish were caught in about the same proportion; and seven- and nine-year-olds are equally represented but in smaller amounts.

It must be remembered that decomposing these age mixtures from different periods of time is not without its hazards. Recruitment and growth rates of fish are markedly affected by sea water temperature and there are good reasons to think that this has varied significantly in New Zealand coastal waters during the last millennium. The mean size of barracouta of different ages could therefore be somewhat different in the two periods of occupation at Long Beach. However, the size-frequency distributions are clearly rather different. Just what this change can be attributed to is a moot point. Given the very large biomass of barracouta in southern waters, we can effectively rule out human influence on the population. These fish move inshore in this area during the summer, and are drawn from a very large benthic population well away from where pre-European Māori were catching them. Although a small human community might have an effect on the inshore fish population during any one summer period, the population would be fully replenished from the main offshore stock the following summer. The significant decrease in mean size at Long Beach is therefore not human induced.

Snapper

This species has much lower Maximum Constant Yield values than barracouta and could possibly be a candidate for adverse impact during the pre-European period. MCY figures for different areas of New Zealand are given below (Annala 1994: 201-205):

Region	tonne per annum
SNA1: Auckland East	3,470 to 6,130
SNA2: Central East	273
SNA7: West Coast South Is	448
SNA8: West Coast North Is	1,175

Although snapper occurs in great abundance in many North Island sites, there are so far only four sites in which it is possible to investigate size changes through time. These are Kokohuia in Northland, Mana Island and Foxton near Wellington, and Rotokura in Tasman Bay. The statistical information about the various catches is provided in Table 26 and size-frequency diagrams in Figure 109.

Kokohuia	**Early**	**Late**
N	357	364
Range	102 to 756	106 to 734
Mean	476.5 ± 6.0	457.9 ± 6.2
SD	113.2 ± 4.2	117.5 ± 4.4
g1/w1	-0.6 and 5.9	-0.5 and 5.8
g2/w2	3.4 and 1.7	3.1 and 0.3
Mana Island	**Early**	**Late**
N	413	111
Range	266 to 939	285 to 777
Mean	463.9 ± 5.6	463.3 ± 11.4
SD	115.0 ± 4.0	120.4 ± 8.0
g1/w1	0.7 and 7.0	0.7 and 3.8
g2/w2	3.3 and 1.3	2.7 and 0.5
Foxton	**Early**	**Late**
N	436	644
Range	254 to 836	239 to 953
Mean	456.5 ± 4.6	481.6 ± 3.9
SD	96.1 ± 3.2	101.4 ± 2.8
g1/w1	0.3 and 4.7	0.5 and 7.8
g2/w2	3.0 and 0.1	3.5 and 3.0
Rotokura	**Early**	**Late**
N	198	475
Range	362 to 746	188.2 to 870.1
Mean	556.9 ± 5.4	586.9 ± 4.4
SD	76.5 ± 3.8	97.7 ± 3.1
g1/w1	-0.0 and 1.4	-0.5 and 6.4
g2/w2	2.7 and 0.5	5.0 and 9.1

TABLE 26

Pre-European Snapper Fork Length mm at Several Sites. (g1/w1 = skewness; g2/w2 = kurtosis).

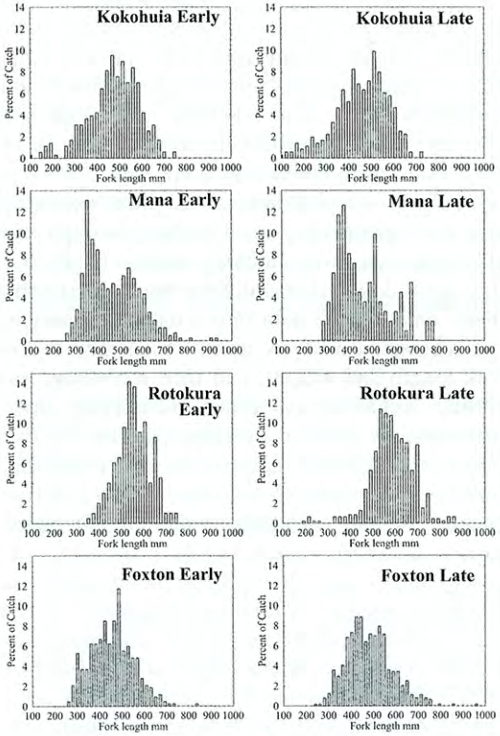

FIGURE 109

Pre-European Snapper catches from four archaeological sites where change through time can be explored. Rotokura from Leach & Boocock (1994: 77); Foxton from Davidson *et al.* (2001: 84).

At Kokohuia there is no significant difference between the earlier and later snapper catches. It will be recalled in the earlier discussion in this Section that there was possible evidence for a slight fall in relative abundance of snapper at this site, and that this shadowed similar trends at Mana Island and Black Rocks. The time gap between the two stratigraphic horizons at Kokohuia may not be very great (Figure 110), but Schmidt, who did the dating, believes it is significant, since it is based on pooling a large number of dates. Taylor, who excavated the site, believes the different phases of occupation were deposited close together in time. His opinion is based on the general similarity of occupation debris and structures in the site. Whatever is the case, as shown above, the types of fish caught and their relative abundances are very similar in the two stratigraphic horizons. Moreover, for the snapper catch in particular, the two size-frequency distributions are almost identical. Inspection of Figure 109 and the data in Table 26 shows that the statistics for the two independent archaeological samples are remarkably similar. The two means, standard deviations, skewness and kurtosis statistics are all within one standard error of each other.

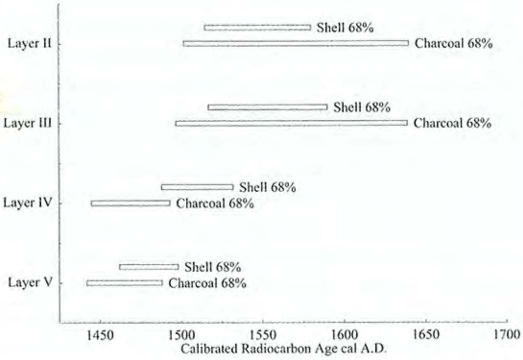

FIGURE 110

Pooled calibrated radiocarbon ages for Kokohuia. After Leach *et al.* (1997a: fig. 4). Layers II and III are `Late' and Layers IV and V are 'Early'.

So here is a useful case study, where there are two independent samples of snapper from two different stratigraphic horizons, both of reasonable size for obtaining reliable statistics, and they show themselves to be near identical in all dispersion characteristics. This particular analysis is an excellent test of the methodology employed in this type of analysis of archaeological fish bone assemblages. It is a laborious process working through each step, beginning with catching modern fishes, boiling them down, extracting the bones, measuring them, entering the data into a database, carrying out regression analysis to link bone size to live fork length and weight, and then recovering and sorting archaeological bones, identifying them, measuring as many as possible, entering the data into a second database, using the best established regression equations to estimate original live size, pooling the data according to stratigraphic provenance, calculating sample statistics, and then comparing these from one horizon to another. Although this process is now well organised, so that each step is fairly mechanical with suitable quality control checks at various points, it is not a small undertaking to set up such a system. The two snapper catches at Kokohuia are as close to identical as it is possible to get, and this must shed some light on the dispute relating to the amount of time between the two stratigraphic horizons.

It may be noticed in the size-frequency catch diagrams in Figure 109 that some very small fish were being taken at Kokohuia. The smallest fish in the sample is only 102 mm fork length, and quite a few fish in both stratigraphic horizons are less than 300 mm fork length, in contrast to the other three sites, where such small fish were not taken. This may indicate that seine nets were being used in the Hokianga harbour for capturing snapper. In any event, there are no signs of bimodality in the Kokohuia catches. There is, however, statistically significant negative skewness in both the Kokohuia assemblages. Once again, this looks like evidence of seine netting. On the other hand, at Mana Island and Foxton, the distributions show significant positive skewness, clear evidence that small fish are not being taken. There are two possibilities – one is that any small fish captured were returned, and the other is that baited hooks were more frequently used and small fish were not being caught. As will be seen in Section 9, it is not a Polynesian custom to return small fish and pre-European Māori were no exception to this. The use of baited hooks is the preferred explanation.

At Mana Island, there are clear signs of bimodality in both early and late assemblages, with the two peaks at 350 and 540 mm in the early sample, and 360 and 515 mm in the second. As with Kokohuia, the dispersion statistics are almost identical, but in this case there is a very clear time gap. The early sample is associated with many artefacts clearly possessing Archaic affiliations, while the later sample is definitely associated with Classic Māori and early European items. In other words, the samples were deposited by people of two quite different cultural affiliations. Despite this, the extent of the actual time gap between the two occupations could be as little as 200 years. Based on modern aging information for Tasman Bay snapper, these two modes are equivalent to fish aged about 5 years for the first mode, and between 12 and 14 years for the second (Gilbert 1996: pers. comm.). With some small exceptions, the marine environment in the vicinity of Mana Island is not suitable for seine netting, as the inshore zone is strewn with boulders and thick with seaweed cover. These fish are most likely to have been taken with hooks, from canoes or off the rocks or both. Snapper first reach maturity from 20-28 cm fork length at 3-4 years age, when they begin to take part in annual schooling for spawning; older fish disperse more widely (Annala 1994: 197). These two modes in the catch therefore relate to fishes with quite different habits, and it is possible that they represent exploitation of two different fishing zones.

At Foxton there is a clear increase in mean size of snapper over time, and as pointed out earlier in this Section, the percentage of snapper in the catches fell through time. These two changes are consistent with declining abundance of local snapper stocks. Unfortunately, the size of the time gap between these two assemblages is not clear, but is not thought to have been great, and both assemblages are thought to date to relatively early in pre-European times. The 'late' assemblage is not likely to be associated with the Little Ice Age (Davidson *et al.* 2001: 83). The difference between these two assemblages could be seasonal – the earlier one more typical of summer conditions, and the later one more typical of winter, when non resident smaller fish migrate further north into warmer waters. This hypothesis remains to be tested.

The last site to be considered which has two samples separated in time is at Rotokura in Tasman Bay. These are two very interesting catches. It can be seen in Figure 109 that the early catch has a lot more fish in the left tail of the distribution than the later sample; that is, fish which are less than 500 mm. In addition, the later sample has a lot more fish in the right tail of the distribution; that is, fish greater than 600 mm fork length. These differences are manifest in the statistical data too (Table 26). The early sample has no significant skewness, but the later one has a small but highly significant negative skewness. This may at first glance appear to contradict the comment above that there are fewer smaller fish in this distribution, but this is not so. The non-normality arises precisely because there are too few smaller fish in the distribution. The left tail extends out further than in the earlier sample, but has fewer fish in it. The later sample also has a highly significant leptokurtic shape, whereas the earlier sample has normal kurtosis. Finally, the mean size is significantly greater in the later sample than the earlier one.

In this respect, the catches at Rotokura in Tasman Bay are somewhat unusual. The reason may lie in the nature of the Tasman Bay population of snapper itself. Tasman Bay is close to the southern limit of the distribution of snapper in New Zealand, and is well known amongst fishermen and fisheries scientists as having an unusual population. Snapper tend to be rather larger in these waters than further north. Another anomaly, which may be particularly important in the present discussion, is that the recruitment of year classes has been found to be highly irregular. This may be partly related to the generally cooler waters than further north. There is a tendency towards a patchy distribution of different sized snapper in Tasman Bay, and over periods of 50 years or more the population can get older with very little recruitment of younger individuals. This is especially likely if such a period coincides with slightly cooler conditions than normally prevail, such as in the Little Ice Age. As this older, larger population dies out, it will be replaced by a considerably smaller population. In such a way, it is easy to see that Tasman Bay can have dramatic shifts in mean fish size over significant archaeological time. Such a phenomenon may not apply further north in New Zealand to the same extent.

Another possible explanation is that the earlier people at Rotokura focused their fishing activities close at hand, perhaps within the small Cable Bay where the site is situated, and in a restricted area like this the resource may not be sustainable. If this is so, the later fishermen may have been obliged to venture further afield for good catches, possibly returning with somewhat larger fish on average than could be taken from waters close inshore. Finally, it has been observed that moa and sea mammals are present in the early part of the Rotokura site, but absent from the later levels. It is possible that as these more substantial items of food became less accessible, fishing became a more significant economic activity, and fishing grounds with larger individuals were more actively sought after (Leach & Boocock 1994: 82-83).

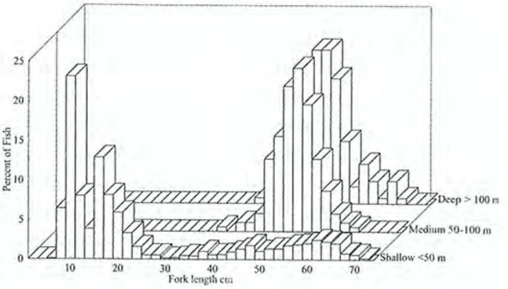

FIGURE 111

Modern snapper sizes in the vicinity of Tasman Bay from trawls in three depth ranges (after Leach & Boocock 1994: 76).

Figure 111 presents size-frequency curves for modern Tasman Bay snapper, based on research trawls in different depths of water. It can be seen that there are abundant juveniles in shallow waters, but also larger individuals. In both medium and deep waters in the bay, the distributions are unimodal with mean fork lengths of 510 and 520 mm, increasing slightly with depth. The mean values for the archaeological samples are 557 and 587 mm, increasing later in time. Clearly, the pre-European people in this area were able to harvest snapper at the larger end of the modern distribution.

BLUE COD

Although no estimates of blue cod biomass for different parts of New Zealand are currently available, there are estimates for Maximum Constant Yield (Annala 1994: 43) which are given below:

Region	**tonne per annum**
BCO1: Auckland	15
BCO2: Central East	5
BCO3: SouthEast Coast	55
BCO4: South East Chathams Rise	525
BCO5: Southland and Sub-Antarctic	565
BCO7: Challenger	85
BCO8: Central Egmont	40

These are based on average catch rates over a period of time when stocks do not appear to be diminishing. They are very low values compared with barracouta or snapper, so blue cod could possibly be a very good species with which to look for any evidence of over-fishing in the pre-European period. In Section 4 it was noted that the species occurs in very shallow water and down to about 80 m depth, and is known to be strongly territorial all year round. There can also be dramatic changes in local abundance of blue cod inshore depending on turbidity and seasonal water temperatures, and these factors could be more important in southern than northern waters. These biological and behavioural matters must be kept in mind when examining changes from one archaeological site to another.

Although live catch information has been reconstructed for this species from quite a few sites, sufficiently large samples have been more difficult to obtain. There are good samples from the two sites on Mana Island and especially important ones in the Chatham Islands (Table 27). However, there is an additional problem here in that radiocarbon dates do not reliably place the three sites in chronological order (Table 28). This is fundamental when considering change through time. There is no published information on the extent of any inbuilt age in the samples dated, and given their close proximity in time, this is a great disadvantage. Sutton (1980: 80) presents a case that all these sites in the Point Durham area of the Chatham Islands were part of one cultural system; that is, each site was a different specialised functional entity within the activities of one community. This implies that any differences between the dates for the sites is due to small statistical variation rather than representative of significant temporal difference. There is, however, an important difference between real and effective temporal contemporaneity. These sites could

Chatham Islands	**CHB**	**CHA**	**Waihora**
N	14,517	2671	8047
Range	119 to 685	181 to 651	81 to 616
Mean	380.6 ± 0.6	355.1 ± 1.3	326.7 ± 0.6
SD	73.4 ± 0.4	67.4 ± 0.9	61.1 ± 0.4
gl/w1	0.4 and 30.0	0.4 and 13.9	0.8 and 33.9
g2/w2	2.9 and 3.1	3.1 and 1.5	4.0 and 19.2
Mana Island	**Early**	**Late**	
N	115	181	
Range	78 to 563	80 to 591	
Mean	237.5 ± 9.1	313.1 ± 7.2	
SD	98.4 ± 6.4	96.9 ± 5.0	
gl/w1	1.0 and 4.5	0.2 and 2.5	
g1/w2	3.6 and 1.6	2.6 and 0.8	

TABLE 27

Pre-European Blue Cod Fork Lengths (in mm) at several sites (g1/w1 = skewness; g2/w2 = kurtosis).

Provenance	**Lab Nº**	**Conventional Age BP**
CHA Area I/2 layer 2	R5750/7	170 ± 60
CHB Area II/19 Crust of layer 2	R5750/3	370 ± 60
CHB Area II/23-24 Base of ash lens in Layer 1	R5750/4	170 ± 60
Waihora Area VII/1+2 Layer 2 (stone structure 2)	R4969/1	380 ± 40
Waihora Area VIII/6+7 layer 3	R4969/2	370 ± 30
Waihora Area IV/23 Lens D	R5091/2	370 ± 50
Waihora Area V/15 Lens B	R5091/2	420 ± 60
Waihora Area Vb/2+7 Layer 1	R5091/3	390 ± 50
Waihora Area V/6 Surface beneath layer 3	R5091/4	410 ± 50
Waihora Area VI/18+19 Layer 1	R5091/5	330 ± 60

TABLE 28

Chatham Island Radiocarbon Dates (charcoal) (From Sutton 1976 & Smith 1997: pers. comm.)

actually be 50 or 100 years apart in time and still effectively be part of the same functioning social system. If they are indeed 50 or 100 years apart, this is an important time gap when studying human impact on the local marine environment. Moreover, if they are exactly contemporary, then any differences between the catch data from the various sites, no matter how small or large, are of considerable interest because they may indicate partitioning of the catch according to social rank or other criteria. In short, precise dating of these sites, while it may not have been possible when the excavations were carried out, is of great interest now. It would be very useful to re-visit this problem in the future.

The fish bone assemblages from these sites in the Chatham Islands are very large, containing not only quantities of blue cod, but also of labrids and greenbone, and the sites show all the signs of being short duration settlements. They therefore offer an exceptional opportunity for detailed study. In the absence of fine control over chronology this possibility is frustrated to some extent, but it is still very useful to point out the characteristics of the assemblages. There are important differences in the dispersion characteristics of the blue cod assemblages from these three sites (Figures 112, 113, Table 27).

These three archaeological sites in the Chatham Islands are quite close to each other near Point Durham. Waihora is thought to be the central village of the site complex, and CHA and CHB are 780 m and 1140 m respectively from the main village. Waihora is closest to the coastline, the other two sites being situated somewhat further inland. It will be readily observed in Table 27 that the mean fork length for blue cod is largest at CHB, followed by CHA, and smallest at Waihora. The differences are highly significant. The change in central tendency is clearly seen in Figure 112 and it will also be observed that the right hand shoulder (the largest fish) of the curves steadily diminishes from CHB to CHA to Waihora. This is illustrated in the bottom right of Figure 112, where the three curves are superimposed. This shape change is partly reflected in a uniform lowering of the standard deviation from one site to the other.

When these changes are plotted out in Figure 113, the trend in characteristics from one site to another is striking. It is tempting to think that this might follow a time series, but there is no concrete evidence for this.

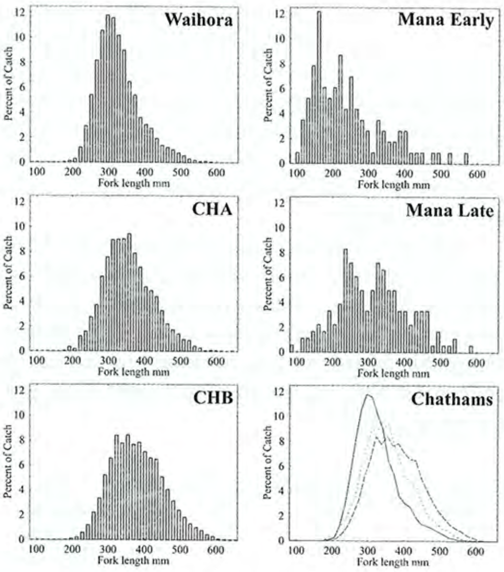

FIGURE 112

Pre-European blue cod catches from three sites in the Chatham Islands and two time periods on Mana Island. The catches from the three Chatham Island sites are superimposed at bottom right. After Leach *et al.* (2000b: 129).

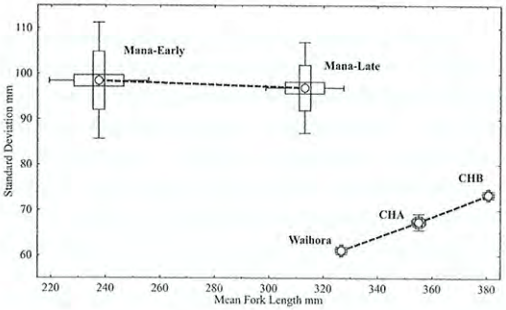

FIGURE 113

Time trends in dispersion characteristics of blue cod catches at Mana Island and three Chatham Island sites. From Leach *et al.* (2000b: 134) and Leach & Davidson (2001a: 155).

When the characteristics of the blue cod assemblages from Mana Island are plotted out on the same graph, a change through time is indicated. Possibly contrary to expectation, the Mana Island trend is towards an increase in mean fork length over time. Once again, the difference is highly significant. The very small fish taken in the earlier period are unlikely to have been captured using baited hook and line. It is more plausible that inshore nets and traps of various kinds were used for their capture. The observed increase in mean size over time could be partly due to a change in fishing technology over time. For example, while in the early period fishing close inshore is most likely, later in time fishing may have been further offshore in deeper water where larger fish could be caught with baited lines. However, this may not be the whole answer.

The size of some of the blue cod in the early catches was very small indeed, some being less than 100 mm long. The current legal size limit for blue cod in most parts of New Zealand is 330 mm. Using this figure, we can calculate the amount of undersized blue cod which were caught in the pre-European period.

Undersize %	OverSize %	No. Fish	Site
82.6	17.4	115	Mana Island Early
59.1	40.9	181	Mana Island Late
27.3	72.7	14,517	CHBChatham Islands
38.9	61.1	2,671	CHAChatham Islands
59.3	40.7	8,047	Waihora Chatham Islands
100.0	0.0	5	Kokohuia
76.3	23.7	59	Black Rocks BR4
81.8	18.2	11	Black Rocks BR3
73.9	26.1	23	Black Rocks BR2

This is a subject which is explored further in Section 9, but it is relevant here to the extent that the idea that fishing pressure results in a lowering of mean size over time may be an item of faith more than a statement of reality. I was certainly surprised to find evidence of an increase in mean size of blue cod at Mana Island over time. It will be recalled that this was also found for snapper at Rotokura. Whether this occurred in the Chatham Islands awaits better information on the chronology of the sites there. I must introduce a note of caution at this stage though, because these three Chatham Islands sites are just that, three separate sites, with no guarantee of continuous local marine exploitation by the occupants of this area. A respite of say 50 years from fishing in a small coastal area is virtually undetectable with current archaeological techniques, but could result in substantial recovery of inshore fish stocks. This has certainly been the finding recently when areas are set aside as marine reserves.

Even so, it is tempting to hypothesise that we have here an indication from the archaeological record that sustained fishing of a species sensitive to human predation may lead to an increase in mean size over time if fishermen are permitted to take as many small specimens as they wish. Polynesian people in the tropical Pacific are no strangers to capturing and eating small fish. There is no reason to think that the first immigrants to New Zealand brought with them a new-fangled conservation notion that stocks are best preserved by taking the largest specimens and leaving the small ones alone. Fish hooks made from bone and shell are nowhere near as efficient as modern steel hooks and it is very hard to make them small enough to catch small fish. The small fish which we find in archaeological sites are bound to have been taken with various net and trap techniques which do not select according to size to anything like the same extent. Polynesian people do not waste small fish by throwing them back. This "take everything" approach may not be as damaging to coastal ecology as is widely believed.

LABRIDS

These fish are very widespread throughout New Zealand, but are not sought after as food by modern Māori or Europeans. They are extremely easy to catch, and are often used as bait for catching other fish. Since they are not a species of any commercial interest there is no information on biomass or Maximum Constant Yield. This is a great pity because in some respects this fish is an excellent one for monitoring human environmental impact. It is argued by Leach & Anderson (1979a) that this species would be heavily exploited in times of food shortage and poor sea conditions when other species are hard to capture. Their presence therefore can be a useful guide to adverse environmental conditions. They live in shallow inshore waters where there is rock and weed, and can be taken with very small hooks, or with hoop nets amongst rough ground. There are several common species, which are very difficult to differentiate osteologically, and this may complicate analysis of size-frequency diagrams, because over time there may have been change in relative abundance of the different species taken, particularly if people were able to fish in somewhat deeper water where larger species are found. Pre-European catches have been reconstructed for a number of New Zealand and Chatham Islands sites in which there is some evidence of localised chronology. These sites have all been discussed previously. A selection of data on labrids is presented in Table 29 and Figures 114, 115, 116.

Chatham Islands	**Waihora**	**CHA**	**CHB**
N	3096	332	1518
Range	148 to 489	166 to 517	107 to 541
Mean	294.6 ± 1.0	314.3 ± 3.1	304.6 ± 1.5
SD	58.7 ± 0.7	57.9 ± 2.2	61.4 ± 1.1
g1/w1	0.2 and 12.0	0.0 and 1.1	0.3 and 8.9
g2/w2	2.5 and 5.0	2.8 and 0.5	2.8 and 0.8
Black Rocks	**BR3**	**BR4**	**BR2**
N	121	444	82
Range	135 to 419	145 to 465	158 to 446
Mean	242.0 ± 3.4	246.7 ± 2.2	262.5 ± 6.0
SD	38.0 ± 2.4	46.5 ± 1.5	55.1 ± 4.3
g1/w1	0.5 and 3.5	0.6 and 7.0	0.8 and 3.4
g2/w2	6.0 and 7.4	4.6 and 7.2	3.8 and 1.9
Mana Island	**Early**	**Late**	
N	462	459	
Range	96 to 521	108 to 498	
Mean	217.6 ± 3.5	276.9 ± 3.3	
SD	76.1 ± 2.5	72.5 ± 2.3	
g1/w1	0.7 and 7.6	0.3 and 5.4	
g2/w2	3.6 and 3.0	3.1 and 0.5	
Kokohuia	**Early**	**Late**	
N	48	84	
Range	96 to 457	130 to 404	
Mean	210.1 ± 9.6	228.8 ± 6.6	
SD	67.1 ± 6.8	60.6 ± 4.6	
g1/w1	1.4 and 3.6	0.7 and 3.3	
g2/w2	6.1 and 5.3	2.9 and 0.0	

TABLE 29

Pre-European labrid Fork Lengths (in mm) at Several Sites.

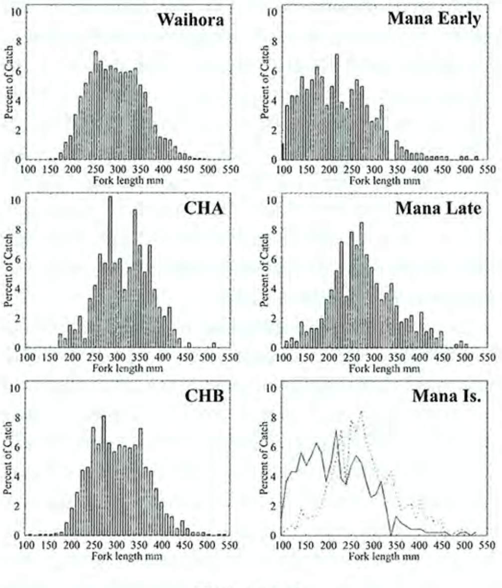

FIGURE 114

Pre-European labrid catches from three sites in the Chatham Islands and Mana Island. The two Mana Island sites are superimposed at bottom right. From Leach *et al.* (1999a: 124).

There are signs here of the same phenomenon seen in blue cod, namely that early fish catches at a locality had more small fish than later catches, leading to an increase in mean size over time. This is very clearly seen in Figure 114. The Mana Island Early fish catch has a large shoulder on the left hand side of the distribution, which has all but disappeared in the Mana Island late catch. This pattern is evident when the various assemblages are plotted out in Figure 116. The Black Rocks assemblages are particularly interesting because the dating evidence for BR3 and BR4 indicates that they are very close together in time, although BR4 is slightly later. The BR2 site, however, is much later, and represents re-use of the area after a period of depopulation. It has been shown that during the interregnum at Black Rocks, shellfish regained their earlier size, but crayfish did not (Leach & Anderson 1979b). It would appear from Figure 116 that labrids increased in mean size through time.

Finally, the two Kokohuia samples also appear to show an increase in mean labrid size over time, though small sample sizes result in overlap

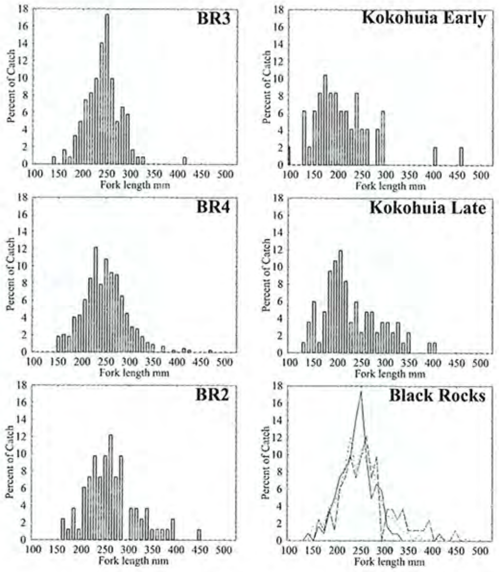

FIGURE 115

Pre-European labrid catches from Kokohuia and Black Rocks. The catches from the three sites at Black Rocks are superimposed at bottom right. From Leach *et al.* (1999a: 125).

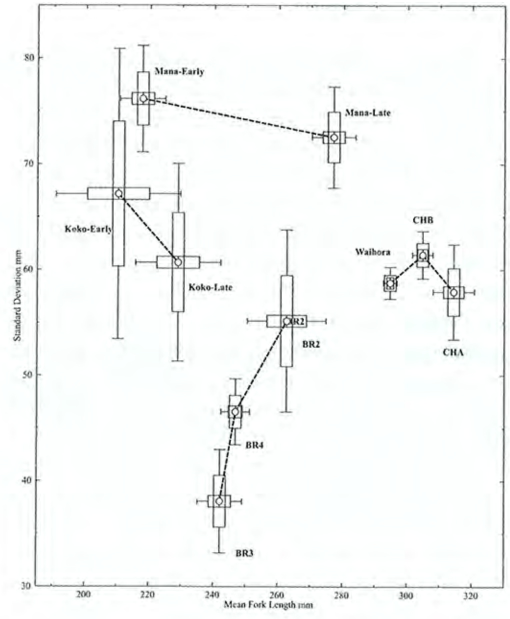

FIGURE 116

Time trends in dispersion characteristics of labrid catches in several archaeological sites. From Leach & Davidson (2001a: 156).

at two standard errors. In view of Taylor's opinion about continuity of occupation at this site, despite the radiocarbon dates, Kokohuia may be the best example in this study of human impact on a labrid population over a short period of time.

At a gross level then, labrid catches show signs of size changes through time in several sites where this can be examined; but what has not been made clear so far is that 'labrids' are not one species of fish. In fact there are about 16 species in New Zealand waters (Leach & Anderson 1979a), although far fewer species inhabit colder waters in central and southern New Zealand. Identification of archaeological bones to species level is almost impossible, although some species may be distinguished using multiple bone measurements and principle components analysis (Leach & Davidson 2001b: 146). The changes illustrated above as changes through time may therefore be changes in labrid species composition.

Fortunately, only three species are common throughout most of New Zealand, and each of these has a slightly different size-frequency distribution. This makes it possible to use Peter Macdonald's MIX algorithm for decomposing such mixtures into their constituent parts (discussed above). This has been attempted for the three archaeological sites in the Chatham Islands just mentioned (Figure 117). On the middle of this Figure is shown the size-frequency histogram of the large catch from Waihora, and below it the distributions of the three species which are assumed to be present after separating them using MIX. At the top of the Figure is shown the separate distributions for the three archaeological sites. MIX estimates the proportion of each species in each of the distributions (Table 30), and this can be used to calculate biomass at each site (Leach *et al.* 1999a: 132 ff.).

According to this analysis, from the earlier site (Waihora) to the two later sites (CHA and CHB) both spotty and scarlet wrasse are seen to diminish in importance over time, while banded wrasse increases. This surely indicates the effects of sustained harvesting pressure on the first two species. The banded wrasse is an extremely shy species, which seldom takes a baited hook and would be the last to be affected by intensive fishing. All three species are solitary, with strongly defended home territories, and habitat recolonisation from any distance is slow.

Common Name	Waihora	CHA	CHB
spotty	91.1 ± 0.6	4.3 ± 1.4	5.7 ± 0.7
scarlet wrasse	62.7 ± 2.0	37.6 ± 6.8	52.8 ± 3.1
banded wrasse	28.2 ± 1.9	58.2 ± 6.6	41.4 ± 3.0

TABLE 30

Percentage of each Labrid species in three Chatham Islands Sites.

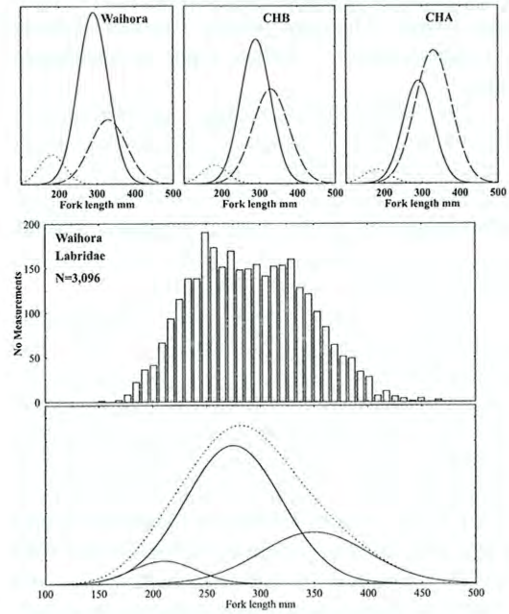

FIGURE 117

Three labrid species in sites at the Chatham Islands. Upper: The three labrid species separated from all three Chatham Island sites (see text). From Leach *et al.* (1999a: 127). Centre: All labrids, unseparated, from Waihora. Lower: Waihora labrids separated into three species.

DISCUSSION

The purpose of this Section was to seek and describe changes through time in the fish catches of pre-European Māori. Two types of change might be recognised: those caused by natural environmental change and those caused by humans themselves, either through changes in behaviour (human cultural change) or through the effects of human habitation in New Zealand. Distinguishing between these is not always easy, and the first part of this Section was therefore devoted to examining evidence of natural change in New Zealand during the last thousand years.

There is now well documented evidence of global changes in climate over this period and the basic features are evident in both hemispheres. A lot of the recent research relating to this has been driven by a need to resolve a political dispute about who or what is responsible for present-day global warming. That is, is it caused by human-made greenhouse gases or is it natural change? A beneficial effect of this dispute is that we now have bountiful primary data on climate in the last millennium. There is no longer any doubt that what was known as the Little Ice Age in Europe was a global phenomenon, affecting New Zealand as much as anywhere else. Palaeoclimatologists are still seeking the causes of this, but changes in solar irradiation reaching earth might prove to be one of the critical factors. To what extent increasing volcanic activity in this period was responsible for shadowing the planet's surface and how much was due to changes in solar activity itself is disputed. Nevertheless the end result is clear. When Captain Cook arrived here in 1769 New Zealand was still suffering the effects of the Little Ice Age, though perhaps not at its greatest extent. The evidence for this is written in his own Journals and those of his companions during their several visits to New Zealand. Before the onset of the Little Ice Age, climatic conditions in New Zealand were probably similar to the early part of the twentieth century, possibly a little warmer. In the northern hemisphere, this period is known as the Medieval Warm Period. Whether this was a distinct event in New Zealand remains to be verified. Nevertheless, the appellation is useful as a contrast to the Little Ice Age. We normally think of Little Ice Age in terms of the effects on the land; that is, air temperatures. However, evidence was also presented of a surprisingly large effect on surface sea water temperatures in New Zealand, at least in Cook Strait. This would have been of great importance to the character of the New Zealand fishery during the Little Ice Age. For example, it was argued that the spawning snapper population of Tasman Bay would have become extinct in this period, and there is now good evidence from archaeological sites that snapper stocks were depauperate during the Little Ice Age.

It was pointed out early in the Section that, for a number of reasons, it would not be easy to make a chronicle of changes from archaeological evidence, since the time depth of the prehistoric period here is very short, at most 1,000 years, and there are considerable difficulties marshalling sites and their contents into reliable chronometric order. In-built age in radiocarbon dates of wood and charcoal greatly complicates dating. In addition, most sites are of short duration, and many were only seasonally occupied with specialised functions. So the search for evidence of change might best begin by focusing on broad time categories. With this in mind, sites with abundant evidence of fishing were organised into three simple groups –early, middle and late– and these combined catches were then examined. A pattern of decreasing relative abundance of snapper, kahawai and labrids was found, and a corresponding rise in the importance of greenbone, blue cod and groper.

However, I am not at all happy with this broad-brush method of looking at changes either regionally or chronologically. Instead, it seems to me that a far better approach is to look for changes at a much smaller scale first. That is, those which would have affected local human communities. So the next part of this Section was concerned with examining individual archaeological sites for changes in the relative abundance of different species. Unfortunately, very few sites have sufficient time depth to permit this analysis, although in a few cases there are sites close to each other which also form a reasonable time series. In the first category are sites at Long Beach, Shag River Mouth, Mana Island, the Washpool, and Kokohuia. In the second category are sites at Black Rocks and, in the Chatham Islands, Waihora, CHA and CHB. Although this is a small number with which to look for evidence of change, some interesting patterns were found, not always consistent from one area of New Zealand to another. Striking features were that snapper falls in abundance at Black Rocks, Kokohuia and Mana Island. This was also found at Tasman Bay on a broad scale, but there are few individual sites where it can be examined. Blue cod increases in abundance at Black Rocks, Kokohuia, Long Beach, and Mana Island. Barracouta falls in abundance through time at Long Beach.

The final aspect of change that was examined was the size of the fish themselves. This is another area where we might be able to discern the effects of human harvesting of marine resources. Somewhat surprisingly, it was found that the mean size of various fish species actually increased at a number of archaeological sites where size could be examined in a time series. This was first noticed in snapper catches in the Tasman Bay area, and then in blue cod at both Mana Island and sites in the Chatham Islands. The same pattern was then observed for labrids from a further eight archaeological sites.

The cause of these changes may not necessarily be the same for each species. In the case of snapper, one possibility is that changes in surface sea water temperature over time was changing the recruitment rate at the various spawning grounds around New Zealand and smaller fish were less frequent in their southerly distribution.

However, this cannot be the explanation for the observed change in blue cod. Blue cod is well adapted to cold waters, and in the case of this species the influence of human fishing is suspected. This looks like a shift in fishing technology combined with adaptation of the species to human predation. In particular, human communities may have been fishing in somewhat deeper water later in time as stocks closer inshore were partially depleted. In addition, the fact that such small specimens were being targeted may have led to a change in growth rate of the species over time.

In the case of labrids, a clear increase in mean size over time can be demonstrated for sites in the Chatham Islands, Black Rocks, Mana Island and Kokohuia; and while in some cases this may again be due to changes in growth rate resulting from harvesting pressure, in others it is more likely to be due to changes in the relative abundance of the three main species present.

Barracouta from Long Beach show the opposite trend – in this case there is a decrease in mean size over time. When these catches are decomposed into the constituent age grades it is found that the early catches are composed of a small number of ages classes, and are dominated by old fish. Conversely, the more recent catch, close to the end of the pre-European period at this site, shows a much more even mixture of a large number of age grades. Barracouta migrate into inshore waters during summer in this part of south-eastern South Island and can be mass harvested from canoes. They are caught with a lure and one has no control over what sized fish is caught. It seems unlikely that people would throw away specimens 750 mm long and yet keep 800 mm fish. I am forced to conclude that harvesting practices are not involved in this apparent shift through time in catch composition.

There are at least two possible explanations for the observed pattern. One is that the migratory patterns of different age grades changed significantly during the last 800 years; this does not seem very likely. Alternatively, the recruitment rate and/or growth rate changed over this period. If so, then the decomposition into age grades for earlier periods may be suspect. It is well known that the recruitment rate for juvenile fish is affected by sea water temperature, so we may be observing in these archaeological catches a natural change in the New Zealand marine environment.

In conclusion, this review of archaeological fish catches has challenged a widespread and somewhat simplistic view that prehistoric people had a significant impact on fish stocks, resulting in a lowering of average size over centuries. It is clear that the real situation is a great deal more complex than that, with a number of factors playing a part – changes in fishing technology, changes in preferred fishing grounds, changing sea conditions inhibiting or permitting canoe fishing away from the coast, and finally changes in surface sea water temperatures over time. There is more discussion in Section 9 of the intriguing trends over time which have been documented in this chapter.