

## Section 9: Modelling human predation and environmental impact

### INTRODUCTION

When human communities harvest fish and shellfish for food, the marine ecosystem will make some form of adjustment, greater or lesser depending on the scale of human intervention. If the people involved possess any knowledge that they are having an effect, they may or may not choose to change their behaviour in some way, perhaps to ensure that they are able to continue to harvest the resource and, in the long run, ensure their own survival. Such a behavioural response to an observed or perceived effect might be termed an 'active resource conservation strategy'. In present-day human societies there are many examples of this type of behavioural response, always well-intentioned, though not always very effective, and Māori society is no exception. For example, Māori have a custom called *rāhui*, which is a ban on taking food from an area, imposed by the senior leader of a group. A *rāhui* can be imposed for a variety of reasons, not just resource conservation. For example, it may be placed out of respect for someone lost at sea nearby.

During a petition to the New Zealand Government in 1988 to call a halt to excessive commercial fishing which was damaging the coastal ecosystem of the Wairarapa area in the south-east of the North Island, several old Māori gave personal testimonies. Some remarks about *rāhui* and respect for marine resources are worth quoting:

*Evidence of John Clarke:* If crayfish with eggs were caught in a specific area, then that area became a rahui or prohibited area. When the kina [sea urchin] was milky this also came under rahui. I have always been interested to know how my people of the north determined the maturity of the paua [*Haliotis iris*] as it was not the size as in the Wairarapa but indications known to them.

When rearing my family in the Wairarapa, I taught them the rules governing kaimoana [sea food] as given me by my parents, the gifts of Tane and Tangaroa, a heritage from time immemorial. I took them to Ngawi on the Palliser Bay coast, where we

pitched our tents among the tauhinu [a shrub] and practically lived off the ocean. Those days kaimoana was plentiful and all within easy reach. Crayfish would be crawling over the seaweeds at low tide. The local Māoris would be drying pauas and crayfish tails and referred to as 'winter bacon'. At Pahaua, on the eastern coast of the Wairarapa, I caught groper in about sixteen feet of water. At Te Kopi, snapper was caught in abundance. At sea, I fished areas where many types of fish were caught and I am sure that these places were known and named by our ancestor[s.] I fished an area known as the Okoro-punga (moon in its fifth day.) now referred to as the Okra-pong. I observed here that the waters were very clear, probably due to some tidal action. A coastal settler tells that he remembers his parents saying that this stretch of beach was known as Wai-ora (pure or living waters.) and that a vast area of that was set aside by the Māoris as a rahui or breeding grounds.

Today, as a Māori, I am ashamed to talk about our kaimoana, our fisheries, our waahi tapus [sacred places]. We have let our tipunas [ancestors] down in this respect and now our coasts and fisheries have been raped, plundered and totally mis-managed, all for the 'fast buck'. The indiscriminate issuing of licences without adequate policing. I am sincerely of the opinion that a management plan is too late, but to impose a total rahui, in accordance with Māori custom and usage is the only sane approach. We must observe the spiritual values of our tipunas from Tane Mahuta to Tangaroa (Leach 2003: 160-161).

Here is another excerpt:

*Evidence of William Te Kani:* As a young man I accompanied my parents and other members of our huge whanau [extended family] to our coastal waahis [places] to gather kaimoana. We went at certain times of the year before or after the moulting of the crayfish and the breeding season of the kina. Sometimes our calculations would be wrong and we often found crayfish with eggs and the kina milky. When we found female crayfish, the area would be rahui as it was said of our people, that during the egg laying of the crayfish, females would congregate in one place and the kina would move out to deeper waters.



I recall my parents picking up female crayfish from under the rocks and examining the berries as the pakeha call it today, then they would go to a deep isolated pool and with the tail held in one hand and head in the other would swish the crayfish around under the water and all the eggs would come off then they would release the crayfish. This was always done when female crayfish was inadvertently caught and when the eggs were ready to be released. The taking of the female crayfish was highly tapu [under prohibition] and if caught you were banished from the area and be subjected to much criticism by the hapu [sub-tribe] (Leach 2003: 162-163).

These are cases of modern-day Māori actively seeking to conserve resources, based on a knowledge of the effects of indiscriminate harvesting. This raises an interesting question – can we detect in the archaeological record any evidence of marine harvesting strategies amongst pre-European Māori which might have been aimed at conserving marine resources? Coupled to this is perhaps a simpler question to answer – was the influence of pre-European Māori on the marine environment benign or malignant?

It is relatively easy for archaeologists to observe changes in the environment over time. Correctly attributing these to nature or humans is not always quite so easy. It is far more difficult again to infer what was in the human minds responsible for these changes, such as specific intentions aimed at managing and conserving resources.

In a recent review of this general problem amongst modern-day indigenous fishermen, Pollnac and Johnson suggest “that it would be prudent to begin as a sceptic – to deny that the existence of FK [Folk Knowledge] or FM [Folk Management] indicates that there is a conservation ethos among indigenous fishers” (Pollnac & Johnson 2005: 37). They cite numerous reasons why it pays to be very cautious in this matter; one of them concerns the invisible nature of the marine environment compared to the above-water environment of hunting communities, for instance, where a great deal more can be seen:

One important consideration is that in most cases, the prey of marine fishers is usually either invisible or hard to see because it is below the surface of the water. This relative invisibility in combination with the fact that most fish are mobile make it difficult, if not impossible, to target specific sizes or gender for conservation purposes; hence, it is less likely that fishers would make such conservation choices than the hunters studied by Alvard ... and others. As a result, it can also be argued that marine

species are even more unpredictable in time and space than terrestrial prey and thus are more likely to be hunted opportunistically. Restraint for conservation – that is, forgoing a harvest today for a larger one in the future – just doesn’t make sense (Pollnac & Johnson 2005: 36).

If folk management of marine resources is difficult to confirm for living indigenous people, it is going to be a great deal more difficult for prehistoric people.

### POPULAR PERCEPTION AND MISCONCEPTIONS

In the popular arena it is usually assumed that with a few notable exceptions, human influences on the New Zealand environment during the period of pre-European settlement were probably fairly minor. The exceptions are the extinction of the avian megafauna (moa) in which pre-European Māori were implicated (Anderson 1989), the disappearance of fur seals from much of the New Zealand coast as a result of hunting pressure (Smith 1989, 2005), and changes in natural vegetation patterns by Māori firing forest and scrubland for cultivation or to encourage fernlands (Holloway 1960). This view was greatly extended following archaeological research in Palliser Bay between 1969 and 1972 which revealed that there was a complex interplay between natural and human-induced changes in both the land and marine regimes (Leach & Leach 1979; Leach 1981).

A somewhat extreme view on the treatment of natural resources by pre-European Māori was presented at the Waitangi Tribunal hearing on the Ngai Tahu Claim in 1989 by Holdaway, in which he stated:

The weight of evidence supports the view that the first immigrants to New Zealand came with a tradition of environmental management which involved over-exploitation of resources, to the extent they, in some instances, had made some islands uninhabitable (Holdaway 1989: 6).

Holdaway presented evidence that the pre-European Māori had a devastating effect on many aspects of the flora and fauna of New Zealand, and concluded:

...in their serial over-exploitation of the natural products of the new land, the Maori were no different from any other colonising culture in history (Holdaway 1989: 22).



This presentation was effectively a challenge to the notion that Māori occupied the 'moral high ground' over issues of environmental conservation in New Zealand. This issue was taken up in an even more pronounced form by Flannery in a book published in 1994 in which he referred to people in both Australia and New Zealand as 'future eaters'; that is, consuming resources so that future generations were disadvantaged. On the subject of pre-European Māori fishing in particular, Flannery stated:

Even fish populations were affected by over-exploitation. Snapper (*Chrysophrys auratus*), for example, was fished early on in the South Island, but then vanishes from the archaeological record, suggesting a local extinction. The average size of snapper declines throughout its distribution in New Zealand with time, suggesting that the fishery was being overexploited by the Maori...

It might seem scarcely believable that the Maori could overexploit such a difficult-to-obtain resource as snapper, but archaeologists have estimated that the northern Northland Maori would have taken about 1200 tonnes of snapper per year. The modern commercial fishery, with its 100 vessels, lands only 1000 tonnes per year, and this probably exceeds the maximum sustainable catch, as stocks have been declining since the 1980s (Flannery 1994: 244).

Flannery cited an article by Anderson and McGlone as the main source of information on the matter of the Northland fishery. In this, they stated:

An over-exploitation argument in the case of fish, especially a major species like snapper, may seem implausible, given the size of the resource against the size and technological capability of the prehistoric population, but is it? If we look at northern Northland, for example, the Maori population was about 5000 in the later prehistoric period, judging from early historical estimates (Lewthwaite 1950). If they relied on snapper, by far the most common species in middens, for a third of their food, this would require approximately 1200 t per year. Currently the commercial snapper catch, mainly taken by about 100 small long-line vessels, which is landed in the district is 1000 t, and that is regarded as near the maximum sustainable catch in the light of a massive decline in snapper stocks in the early 1980s (Habib 1987). Our estimates may be generous, but they suggest that a snapper overkill hypothesis is by no means implausible (Anderson & McGlone 1992: 232).

Because of the importance of this type of argument, it warrants close examination, and I shall

devote some space to do this. There are a number of distinct steps which must be followed in order to arrive at a reasonable conclusion of the scale of Māori exploitation of the snapper fishery in Northland. These steps are:

*Step 1: Population Size.* Estimates at the period of European contact are notoriously difficult to arrive at. A thorough review of this was carried out by Pool, who concludes that "the population would have reached barely 100,000 people before it suffered the shock of European contact" (Pool 1991: 57). In Pool's assessment, 15% of the population lived in the Northland area (Pool 1991: 51), which would be about 15,000 ± 3,000 people. This estimate seems quite reasonable on other grounds (density of late period archaeological sites, knowledge of carrying capacity of the land given the type of economy Māori at this period had, etc.).

*Step 2: Daily Energy.* In a recent review of dietary requirements relating to prehistoric groups in the tropical and temperate Pacific region, a mean caloric requirement of 2,150 ± 215 calories per person per day is suggested for the pre-European Māori (Leach *et al.* 1996c: 24).

*Step 3: Percent Mean Energy from Snapper.* Assessing the mean contribution of a particular species in prehistoric diet is a two stage procedure. Firstly, by examining the  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$  and  $\delta^{34}\text{S}$  isotopes from archaeological samples of human bone collagen the contribution of marine fish in the diet may be determined. Secondly, archaeological sites are examined in the area of interest to work out the proportion of the species involved in the total fish catch for the prehistoric group involved.

*Step 3A: Mean Energy from Fish.* As far as the first stage in this process is concerned, no human bone samples have yet been analysed from the Northland area, but the likely contribution of fish in this diet may be estimated from two other communities which represent extreme ranges for the New Zealand and Pacific region. The first determination is from the island of Watom off New Britain (Leach *et al.* 2000c: 154) where it was found that fish contributed 21.8% of the mean caloric intake (473 of a total 2172 kcal) in the prehistoric economy. The second determination is for the Moriori people of the Chatham Islands (Leach *et al.* 2003: 67) where it was found that fish contributed 17.2% of the mean caloric intake (377 of 2193 kcal) in their economy. In another aspect of their diet, namely the contribution of carbohydrate foods, the diets of the people of Watom and the Chatham Islands differed dramatically. However, as can be seen from the figures above, there was a relatively small difference in the contributions from fish.



The Mori people had an extremely low contribution from carbohydrate foods, whereas the Watom people had an essentially horticultural economy, much closer in focus to the Māori people of Northland. The Watom figure of  $21.8\% \pm 0.8$  would be a reasonable estimate of the contribution from fish of the total caloric intake for Northland people.

*Step 3B: Percent Snapper in the Fish Catch.*

Regarding the second stage in this process, there are three major sites in Northland which provide good evidence of the relative abundance of snapper in the fish catch of these people. These are:

- 92.6% Twilight Beach, northwest Northland (Leach 1989a: 95)
- 89.4% Houhora, east Northland (Leach 1989a: 95)
- 53.6% Early Kokohuia, Hokianga (Leach *et al.* 1997a: 109)
- 48.1% Late Kokohuia, Hokianga (Leach *et al.* 1997a: 109)

A figure of  $48\% \pm 3.0$  would be a reasonable estimate of the relative abundance of snapper in the fish catch of Northland people at the time of European contact.

We can therefore calculate the *Mean Energy from Snapper = Mean Energy from Fish \* Percent Snapper in the Fish Catch* to the caloric energy intake of Northland Māori as  $0.48 \pm 0.03 * 0.218 \pm 0.008 = 0.1046 \pm 0.0104$ , or  $10.5 \pm 1.0\%$  (The procedure for combining errors is described in Section 8).

*Step 4: Energy from Snapper.* Vlieg (1988: 49) gives a figure of 92 kcal/100g wet weight for snapper fillets. The values for different species of fish are highly variable from 45-296 kcal/100g, and condition factor is partly responsible for this range. An error of at least 10% would be reasonable. Energy from Snapper =  $0.92 \pm 0.092$  kcal/g.

*Step 5: Mean Body Weight of Snapper.* There are two estimates of the mean body weight of snapper caught by pre-European Māori in Northland (Leach & Davidson 2000). These are from two major archaeological sites: Houhora (N=8,847) and Twilight Beach (N=1,914). The two mean values are  $2,362 \pm 12$  and  $3,252 \pm 44$  g respectively. In view of the large size difference between these two sites (a range of 890 g), a correspondingly large error must be allocated to any mean value for Northland as a whole, perhaps 10%. So a suitable value for the Mean Body Weight of Snapper would be  $2,807 \pm 280$  g per fish.

*Step 6: Percent Snapper Body Eaten.* Next we need to evaluate the proportion of the fish that was eaten. From the Fisheries Conversion Factors Notice (Anon. 1993), various figures are given from processed states to green weight (total ungutted weight).

Condition	Factor	Percent
Fillets skin-off	2.7	37%
Fillets	2.4	42%
Dressed	1.8	56%
Headed and gutted	1.6	63%
Gutted	1.1	91%

For pre-European Māori, the conversion factor would be between gutted and headed and gutted, so a reasonable estimate would be:

Edible Weight =  $70 \pm 10\%$  of Ungutted Weight

*Step 7: Calculate Total Annual Harvest.* With estimates from each of the foregoing six steps, some simple calculations provide the following summary:

Step 1: Population	=	15,000 $\pm$ 3,000 Persons
Step 2: Average Energy Intake per day	=	2,150 $\pm$ 215 kcal per person
Step 3: Mean Snapper in diet	=	10.5 $\pm$ 1.0 % of caloric intake
Step 4: Energy per g for snapper	=	0.92 $\pm$ 0.092 kcal
Step 5: Snapper Mean Ungutted Weight	=	2,807 $\pm$ 280 g
Step 6: Proportion of snapper eaten	=	70 $\pm$ 10 %
Energy needed per year		15,000 * 2,150 * 365 = 11,771,250,000 kcal
Error		20 + 10 = 30%
Energy from snapper per year		11,771,250,000 * 0.105 = 1,235,981,000 kcal
Error		30 + 10 = 40%
Energy from each snapper		2,807 * 0.7 * 0.92 = 1,808 kcal
Error		10 + 14 + 10 = 34%
Number of snapper caught per year		1,235,981,000/1808=683,618 fish
Error =		40 + 34 = 74%
Number of snapper per person		683,616 / 15,000 = 46 fish per year
Total weight of snapper harvested		683,616 * 2,807 = 1,918,910,112 g
Error		74 + 10 = 84%
<b>Final Estimate of Northland Harvest</b>	<b>=</b>	<b>1,919 <math>\pm</math> 1,612 Tonne</b>

Thus, I estimate that for the Northland area the pre-European catch of snapper at the close of the prehistoric era would have been between 310 and 3,530 Tonne per annum.

This can be compared with historical modern catch data for snapper in the Northland region [1960-1973 from Larry Paul (pers. comm. 1995), and 1974-1986 from Paul & Sullivan (1988)]. The figures below include landings for east Northland on grounds adjacent to the coast from North Cape to Whangarei; the east Northland ports of Maungonui, Whangaroa, Russell and Whangarei minus Hauraki Gulf; west Northland and Auckland ports of Hokianga, Kaipara, Manukau, Raglan and Kawhia. These landings are the-



refoe both east and west coast Northland. The combined annual snapper catch figures for these areas of are:

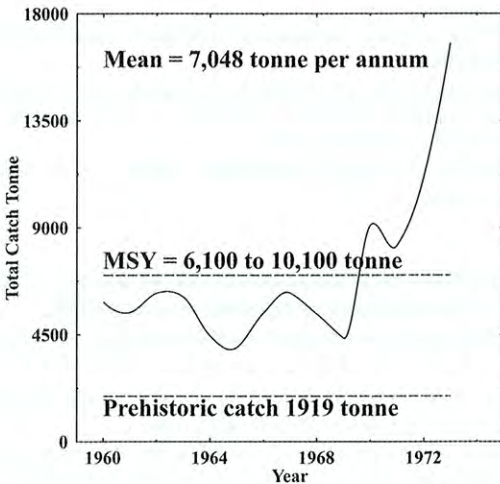
Year	Tonne
1960	5,876
1961	5,434
1962	6,241
1963	6,084
1964	4,452
1965	3,956
1966	5,406
1967	6,250
1968	5,369
1969	4,353
1970	9,101
1971	8,254
1972	11,134
1973	16,763

These figures are plotted alongside the estimated pre-European catch for Northland in Figure 135 on the left. This shows that although the Māori snapper catch in Northland was significant, it is nowhere near as high as what is considered to be the Maximum Sustainable Yield (MSY) for the eastern part of this region alone (SNA1), which is between 6,100 and 10,100 tonne per annum, based on present-day biomass (Annala 1994: 211). It should be noted that the

scales of the two vertical axes on the left and right hand parts of this Figure are completely different. Moreover, even if the pre-European Māori population were as high as 30,000 people in this region, the mean estimated snapper catch would still be less than the lowest recorded catch rate during the historic period.

I have spent some time looking at this matter because I think it is very important to try to get these kinds of estimates right, and certainly to estimate the size of errors wherever possible. It should be obvious from this single worked example that Flannery’s claim is outrageous, and does not do justice to the many serious attempts by archaeologists to understand the reality of prehistoric human predation on the fishery and the resulting effects upon it. On a slightly different matter, his comment above “The average size of snapper declines throughout its distribution in New Zealand with time, suggesting that the fishery was being over-exploited by the Maori” (Flannery 1994: 244) is also manifestly incorrect as shown in Section 7. On the contrary, in the few places in which this can be tested with reliable archaeological data, snapper sizes either stay the same or actually increase over time. Well known authors who write popular accounts like this have a responsibility to get things reasonably correct.

**Modern Snapper Catch**



**Prehistoric Snapper Catch**

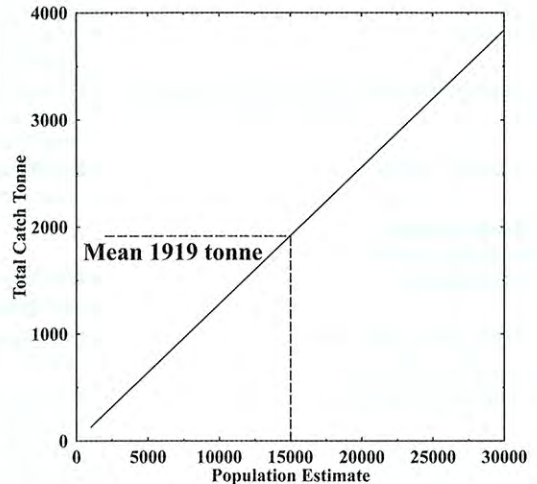


FIGURE 135

The pre-European Māori annual catch of snapper in Northland was far below the lowest recorded commercial catches in the same area, and well below the sustainable yield. This shows that their effect on this fishery was negligible. NB: the two vertical axes are different scales (see text).

FROM CAUSE TO EFFECT AND BACK AGAIN

A more fundamental issue arises here — when we detect changes in fish size or relative abundance over archaeological time, how should we interpret this and get it correct? For example, how should we distinguish between human-induced and nature-induced change? I suspect that in many cases, the decision that archaeologists make on this question tends to be rather *ad hoc*, and when repeated often enough, takes on a life of its own as proven fact. Rather than proffering a conclusion, it might be more honest to proffer one or more hypotheses, and then make some concrete suggestions about how they could be tested. This would be more like the normal language of science rather than guesswork.

Unfortunately, there is an ever-present problem in archaeology, not found in most other branches of science. Whereas a physicist can repeatedly test hypotheses by carrying out experiments over and over, in archaeology it is not possible to repeat an excavation, since we are destroying the very thing we are testing. Excavation of sites of similar age in the same area can go only so far to alleviate this problem. Every archaeological site is unique. It has

sometimes been said that this is a significant failing in archaeology, encouraging those snobbishly inclined to brand archaeology as pseudo-science at best. This problem of testability is certainly present when it comes to hypotheses that rely solely upon information detected by excavation; but it is not such a deep problem with the objects recovered from excavations, such as large samples of archaeological fauna. In this case, the normal rules of experimental science do apply. This is one reason why large faunal collections are so valuable and why, when well curated in a museum, they can be the source for numerous scientific investigations stretching into the future.

Even so, we have, as yet, only poor guidelines for distinguishing between natural -and human-induced changes in size and abundance of fauna, and then correctly interpreting them. This is not the only ambiguity that arises during interpretation of archaeological remains. The reason is that there are many cases of different causes having the same ultimate effect. Archaeology is beset with this problem (although this is not always fully appreciated even by archaeologists). It has been dubbed ‘the problem of equi-finality’ (Torrence 1986: 21-22; Torrence *et al.* 1992), and also ‘the problem of multi-causality’

Causal Agent	Effect on Environment
<i>Natural Environmental Change</i>	
<ul style="list-style-type: none"> <li>• Firing of coastal forest</li>   <li>• Tsunami</li>   <li>• Increase/Decrease Surface Sea Temperature</li>   <li>• Tectonic Change</li> </ul>	<ul style="list-style-type: none"> <li>• Increased sediment in the drainage system, followed by local extinctions of filter feeding shellfish, and the knock-on effects to the food chain above them.</li> <li>• Stripping of inshore marine communities, and fairly rapid recovery to pre-existing conditions.</li> <li>• Change in recruitment rate and growth rate of fish species, followed by change in population density, and change in age structure in populations of individual fish species.</li> <li>• Rapid change in local biological communities, followed by recovery over a longer period.</li> </ul>
<i>Human Activities</i>	
For all fish species	
<ul style="list-style-type: none"> <li>• Non-selective</li>   <li>• Select some, reject others</li> </ul>	<ul style="list-style-type: none"> <li>• If harvesting is heavy and sustained, overall biomass will decline, but age structures and relative species abundance may change little.</li> <li>• Biomass of some species will decline, and the biomass of some other species may increase as they expand into partly vacant niches.</li> </ul>
For any one fish species	
<ul style="list-style-type: none"> <li>• Non-selective by size</li>   <li>• Select small specimens</li>   <li>• Select large specimens</li> </ul>	<ul style="list-style-type: none"> <li>• If harvesting is heavy and sustained, the biomass of the species should decline, but age structure may change little.</li> <li>• This will encourage higher survival rate for larger specimens, and the growth rate of the species may increase in response to this.</li> <li>• This will lead to preferential survival of small specimens and might result in a lowering of the growth rate.</li> </ul>

TABLE 39

Examples of different causes and their possible effects for inshore fish communities.



(Leach *et al.* 1996c: 2; Leach *et al.* 2003: 63). This can be illustrated with some examples of the likely relationship between cause and effect for inshore fish communities following various natural events and human activities in Table 39.

If we found in an archaeological site that bones of one species declined in relative abundance over time, this could be due to a number of different causes. It might be a change in human behaviour over time, such as species avoidance behaviour (e.g. totemism or some other form of prohibition disguised as 'we don't like it'). It might be due to a natural lowering of surface sea water temperature which lowered the recruitment rate, ultimately leading to the loss of the local population. A shorter term effect of this would be increasing mean size of the population, detectable in the archaeological record. If it was a species which relied upon filter feeding shellfish for survival, the observed decline of the species could be due to nearby forest clearance and its subsequent effects on shellfish beds.

I think it can be seen from this one example that while it is usually fairly clear what happens from left to right in Table 39, it is nowhere near as clear when trying to work from right to left. This is what is meant by 'multi-causality', or 'equi-finality'. It might also be noticed that in the table there is no mention of behavioural terms like 'totemism' or 'species avoidance behaviour'. These are amongst many forms of human behaviour which anthropologists observe amongst living people, but which all would be put in the 'select some, reject others' cause which does occur in Table 39. In other words, there is yet another step from right to left involving 'equi-finality' in which the actual human behaviour responsible for the observed archaeological observation must be deduced. It is precisely this bird's nest of logical deduction which, when some archaeology students were once confronted with it and complained to their professor, provoked the response: "I never said archaeology was easy".

There are basically two ways of confronting this type of problem in archaeology. One is to work from the top down, and the other is to work from the bottom up. I am a bottom up kind of archaeologist. In my view, top-down models suffer from a fundamental problem of presuming an answer before examining the evidence for it. This is not the same thing as hypothesis testing, because advocates of top-down models are inclined to sweep aside all problems like sample size and alternative explanations in the quest to validate their presumed answer. A case in point is known as 'Optimal Foraging Theory'.

## OPTIMAL FORAGING THEORY

This is one example among many of the top down approach to understanding how humans harvest natural resources. To explore this subject in any detail would require a book by itself, and I can only touch upon it briefly here. This is an influential theory about the way human communities may approach their harvesting of natural resources, borrowed from observations about predator-prey relationships in the natural world. For example, studies of the capturing behaviour of the bluegill sunfish have clearly shown that they select their prey on the basis of size, and that this behaviour is related to the average time spent searching and handling prey. Confronted with low density of prey, sunfish are non-selective and take prey as they are encountered. At successively higher prey densities, sunfish preferentially take the largest specimens (Werner & Hall 1974: 1048). Why archaeologists would entertain the idea that humans, who are less inclined to behave instinctively and, perhaps less intelligently, are more prone to follow cultural norms of their society, would emulate the hunting behaviour of a sunfish is, to me, a mystery.

I have always felt that there is a slight hint of 'holier-than-thou' in this approach to exploring and describing ancient human societies. It tends to carry with it an implicit assumption that in our own comfortable and technologically advanced society we do not conform to such mindless strategies, perhaps because we are above that sort of thing. In our equivalent of foraging for food we visit a supermarket, and we might select small red onions, for example, and forego the much bigger brown ones (which ancient people would select following their optimal foraging stratagem), because television advertising has informed us that the red onions are preferred by upwardly mobile people. In short, the optimal foraging strategy is something to help us explain the curious behaviour of primitive peoples, such as in prehistoric societies, and certainly does not apply to us. In truth, although the optimal foraging theory might be *very* applicable to describing the modern commercial fishing industry, in my view it is a nonsense when applied to humans in everyday life, except perhaps in very unusual circumstances, such as imminent starvation.

In a recent expression of this theory, relating to prehistoric fishing in a small Pacific island close to New Zealand, Butler describes a scenario which she calls a 'prey-choice model' (Butler 2001). She describes a process whereby the predator (a prehistoric



fisherman) will tend to adopt the most efficient strategy in seeking out and capturing prey (fish). The most efficient strategy is to take the highest ranking prey. The question is: what is the highest ranked prey? This is where things can get a little bit complicated, but the simple answer is 'the biggest individuals', because they provide the greatest return of energy per unit of effort. Whether the predator (our fisherman) will take lower ranked prey depends on encounter rates, and encounter rates depend upon prey densities. Predators will shift to lower ranked (smaller) resources as higher ranked ones become less common (fished out). Natural selection will favour predators who operate like this.

To test such a model in a real situation demands good data forming a time series. After all, the process being described is a time-related process. Butler studied fish remains from a rock shelter known as Tangatatau on the island of Mangaia in the Cook Islands and used these data to test this hypothesis. 1,475 bones were identified from 52 taxa, spread across 17 stratigraphic zones covering a time period from about A.D. 1,000 to A.D. 1,700. Analysis of NISP numbers for different species showed "an empirical trend towards increasing abundance of small-bodied fish over time" (Butler 2001: 93). She also looked at mean size for two different kinds of fish, but small sample size hampered conclusive results. In searching for possible causes of the observed change, changing technology was ruled out, as was natural environmental change. She concludes:

Trends in the fish faunal data... follow the predicted response: over time, high ranked fish resources decline in frequency and lower ranked resources increase in abundance. Resource depression caused by human predation is the best explanation of these trends. ... The study suggests that the prehistoric fishery depleted near shore marine and freshwater fish populations and that the fishers in turn adjusted to the changes by taking resources of lower rank. ... Finally, this study joins a growing body of evidence that shows how profoundly Polynesians affected the indigenous biota on islands they colonized" (Butler 2001: 98).

In an earlier time, someone might have reached a more harshly worded and judgemental conclusion from this research along these lines: *'Not only were these greedy ignorant savages grabbing the biggest fish first and leaving the others, but over a period of time they were destroying the very thing they needed for survival'*. The fact that the observations concerning these prehistoric fishermen make use of language with apparently neutral

terms like predator and prey does not really disguise the underlying implication. I would not for a moment attribute such brutal sentiment to Butler; on the contrary, the research is thorough and the conclusions well-intentioned. Nevertheless, the conclusion is drawn that these people had a profound [adverse] effect on the indigenous biota, and this is attributed to the inferred harvesting strategy employed. This raises an interesting point –her comment above 'that natural selection will favour predators who operate like this' – is clearly a recipe for disaster rather than survival because it will eventually result in the loss of the prey altogether, and then ultimately of the predator itself! When the human predator progressively fishes further and further down the food web this can hardly be called an optimal strategy. On the contrary, humans, able to use their grey matter, can (if they are sensible) devise a resource conservation strategy that will ensure the continuation of their food supply and, as a result, their own survival. So, perhaps 'optimal foraging' should be described as a tactic rather than a strategy<sup>1</sup>, and a poor one at that.

Butler is the first to point out that the numbers of bones involved are frustratingly small, and the last thing in my mind is to heap criticism on what is actually a valiant attempt to find changes in fishing behaviour over time. My worry is not about the details of the analysis, but at the general approach taken in seeking to understand what fishermen were doing in the distant past, how they may have affected their fishery, and what they may have known about conserving their natural resources. Information abounds amongst indigenous peoples about their caring approach to resources in the sea. Although a lot of this may be self-serving, it should not be brushed aside lightly, as excellent published research has shown otherwise (for example Johannes 1981).

A really important question remains about the Tangatatau example – is it true that these prehistoric people were fishing down the food chain? I am not at all convinced. Selecting species which can attain large size is not the same thing as selecting large specimens of the same species. Optimal foraging is about optimising return for effort, and in this case it is claimed that it is all about size, not potential size. The study was unable to show significant changes in fish size over time. Regardless of how difficult it might be, the only way to do that

<sup>1</sup> Hence the expression that one could be a brilliant tactician, but a terrible strategist, by winning individual battles but losing the war.



is by reconstructing reliable size-frequency diagrams for individual species. This is a simple matter for modern fisheries scientists, but for archaeologists it is an immense undertaking. In New Zealand, it has taken many years of background research on modern comparative material before analysis of archaeological collections could even begin. This type of research is difficult to find funding for, and it does not lend itself to a steady stream of significant publications. It requires a certain dogged determination over many years to lay the foundations for promised future rewards. Finally, obtaining large enough collections from archaeological sites has also proven extremely difficult, and very few sites have yielded enough material for reliable size-frequency diagrams to be obtained. Some of these have been described in earlier Sections in this volume, and the pattern which emerges from this, surprisingly, shows increase in mean size over time, not the reverse.

In short, there is no substitute for the time-consuming and often boring work that must be undertaken to get the basic facts right before offering answers to high level questions.

What Butler's study shows to me is that over a period of time the mix of different species has changed. Seeking an explanation for this might be more profitable than trying, unsuccessfully, to show decreasing size over time. A case in point concerns freshwater eels at this site. The changing relative abundance of these over time is most interesting, and has been noted before by Kirch *et al.* (1995: 56). I plot in Figure 136 the percent freshwater eels, together with their standard errors, for each of the stratigraphic zones for which Butler provides data. In spite of the small numbers involved, there is a hint that eels were more important in the earliest

period, declining thereafter, and possibly increasing at the end of the sequence. As described in Section 7, eels in general, and freshwater eels in particular, occupy a very special place in all Polynesian societies, and myth and prohibitions abound. This change, therefore, may have nothing whatever to do with food or optimal harvesting strategies, but may lie in the realm of non-rational magico-religious beliefs.

One final point about optimal foraging strategies: large size of prey features prominently in defining optimal strategies; however, size is not the only criterion to take into account, and in many cases may be quite misleading. A more refined statement of the position is "Optimal foraging theorists argue that humans make rational decisions so as to maximise the net rate of energy captured, measured usually in calories, though other measures could be used" (Reitz & Wing 1999: 26). The concept of 'return for effort' therefore should not necessarily be only about weight of meat. As I hope that Section 8 has shown, one can quickly starve even when there is a super-abundance of meat. Obtaining a balanced diet is far more important to all animals in the long run than just abundance of any one food commodity. In New Zealand, and in all Pacific islands, access to protein was seldom the driving force behind the economic quest. In almost all places, fish and shellfish are available in sufficient quantity to be effectively taken for granted. One of the best examples I know of an optimal foraging strategy in action is the hunting behaviour of polar bears, yet large size of the prey is not the criterion that is most important to them. On the contrary, "In the Western Arctic, we found that over 80% of the ringed seals killed by polar bears were less than 2 years of age" (Stirling & McEwan 1975: 1022). Moreover, "After a polar bear kills a seal, it feeds predominantly on the blubber and often abandons the meat" (Stirling & McEwan 1975: 1022). The reasons for this became clear when analysis of blubber/meat proportions were undertaken for seals of different age and body weight. At birth, these seals have about 13% blubber, quickly rising to about 45% by the time they are weaned. Thereafter, although body weight increases, mean blubber proportion does not, and in many cases falls. Newborn pups which are killed by polar bears are infrequently eaten; the bears target the young blubber-rich sub-adults as an easier prey than older adults.

Humans are not like polar bears and certainly not like sunfish. It is possible that in extreme conditions, such as starvation, humans may begin to behave like polar bears and eat train oil in preferen-

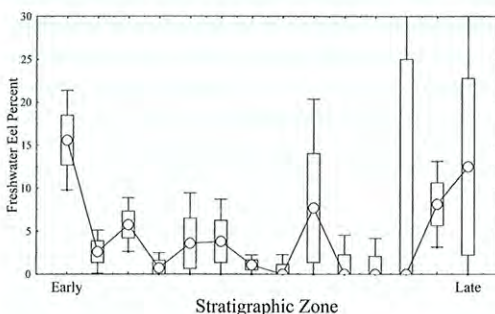


FIGURE 136

Freshwater eels were about 15% of the fish catch in the earliest times at Tangatatau on Mangaia, but declined in abundance later.



ce to fish, as was described in Section 8. But, in my view, at normal times of adequate food, their choice of prey, and the size of animals chosen for capture, will have far more to do with cultural precepts and perceptions than anything else. That may make the task of archaeologists interpreting the past considerably more difficult, but at least they will be on stronger grounds by dealing with the subject they know best – the study of human culture.

## ENVIRONMENT CONSERVATION MODELS

When considering how best to conserve environmental resources, we need to distinguish between a short term and a long term view, and also decide whether to impose a continuous harvesting system, or permit cycles of exploitation and recovery. Actually, these two things can be related. For instance, if our thinking is of the former kind (short term perspective and continuous supply from resources) we might be more inclined to think in terms of *A Sustainable Yield Model*; that is, a conservation strategy (tactic?) whereby we exploit natural resources at the same rate that they can be replenished by new recruits. For example, we could aim to harvest fish at the same nett rate that juveniles are coming into the system and building up the supply of fish<sup>2</sup>. This model assumes that we are content with the current nett yield from an existing biomass, even though it might be drastically reduced from a former period of time. A variation of this approach is known as *Back to the Future*, where efforts are made to rebuild ecosystems so that over a period of time biomass is increased and the sustainable yield is increased as well (Pitcher 2005; Pitcher *et al.* 2005).

An alternative to this strategy might be to take a somewhat longer term view and exploit environmental resources in a patchy manner, by focusing on a discrete area and taking from it everything available, with no regard to the rates of recruitment over a short period. In other words, clear-felling an area, and then leaving it strictly alone by moving attention elsewhere to another patch, and starting over again. This might be referred to as the *Slash and Burn and Fallow Model*.

In the Pacific region, there has clearly been a long history of slash and burn and fallow as the basis for horticultural activities. Land plots abandoned after intensive cropping are left alone for up to 25 years before they are returned to for re-use

(Leach 1976: 181). In New Britain, an immense investment of labour is required to set up new gardens, because they must be fenced off with the trees cut down when clearing the land to keep pigs out of the garden areas. These gardens must eventually be abandoned when fertility and yields fall, and they are re-forested. Ultimately the cycle is repeated. Given the widespread use of this system of land utilisation, it is quite possible that a similar approach to harvesting marine resources could have applied during prehistoric times too. There are numerous early historic accounts of the mobility of Māori in New Zealand, and apart from more highly populated areas in the far north of the country, a shifting settlement pattern appears to have been common. A community's vision about resource conservation might be quite different if groups are regularly moving their location. Although it is thought that most groups in New Zealand may have had a 'base-camp' to which they frequently returned (Davidson 1984: 166), very few archaeological sites in New Zealand have shown clear evidence of long and sustained occupation. More typically, archaeological sites have several stratigraphic layers representing a relatively short period, or periodic interrupted occupation over a longer period.

It is well known that the Māori during the historic era employed a system known as *rāhui*, under which resources could have a tapu placed on them by a chief, effectively prohibiting anyone from taking food from an area. Although such prohibitions could be invoked for a number of reasons, a *rāhui* could be placed on an area that showed signs of diminishing resources. This is a clear sign that a longer term perspective was being employed in managing resources by Māori in the historic period. Such a system is possible in areas where there is low population density and therefore alternative patches which can be periodically exploited.

One of the noticeable features of many archaeological sites in New Zealand is their essentially short-term occupational character. This has been attributed to the seasonal round of food gathering activities whereby people moved from place to place. This settlement pattern model is often considered more appropriate to the South Island, where people did not have fixed garden areas and were basically hunter-gatherers. However, in those parts of the North Island where horticulture was possible, it is also rare to find settlement sites which were consistently occupied for hundreds of years, and a similar

<sup>2</sup> Nett rate means after natural mortality is taken into account.



model may well apply (Walter *et al.* 2006). It is very likely that this reflects the need of communities to change the location of their settlement as a piece of garden land became exhausted and required a long period of fallow. Once the home base shifted in this manner, the exploitation of marine resources would also be focused on a somewhat different area of the coastline.

Such a system of regularly shifting settlements should also leave a distinct signature in the archaeological record relating to marine foods. With perfect archaeological control over the chronology of different layers in nearby midden sites we might see shellfish, for example, showing signs of depletion, followed by a period of recovery, and then depletion again. This would only occur for marine species of low biomass or low recruitment rate, which are susceptible to the effects of intensive human predation. It has already been shown in Section 7 that prehistoric human communities would not be able to have any influence on the barracouta fishery, for example, not only because of its very large biomass, but also because the access which humans have to this fishery is only indirect. The barracouta population spends most of its time in deep waters beyond the reach of prehis-

toric fishermen. They were able to harvest barracouta only when they migrated into shallow waters during the summer. The same phenomenon might apply to other migratory species such as kahawai and snapper, but perhaps to a somewhat lesser extent. Snapper migrate into shallow waters to spawn during the summer and may be harvested in large numbers at this time. They are therefore less susceptible to the fishing activities of prehistoric people than fish species which spend all their life in shallow inshore waters where fishing activities were greatest.

These factors must be kept in mind when evaluating human impact on the New Zealand fishery.

#### ARCHAEOLOGICAL EVIDENCE OF HARVESTING STRATEGIES AND THEIR IMPACT ON THE MARINE ENVIRONMENT

In this section, I consider some archaeological case studies of the harvesting of particular marine resources. At the risk of straying a little from the main subject of this paper (fish), I begin with two good examples of prehistoric harvesting of marine invertebrates, and then return to fish.

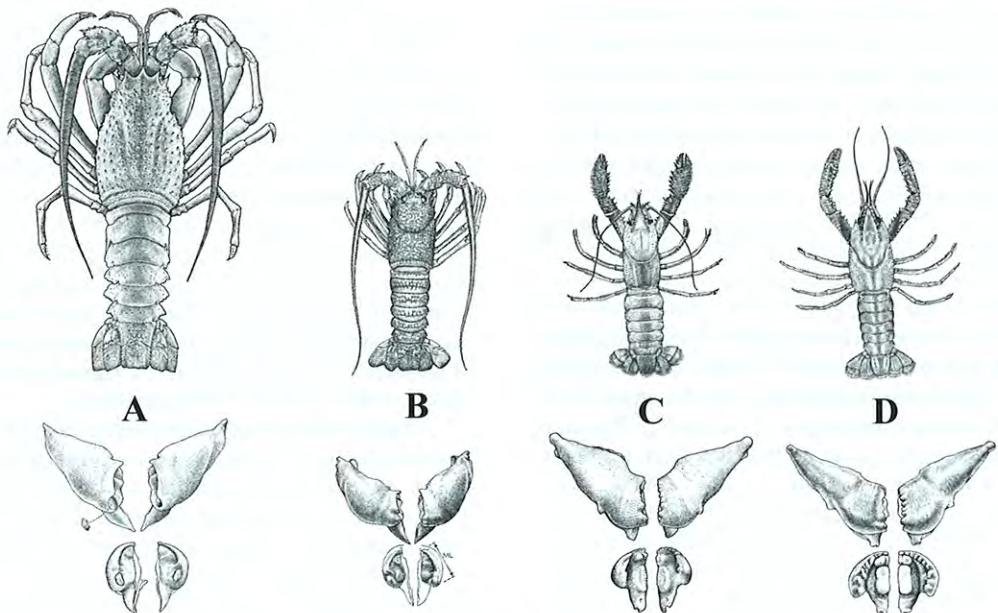


FIGURE 137

The four New Zealand species of crayfish. A: *Jasus edwardsii*, B: *Jasus verreauxi*, C: *Paranephrops planifrons*, D: *Paranephrops zealandicus*. A and B are marine, C and D are freshwater (not to scale). Illustrated below are their mandibles (adapted from Leach & Anderson 1979b: 146 ff.).



## CRAYFISH HARVESTING STRATEGY IN PALLISER BAY

During archaeological studies in Palliser Bay quantities of mandibles from marine crayfish were found in several sites. These were first identified by Falla, the Director of the then Dominion Museum, who accompanied Adkin when he was surveying and carrying out test excavations in the area (Adkin 1955: 469). In 1969-1972 further midden excavations in the area revealed much large numbers, prompting a detailed study (Leach & Anderson 1979b).

The exoskeleton of crayfish is composed of calcium carbonate interspersed with a mucoprotein and readily breaks down after discarding on a midden heap. However, the mandibles are much more durable and it is these parts which survive for long periods. There are four species of crayfish in New Zealand (Figure 137), two marine and two freshwater. To date only *Jasus edwardsii* has been identified archaeologically, although the mandibles of the other species are quite distinctive.

There is an important commercial crayfish industry in Palliser Bay today and a modern comparative collection of 252 specimens was obtained to permit measurements of their mandibles and various body dimensions. Regression analysis enabled equations to be developed for estimating body size and weight from mandible measurements (standard errors for tail length are less than 15 mm in all cases). These equations were used on the archaeological specimens to obtain size-frequency diagrams of catches at various stratigraphic horizons. The most useful series of samples, with which to examine catches over archaeological time, was from the Black Rocks middens. The mean tail lengths at various periods are shown in Figure 138.

Several lines of evidence at Black Rocks point to the likelihood that there were two periods of intensive occupation in this area, separated by up to 300 years of only sparse occupation. This may correspond with the onset of the Little Ice Age, discussed in Section 7. The main evidence of this at Black Rocks is from the land-nail fauna in the archaeological sites. Wallace has shown that repeated burning of the original coastal scrubland had left Black Rocks as an open grassland during the period of the earliest sites (BR3 and BR4), but that climax vegetation had reappeared by the time the late site (BR2) was occupied (Wallace 1979: 226 ff.). This is an important consideration when interpreting the changes observed in Figure 138.

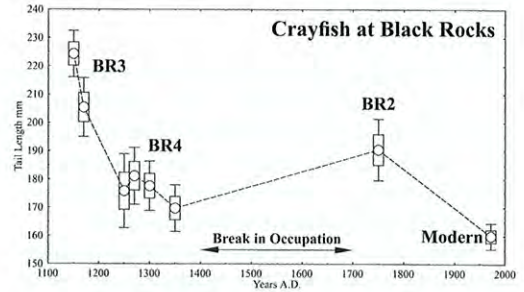


FIGURE 138

Changes in mean size of crayfish at Black Rocks, Palliser Bay, over archaeological time (adapted from Leach & Anderson 1979b: 160).

In the earliest stratigraphic layer at BR3 (the Black Midden) the mean tail length was 224 mm, falling to 205 mm in the upper layer. At BR4 (the Crescent Midden), the mean tail length was about 176 mm for the whole site, and once again there are signs that with each successive stratigraphic layer the size decreased. Then followed the period of sparser occupation, and by the time of the next significant archaeological sample there appears to have been a slight recovery of crayfish size, with a mean tail length of 191 mm for BR2 (the Pond Midden). Also plotted on Figure 138 is the mean tail size for the 1972 commercial sample at 160 mm.

There is no doubt that pre-European Māori harvesting the marine resources at Black Rocks were engaged in systematic gathering of crayfish. The left and right mandibles are easily distinguished, and the MNI was 1,529 from these three small midden excavations (Anderson 1979: 53). It stretches credulity to think that the considerable reduction in mean size over the time period of the first two sites could be due to a change in cultural preference of some kind, and there is no known natural environmental change during this early period of habitation. It surely indicates a human-induced effect on the nearby crayfish population.

A further interesting feature here is that despite a long period of only sparse occupation at Black Rocks after the first two earliest sites, the crayfish did not recover to anything like their former size, and the modern commercial fishery has reduced the size even further. To provide a perspective on this I have given a sketch (Figure 139) of a pre-European male, height 1,750 mm, alongside two crayfish at the same scale. The larger of the two represents Layer 1 at BR3, the crayfish from which had a mean total length from the tip of the



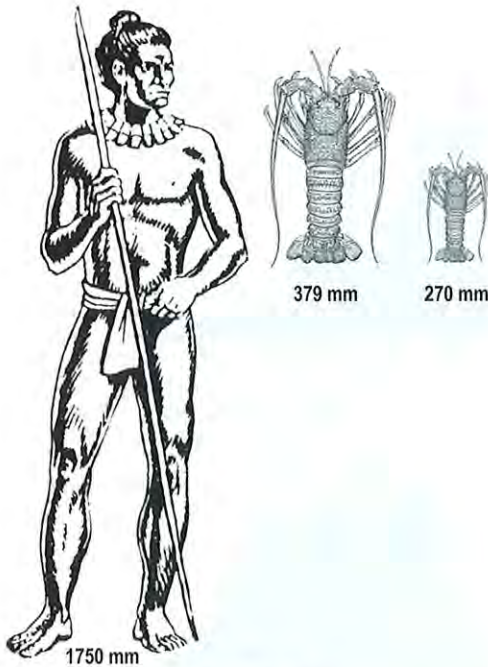


FIGURE 139

The average size of crayfish in the earliest archaeological site at Black Rocks compared with the average size in 1972. The three figures are drawn to the same scale. The drawing of the pre-European male is taken from Duff (1956: 24-25). See text.

rostral spine to the extended tip of the telson of 379 mm. The smaller of the two specimens shown represents the mean crayfish size in 1972, averaging only 270 mm.

Here then we have, I think, clear evidence that pre-European Māori were responsible for a lowering of the mean size of crayfish at one locality during their endeavours. Since we were able to estimate body weight as well as body length from the mandibles, we have been able to quantify the total weight of the catches at Black Rocks at different periods using the MNI values obtained. This is estimated to have totalled 8,381 kg at the first two sites (Leach & Anderson 1979b: 155).

What kind of harvesting strategy did these Black Rocks people employ for crayfish? To answer this question we need two things: firstly a size frequency distribution of the natural population at the time from which they were gathering crayfish, and secondly a size frequency distribution of the actual catch. Comparing these *two* distributions would reveal the nature of their selective behaviour. Unfortunately, we will never be in a position to be able to provide the former distribution. I do not know of any

clever way reliably to reconstruct or estimate the shape of the natural population structure from which prehistoric people selected their food. At best, we could sample a population which has no modern harvesting pressure on it and use that. This may not fairly represent the population we are interested in because the ecological conditions and water temperature may be somewhat different from those that prevailed for the archaeological collections we are studying. Despite this shortcoming, some general observations can be made nevertheless.

In Figure 140 I present size frequency distributions which combine all the crayfish assemblages from Black Rocks together. On the top left is the diagram for tail width, which is the modern fisheries management measurement criterion. I have given these four distributions because different researchers use different measurements, and this should assist direct comparison with modern fisheries information.

I also plot on to the distribution of Tail Width the current legal size limits that apply in most parts of New Zealand for both male and female crayfish. Unfortunately the mandibles are not able to be sexed, so equations chosen from Leach & Anderson (1979b) were those appropriate to both sexes combined. Clearly the pre-European Māori at Black Rocks were taking a significant number of undersized crayfish by modern standards; 41% are undersized if the female legal size limit is used, and 25% if the male size limit is applied. Does this mean that these people were uncaring or lacked the knowledge to care for the resource they were harvesting? Not necessarily. As explained above, there are several possible ways to care for resources, and our current notion in New Zealand of imposing a minimum size limit does not, on the face of it, seem to have been what pre-European Māori thought was the most appropriate thing to do. The smallest crayfish caught by these people had a tail width of barely 42 mm (tail length 111 mm, total carapace length 71 mm, body weight 167 g). This does not mean that they were specifically targeting small crayfish. There were abundant large crayfish in the catch, and in addition some monsters by modern standards. The largest crayfish caught by these people weighed an estimated 2,893 g and had a total length of 522 mm. The shape statistics of these distributions shows very slight +ve skewness ( $g_1=0.14$ ), and slight -ve kurtosis ( $g_2=2.1$ ), both values being significant. Not a lot can be inferred from this, particularly as several assemblages from different time periods have been combined. This



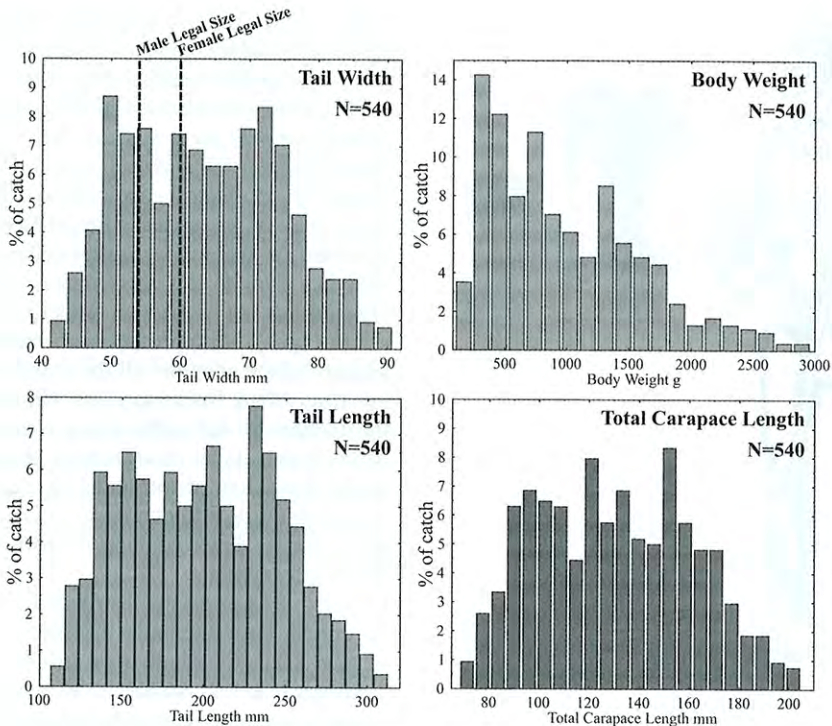


FIGURE 140

Size frequency diagrams of the crayfish catch from Black Rocks, all assemblages combined. From databases left by Leach & Anderson (1973). See text.

was necessary in order to get a reasonable picture of the general character of the overall catch.

Crayfish are well known to be slow growing and their growth rate is rather variable by region. Using information from the stock in the vicinity of Mahia East (McKoy & Esterman 1981: 133), the Black Rocks catch is predominantly of very old specimens. More than half must be well over 10 years of age, and a sizeable number are well beyond the limits of the Bertalanffy growth curve for Mahia East.

The people at Black Rocks were certainly not preferentially targeting the largest specimens of crayfish, and were therefore dismal practitioners of Optimal Foraging Strategy. Instead, they were taking specimens across the entire size spectrum from tiny to gigantic. The fact that such a large proportion of the crayfish they caught were, by modern standards, enormous, simply shows the wonderful abundance of crayfish available in pre-European New Zealand. The evidence points to a strategy which might be dubbed 'if they saw it and caught it they kept it'. This is a little like the behaviour described earlier for the Sunfish when faced with conditions of low prey den-

sity. This is a poor analogy, though, because the fact that such large crayfish were readily available at Black Rocks points to abundance, not poverty. So, the situation then is closest to the clear-felling strategy, or what was referred to as the *Slash and Burn and Fallow Model*. This fits quite well with the evidence of intense occupation followed by sparse occupation or even depopulation of this area.

#### SHELLFISH HARVESTING STRATEGY IN PALLISER BAY AND THE CHATHAM ISLANDS

Shellfish present wonderful opportunities for studying marine harvesting strategies and human effects on natural resources over archaeological time. Sadly, the samples taken by archaeologists in New Zealand during excavations are usually far too small to learn much. This is very short-sighted, because even if the archaeologists involved did not intend to study the remains themselves it represents lost opportunities for future research by others. However, there have been some large samples taken and really good analyses done of shell-



fish in middens in Palliser Bay by Anderson (1973) and in the Chatham Islands by McIlwraith (1976), coordinated with marine surveys of nearby modern populations. Not only were all the shellfish from these excavations kept after analysis was completed, but all the thousands of measurements taken are readily available for future studies with different research objectives in mind<sup>3</sup>.

An example relates to the gathering of a shellfish, *Haliotis iris*, known by the Māori name of *pāua*. This gastropod has a large meaty foot which it uses to attach itself very strongly by suction to rocks, rather like a limpet. Size-frequency diagrams are given in Figure 141 for samples from three sites at Black Rocks combined and from five sites in the Chatham Islands combined. For comparison, a modern sample from the vicinity of these sites in the Chathams is included. Also shown is the modern-day minimum legal size of 100 mm.

It will be obvious from these diagrams that two different harvesting strategies were being employed by the two separate groups of people. The pre-European Māori at Black Rocks appear to have had no size limit at all, taking everything from tiny to very large. The Chatham Islands pre-European Moriori, on the other hand, do seem to have had a minimum size limit, though this was still very small. Almost all *pāua* are greater than 50 mm, whereas at Black Rocks anything greater than 10 mm was gathered. Compared to the modern size frequency distribution, the Moriori were clearly focusing their attention on larger specimens and ignoring smaller ones. At Black Rocks, the gathered collection is quite similar to the shape of the modern population.

The modern legal size limit for *pāua* is 100 mm. Using this standard, 83% of *pāua* gathered by people at Black Rocks were undersized, compared with 69% in the Chathams. It can readily be seen from this that whatever resource conservation idea these pre-European people had, it was certainly nothing like the modern resource management system in New Zealand. It is worth noting too that the basis of the subsistence economy in the Chatham Islands was quite different to that which prevailed in Palliser Bay. Whereas the Palliser Bay people were horticulturalists with a shifting settlement pattern, engaged in 'slash and burn and fallow', the Chatham Islands people had an economy that relied primarily not on starch, but on fat from sea mammals

<sup>3</sup> These collections and the metrical databases are held in the Archaeozoology Laboratory, Museum of New Zealand, Te Papa Tongarewa.

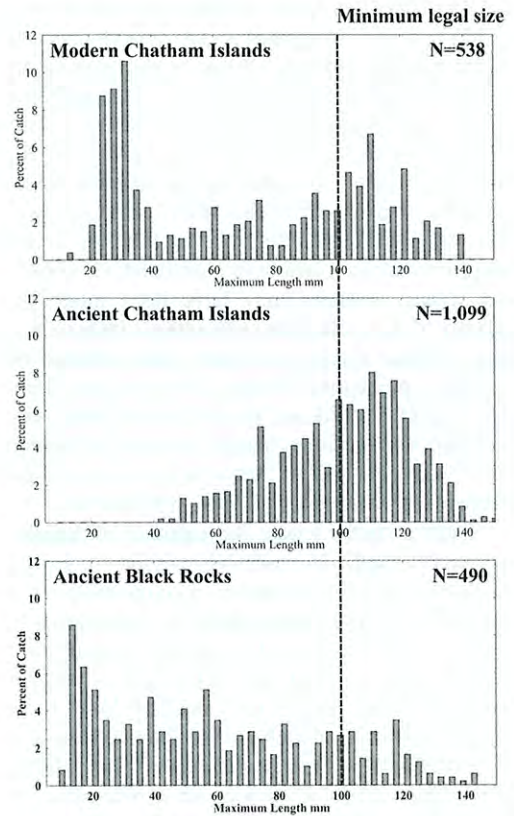


FIGURE 141

*Pāua* size in archaeological sites at Black Rocks and Chatham Islands compared with modern specimens. From databases left by Anderson (1973), and McIlwraith (1976).

(Leach *et al.* 2003). The latter might better be described as hunter-gatherer, more like that of southern South Island Māori than like that of North Island horticulturalists. The *pāua* shellfish gathering strategy at Black Rocks is similar to that described above for crayfish, 'if they saw it and caught it they kept it'. This concept does not apply to the Moriori, who were definitely selective.

SNAPPER HARVESTING STRATEGIES

At the beginning of this Section, the annual harvests of snapper in modern and pre-European times in Northland were compared. It was estimated that at the close of the prehistoric period, at the climax of Māori population growth, the snapper catch would have been about 1,900 tonne per annum, which is only about one third to one fifth of what is currently considered to be the Maximum Sustaina-



ble Yield (MSY) from this fishery. This assessment of MSY is of course based on the present-day state of the snapper biomass in this region, not on the biomass which existed at the close of the prehistoric era. Any estimate of MSY appropriate to A.D. 1769 would be a great deal more. I point this out because it serves to underline the strength of the inference that pre-European Māori could not have had any significant effect on the biomass of the snapper stock as a whole in Northland. Of course, old solitary snapper may have been more frequently found around rocky headlands inshore, and these inshore stocks could have been affected by sustained prehistoric fishing; however, the abundant historical evidence for the use of seine nets, sometimes of enormous length, described in Section 5 for Northland, implies that in this area, most of the snapper were taken along sandy open beaches.

Further south, where the biomass of snapper was much smaller, the possibility of human impact cannot be ruled out; but there is a complication here – natural environmental change. It was shown in Section 7 that the Little Ice Age was a significant event in New Zealand, and in the case of snapper stocks probably caused the complete loss of the resident spawning population in Tasman Bay, and the virtual loss of snapper along the western shores of the North Island at least as far as Wanganui, as these fish moved north away from increasingly cold waters. This interpretation would explain the fact that snapper are basically absent in later archaeological sites in Tasman Bay and Golden Bay, and less common in late sites in the southern coastal areas of the North Island and the later layers in one northern North Island site (Black Rocks Figure 98; Mana Island Figure 102; Foxton (Davidson *et al.* 2000b: 82); Kokohuia Figure 104).

In the case of fish size, there are a few sites where there is a time gap between samples of snapper and these samples are large enough to assess statistical significance. No change was detected in the sites at Kokohuia or Mana Island, but for both Rotokura and Foxton snapper size increases significantly over time. A number of hypotheses were offered to explain this — low recruitment rate with the onset of colder sea water temperatures, different seasonal occupations at these sites, changes in the areas where people were fishing. At the present state of knowledge it is not easy to distinguish between these alternatives.

In short, in the case of both relative abundance of snapper at different periods and changes of fish size through time, I cannot clearly see any evidence of

human impact on the snapper fishery for any part of New Zealand. Flannery's bold claim that Māori were responsible for the extinction of snapper in the South Island (Flannery 1994: 244) is not credible. A few snapper bones have been found in sites like Papatowai and Pounawea on the southern east coast South Island, and Southport, Coopers Island and Breaksea Sound on the west coast Fiordland area (MNIs of 4, 3, 2, 3, and 2 respectively, see Appendix 1). Two specimens were also found at the Panau site on Banks Peninsula, with fork lengths of 667 and 566 mm (Leach *et al.* 1994b: 4). These are most likely to have been stragglers running along seasonally warm currents southwards, and have been recorded in historic times about as frequently as during the prehistoric period. Based on his experiences as a commercial fisherman in the North Otago area, Graham lists snapper as present but rare (Graham 1963); and Dickinson mentions snapper as an incidental catch during experimental trawling in Otago waters in winter 1957, although the numbers are not reported (Dickinson 1958). Graham makes the following observation:

During 1930 to 1933 at least one or two [snapper] were taken by trawlers every week in Otago waters at Blueskin Bay, Taiaroa Head, and Taieri Mouth in from six to twenty-two fathoms. Odd ones were hooked at the North Reef, sixteen miles north-east from Otago Heads, by line fishermen. As these men made a practice of keeping this fish for their own table, it may be that many more have been caught in Otago waters than seen or recorded by me.... For some reason or other which I am unable to explain, Snapper from Otago were much thinner than those of the same length caught in Auckland and Bay of Plenty.... One small Snapper, measuring six inches, caught by us while seine netting in Otago Harbour, was of a delicate salmon pink with numerous white or grey spots scattered over the whole of the body.... It was seldom seen in Otago Harbour (Graham 1956: 243).

Snapper run down the west coast of the South Island somewhat more frequently than the east coast. According to a retired commercial fisherman with 40 years experience in south Westland, snapper are not uncommon as far south as Jacksons Bay, but he only ever caught one specimen in trawls as far south as South Nugget Point in 75-90 metres depth (Rex Bradshaw 2006 pers. comm.).

In Section 7, when I was concerned with changes through time, only those archaeological sites which had more than one distinct time horizon were considered. There are other sites with less



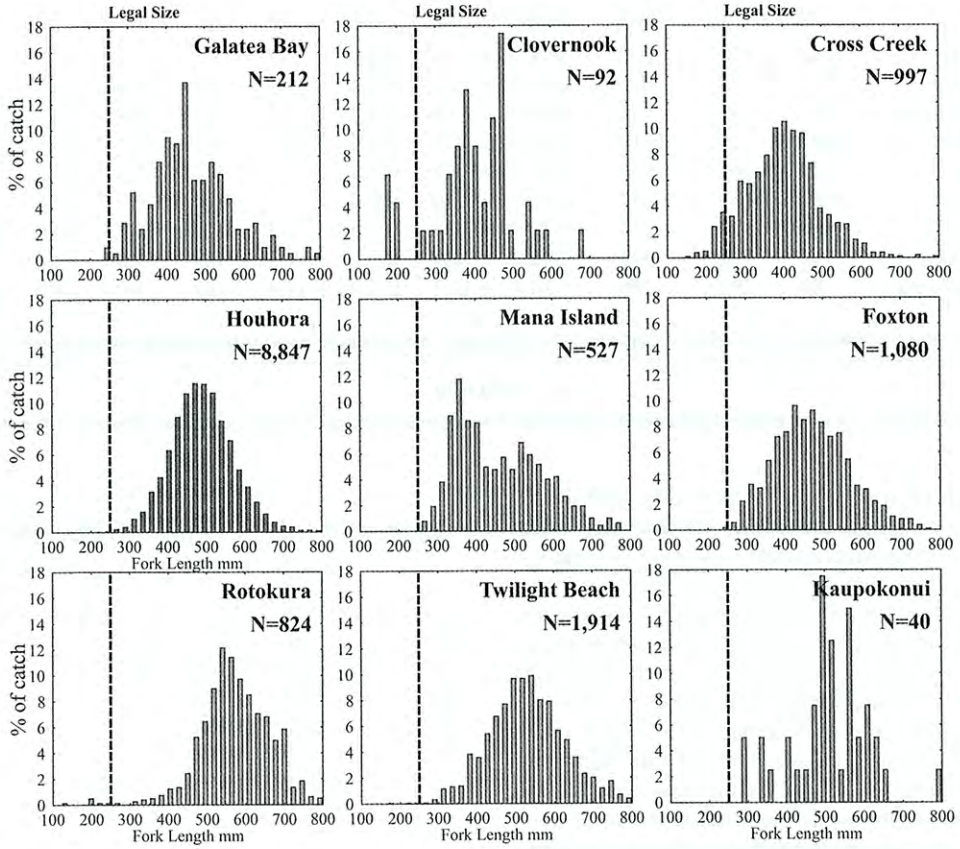


FIGURE 142

Size frequency diagrams of archaeological snapper catches. From data in the Archaeozoology Laboratory database at the Museum of New Zealand.

evidence of change through time, but which have abundant snapper remains, and these are especially useful for observing size-frequency distributions. This should reveal any evidence of selective targeting by size, which can also have an effect on a natural population. Several of these are given in Figure 142 along with the current Minimum Legal Size (MLS) of 250 mm for commercial fishermen. The MLS for recreational fishermen is 270 mm.

These catch diagrams consistently show a broad spread from about 300 to 800 mm fork length. Some show slightly non-normal tendencies and bimodal shape, such as Mana Island, Cross Creek and Rotokura, and this probably reflects the changes through time at these sites, commented on earlier. By far the largest assemblage is from Houhora, but unfortunately this cannot be separated into a time-sequence. This assemblage is almost perfectly Gaussian. Hardly any fish were

taken during pre-European times which are below the current MLS. This was initially somewhat surprising to me because given the prevalence of seine netting by Northern communities, small fish should become entangled unless the mesh was very large. Baited line fishing is unlikely to have caught many small snapper. If pre-European Māori were self-imposing a minimum size as part of a resource management strategy I would not expect to see Gaussian-shaped size-frequency curves. Instead the catch-frequency curves would be truncated at this minimum size, with a strong peak close to it, and a long tail towards large fish; that is, marked positive skewness and negative kurtosis. None of these snapper catches possess these characteristics (see Table 40).

There are probably two reasons why so few small snapper were being caught by pre-European Māori. Firstly, young snapper (two and three year



Site	N	Min	Max	Mean - SE	SD - SE	g1	w1	g2	w2
Galatea†	212	246	799	464.2 ± 7.1	103.2 ± 5.0	0.5	4.4	3.3	1.1
Clover†	92	177	673	401.4 ± 11.2	107.1 ± 7.9	-0.2	1.8	3.2	0.7
Cross Creek	997	146	782	400.0 ± 3.0	94.9 ± 2.1	0.3	6.9	3.3	1.8
Houhora	8847	218	1010	490.5 ± 0.9	81.6 ± 0.6	0.3	22.1	3.8	15.3
Mana Is	527	266	939	463.7 ± 5.1	116.1 ± 3.6	0.7	7.9	3.2	0.8
Foxton	1080	239	953	471.5 ± 3.0	100.0 ± 2.2	0.5	9.3	3.4	3.0
Rotokura	824	138	870	575.0 ± 3.3	93.5 ± 2.3	-0.4	7.2	4.9	11.1
Twilight	1914	176	994	532.0 ± 2.3	102.5 ± 1.7	0.4	10.8	3.6	5.7
Kaupokonui†	40	293	786	510.4 ± 16.1	102.0 ± 11.4	-0.1	1.0	3.5	0.9

† These three fish collections do not appear in Appendix 1. The full range of fish remains have not yet been studied, only the snapper bones.

TABLE 40

Dispersion statistics for some archaeological snapper assemblages. Source: Archaeozoology Laboratory database, Museum of New Zealand.

old fish measuring about 150 to 200 mm) mainly live on rough ground further offshore than where pre-European Māori would be seining. Secondly, it seems likely that the mesh sizes being used were large enough for small fish to escape. Modern commercial trawl nets have 4 1/2 inch mesh size (114 mm), and are designed not to catch significant numbers of snapper below the MLS of 250 mm. The escape rate would be higher for a seine net of the same mesh size since there is not the same pressure of large fish against the mesh preventing small fish getting through, which happens during trawling. The only archaeological examples of seine nets have 5 1/2 inch (140 mm) mesh size (discussed in Section 5), and assuming this was a common size, it might account for the lack of small fish in the assemblages shown in Figure 142 (statistics appear in Table 40). Even so, it does not account for the Gaussian character of the Houhora catch.

The theory of escapement of small fishes was studied in detail by Cassie (1955), with special emphasis on snapper. His results are summarised in Figure 143.

The dotted lines in this figure show the 50% escapement value for snapper of minimum legal size of 250 mm, which corresponds to just over 4 inch mesh size (102 mm). Cassie's study shows that for all practical purposes:

- The fork length with a mean probability of escape of 50% = 2.35 x mesh size,
- Standard deviation = 0.8 inches (20 mm).

Thus, a net with a mesh size of 100 mm will permit 50% of fish of fork length 235 mm to escape. Cassie used a highly standardised method of measuring mesh size with a 10 lb (4.5 kg) lead

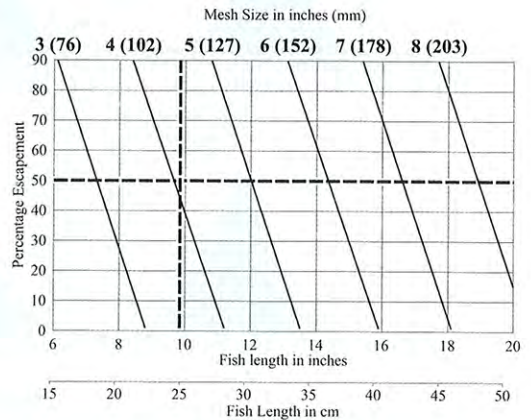


FIGURE 143

Relationship between mesh size, snapper length and escapement. Adapted from Cassie (1955: 73).

weight stretching the net mesh a constant amount along the diagonal before measurement. No doubt a seine net would perform somewhat differently than a trawl net. Nevertheless, this relationship is a useful starting point from which to examine archaeological catches and infer possible forms of net which could have captured them.

For example, the catches shown in Figure 142 have a left tail in the size frequency distribution which decreases dramatically between 300 and 400 mm fork length. If a seine net of 140 mm mesh (the Canterbury Museum examples) were used for these catches, the 50% escapement would occur for fish with a fork length of 330 mm (330 mm = 2.35 x 140). However, even if we presumed that a net was used to catch all the fish involved, it must be accepted that working backwards from a



prehistoric catch distribution to a mesh size is fraught with many untestable assumptions. Just two of these will be mentioned: 1) people may have thrown back small fish, 2) people may have been fishing in an area where there were very few small fish.

Another very interesting aspect of these snapper catches is the generally large size of the fish compared to catches today. This is put into sharp relief in Figure 144 where the catch data from the nine sites appearing in Figure 142 are combined together and compared with three modern samples from trawls. The Ninety Mile Beach sample is

from commercial trawls, which partly explains the low frequency of fish below MLS. The Houhora and Thames samples are from research trawls in these areas, designed to catch small specimens as well. Biomass was calculated using equations published by Leach & Boocock (1995). On the right is plotted the relationship between age and fork length using data from Walsh & Davies (2004) and Walsh *et al.* (2004) for Northland and from Paul (1996 pers. comm.) for Tasman Bay. This shows that above about 600 mm fork length it is almost impossible to estimate the age of snapper, and yet archaeological sizes reach 1,010 mm

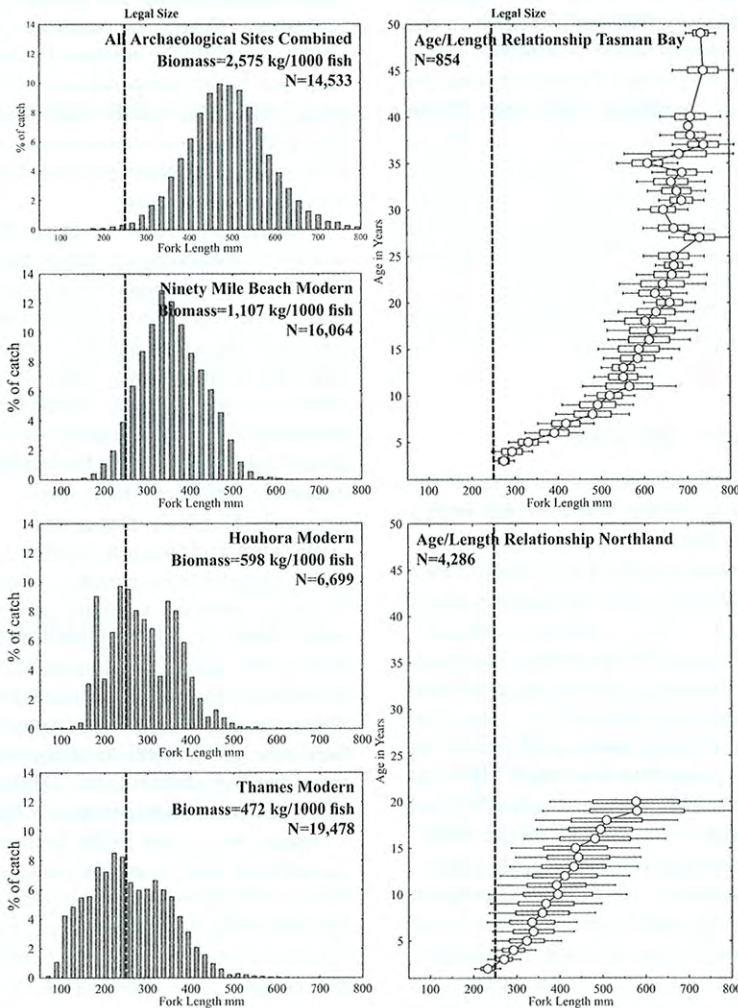


FIGURE 144

Size frequency diagrams of archaeological snapper catches compared to modern trawl data. From data in the Archaeozoology Laboratory database at the Museum of New Zealand, and modern data courtesy of Larry Paul.



(Table 40). Age is much more important than length when trying to understand population dynamics of fish stocks, and this is only really feasible with otoliths for long lived species. Unfortunately, there is no known method for systematically recovering otoliths from archaeological sites short of going through tonnes of sediments a teaspoonful at a time, as was done by Fitch (1969). Existing otolith collections from archaeological sites are at best grab samples and always biased towards large size.

The biomass of archaeological catches of snapper averages 2,575 kg/1000 fish, which far exceeds the modern distributional data. The Ninety Mile Beach trawls on the west coast Northland area come closest to this at 1,107 kg/1000 fish; this is followed by 698 kg/1000 fish in the vicinity of Houhora east coast Northland, and a mere 472 kg/1000 fish in the Thames area on the east coast south of Auckland. The bulk of the archaeological samples derives from the site at Houhora, so this should be most comparable to the modern samples from the same area. Clearly, the mean fish biomass is now less than one quarter of that in pre-European times. Such an enormous change is due to fishing during the historic era. As pointed out already, snapper biomass during prehistoric times was increasing over time, not decreasing.

#### BLUE COD HARVESTING STRATEGIES

At both Mana Island and several sites in the Chatham Islands it is evident that there has been a change in the mean size of blue cod over archaeological time. This was described in Section 7 (see discussion of Figure 113 & 112), but requires closer scrutiny now because it has a bearing on the harvesting strategy employed by the people concerned.

When the size-frequency curves are examined for each of the samples involved it is clear that very small fish were being taken at all periods in these sites, but the proportion was much higher in the earliest horizons. This pattern of collecting and eating very small fish is consistent with the widespread Polynesian cultural attitude towards harvesting fish. It is contrary to modern European notions of conserving fish stocks where a lower size limit is imposed, but no such prohibitions appear to have operated either in Polynesia or in pre-European New Zealand. This is a very important point to bear in mind when thinking about conservation practices and attitudes. Figure 145 shows the size frequency distribution for the two

periods at Mana Island and also the proportion of fish caught, which by today's standards are under-sized, for various other archaeological sites in New Zealand. It is clear from this that taking small blue cod was a widespread custom in pre-European New Zealand, not just at Mana Island and the Chathams.

Unfortunately, very few sites contain adequate numbers of blue cod in several stratigraphic horizons to be able to evaluate how widespread was this increase in size, which has been identified at Mana Island and the Chathams; however, coupled with the same finding in the case of snapper in some sites there is a hint here of a more general phenomenon during the course of New Zealand prehistory. While the increase in snapper size could potentially be attributed to a lowering of surface sea water temperatures over time in some areas, this cause can be ruled out in the case of blue cod. Blue cod is a cold water species, thriving further south in New Zealand. Some other factor must be involved here.

The key to finding the cause of this increase in size over archaeological times may lie in the very fact that pre-European Māori were catching very small fish. This is not the first time that fish size has been shown to increase over archaeological time. In an interesting study by Hales & Reitz (1992) of the Atlantic croaker (*Micropogonias undulatus*) in archaeological sites in Florida they found that "otoliths from Prehispanic periods were generally smaller than those from Hispanic periods" (Hales & Reitz 1992: 80), and while "both adult and juvenile croaker were taken in all archaeological time periods ... large adults (TL > 35 cm) comprised a greater percentage of individuals from the First Spanish Period" (Hales & Reitz 1992: 82). They conclude that "the biology of Atlantic croaker has changed dramatically since Spaniards discovered North America. Atlantic croaker now grow faster to attain similar maximum sizes, but live shorter lives" (Hales & Reitz 1992: 95). They were unable to decide the causes of such a change, but a clue might be provided by recent research on how some fish species evolve in the face of selective harvesting pressure (Conover & Munch 2002). In controlled experiments with the Atlantic silverside (*Menidia menidia*) they harvested samples of 1,000 fish in six separate tanks using three different size-specific rules.

1: *Large harvested*. In two populations, the largest 90% were harvested.



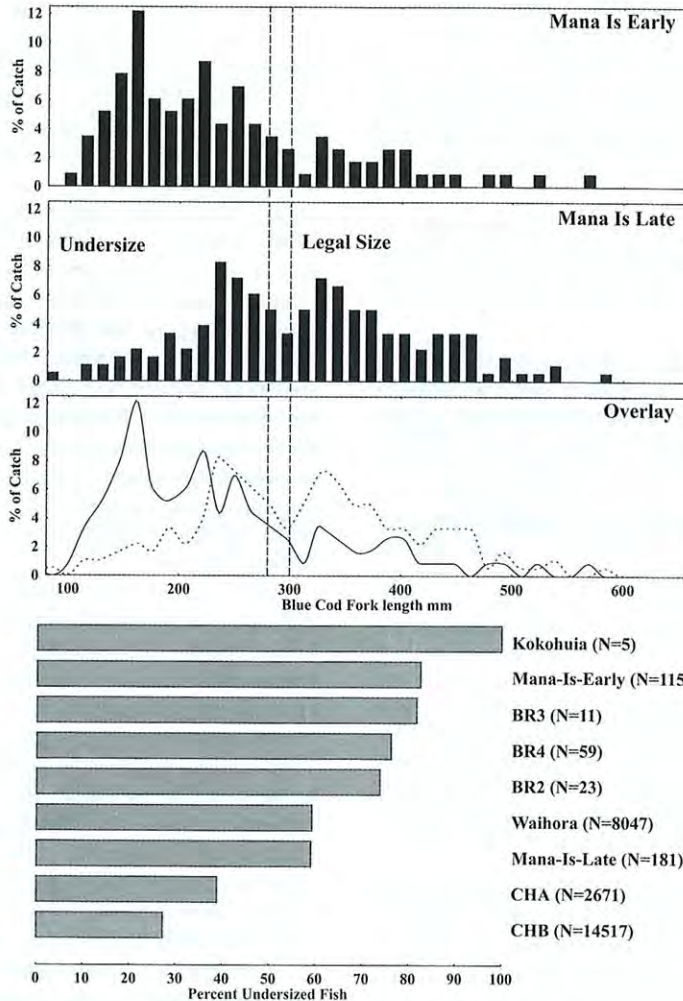


FIGURE 145

The blue cod catch at two time periods at Mana Island, showing a shift towards larger fish. Below: By today's standards, very small blue cod were being consistently taken for food in pre-European times.

- 2: *Small harvested.* In two populations, the smallest 90% were harvested.
- 3: *Random harvested.* These were control samples in which 90% were randomly harvested

The 100 surviving fish in each tank were allowed to spawn, and their progeny then used in identical harvesting procedures to their parents for multiple generations.

The results of this study are fascinating:

Large-harvested populations initially produced the highest total yield and mean weight of fish but then declined. Small-harvested populations started

with low yield and then increased. By the fourth generation of selection, the biomass harvested and the mean weight of harvested individuals in the small-harvested lines was nearly twice that of the large-harvested lines. Moreover, the spawning stock biomass differed even more [6 times] (Conover & Munch 2002: 94).

They also noted that:

Moreover, the genetic changes caused by selective harvest may be irreversible; cessation of harvest does not guarantee reverse selection back to the original state. Ignoring evolutionary consequences of



selective harvest contradicts the precautionary approach to resource conservation. ... reliance on minimum size restriction (all fish below a given size are protected) as a basis for management needs rethinking. Where feasible, maximum size limits (all fish above a given size are protected) may offer some important advantages (Conover & Munch 2002: 96).

The importance of leaving big specimens of fish is also emphasised in research carried out by Birkeland and his collaborators as the following makes clear:

Larvae produced by older female black rockfish *Sebastes melanops* grow more than three times as fast and survive starvation more than twice as long as do larvae produced by younger females. Furthermore, older fishes can be more experienced and successful at spawning, can provide the population with a longer spawning season and, as larger fishes, have an exponentially great fecundity. Selective harvesting of older individuals leads to the exponential reduction in the number of larvae produced, a shortening of the reproductive season, a decrease in the chance that some larvae of the population will encounter favourable conditions, a lowering of the average survival potential of larvae produced, selection for slower growth and reproduction at a smaller size and, in extreme cases, lowering of genetic heterogeneity. ... Thus, to improve the growth rate of fish and yield of the stock, they should instead target smaller fishes (Birkeland & Dayton 2005: 356).

They found examples of increased quality of progeny with maternal age in haddock (*Melanogrammus aeglefinus*), and Atlantic cod (*Gadus morhua*), and five to tenfold increase in larval survival with increased growth rate in bluefish (*Pomatomus saltatrix*) and Atlantic cod. They also found some evidence that it is primarily the longer lived species that are most vulnerable when there is fishing pressure on the larger and older individuals, and that this may not affect pelagic species such as tuna and dolphinfish (Birkeland & Dayton 2005: 356-357). They also state that traditional Hawaiians understood the importance of leaving large females in the breeding stock of at least one species, the threadfish *Polydactylus sexfilis*, by harvesting only medium sized fish. Unfortunately they do not cite their source for this interesting observation, and Titcomb, when she reviewed traditional Hawaiian customs concerning conservation of their fishery in 1956 does not mention this (Titcomb 1977: 11-18).

Is it possible that these observed increases in mean fish size over archaeological time in New

Zealand are a response by some species to human predation, and in particular to the strategy of selecting small specimens? This would depend on whether the species was under pressure from humans. In the case of snapper, they were clearly not under pressure in pre-European times, at least in the northern areas. However, snapper could in theory have been experiencing stress further south, around Cook Strait, for example. Against this is the fact that human population size was relatively small in the Cook Strait region for reasons relating to the difficulty of maintaining reliable harvests of kūmara. In any event, snapper spawning did not take place in Cook Strait, so any pressure that fish might have been under in these southern waters may not have resulted in evolutionary changes in growth rate in the spawning areas further north. This should be testable with otoliths by comparing size against age at different periods.

Blue cod are quite different to snapper; their biomass is much lower, and they have constrained home ranges. Even a moderate sized human population could place considerable pressure on inshore stocks of blue cod in a rocky habitat. Blue cod, therefore, could well be a species which is sensitive to humans and evolves quickly to accommodate their harvesting behaviour. Once again, a lot depends on how exactly pre-European Māori were catching these fish; that is, what kind of technology was used. If baited hooks were used for this species, small fish would not be common in the catch. The early catch at Mana Island shows a very clear preference for very small fish, and these must have been caught in small mesh nets, or perhaps the kind of trap illustrated by Sydney Parkinson in Queen Charlotte Sound in A.D. 1770 (Figure 61, Figure 62).

Is this an example of a deliberate strategy of resource conservation by pre-European Māori? Much as I would like to be able to say that we have here a glimpse into the mind of prehistoric people, that would be taking archaeological evidence into the realm of the non-falsifiable<sup>4</sup>. At best we can say that pre-European Māori consistently favoured small and very small fish, and blue cod (Figure 112 and Figure 145) is a good example of this. In the case of strongly territorial species with relatively low biomass such a har-

<sup>4</sup> Karl Popper wisely held that the "criterion of the scientific status of a theory is its falsifiability, refutability, or testability" (Popper 1972: 37).



vesting strategy will have had consequences on the population, and one of these might have been that their growth increased as a selective survival mechanism. Over a period of time the mean size of the species would therefore increase. Such a biological response to human predation could be localised in the case of a species that does not travel elsewhere to congregate and spawn. It might therefore be a detectable phenomenon in archaeological sites in one part of New Zealand and not elsewhere.

#### LABRID HARVESTING STRATEGIES

The same phenomenon of increasing mean size over time has been documented for labrids at a number of archaeological sites in both New Zealand and the Chatham Islands. This has been partly discussed earlier in this volume (Table 29, Figure 114, Figure 115, Figure 116). There is a complication when trying to interpret this change because we are not dealing with one species and anatomically the bones are extremely similar and not able to be separated. Consequently, we cannot be certain whether the observed changes through time are the result of shifting abundance of one species relative to another or to changes in the population size structure of one or more species, or a combination of both of these effects. The three most common species have somewhat different size distributions and this knowledge has been used to decompose mixtures of archaeological bones into these three species for the sites in the Chatham Islands. It was suggested in Section 7 that spotty and scarlet wrasse may have decreased in abundance over time and banded wrasse increased (Leach *et al.* 1999a: 127; Leach & Davidson 2001a: 159). This, however, is only an hypothesis, and not easy to test without an independent method of separating the species from their bones. In any event, it is not very likely that the cause would be the same in all the archaeological cases observed in Figure 116 of an increase in labrid size through time.

Once again, closer examination of the size-frequency distributions provides an additional clue. In focusing attention on the change through time we might be missing the main point, which is that as with blue cod, people were catching and eating very small fish! This will be hard to understand for many Europeans, who have a deeply entrenched belief that the biggest fish are the best, proudly stuffing them and putting them above the fireplace

on a placard. This is probably related to the attitude that fishing as an activity is primarily a sport rather than a source of food<sup>5</sup>, and if you want fish to eat you get it at a supermarket or fish shop. A large number of the fish appearing in the catches at Black Rocks, Kokohuia, Mana Island, and the three Chatham Island sites are less than 200 mm in length, and at two of these sites the range extends down to 96 mm fork length. These are very small fish by European supermarket standards. I find it hard to believe that such skilful fishermen, as all Polynesians are, would not be able consistently to catch large fish and discard small ones if that was their objective. Instead, this has all the hallmarks of an intentional fishing strategy. To be sure, large specimens were caught too, well above 500 mm at all the Chatham sites, and close to that for the others in mainland New Zealand; but the point needs stressing that people did not discard the small fish they caught.

Like blue cod, labrids are strongly territorial with well established home ranges, which they vigorously defend. They also have low biomass compared to species that are able to move away from habitats close inshore. That makes them vulnerable to the activities of humans and when a habitat is depleted recolonisation will be relatively slow from any distance. So we are confronted again with the real possibility that increasing size over archaeological time might be a biological response of selective survival in the face of human activities, passing this on to offspring genetically.

#### DISCUSSION

This Section has presented the results of several studies where changes in size or abundance of marine fauna can be demonstrated over archaeological time. Interpreting these changes is not easy. In some cases, natural changes in the environment, such as the loss of snapper in Tasman Bay, are likely causes; this is reflected in the absence of snapper in late prehistoric deposits. In other cases, there are clearer signs that humans have had a significant impact on the marine environment; crayfish are an example. It would be wrong to jump to the conclusion that such effects were not recognised by prehistoric communities,

<sup>5</sup> Polynesians are astounded at the idea of 'catch and release', which is in vogue amongst fly fishermen.



or indeed anticipated by them. It has been suggested that our modern-day model of conserving resources in the marine environment is not the only way of approaching this problem. The current approach of 'steady-as-she-goes', whereby we take a short term view and only harvest resources at a sustainable rate as they are being naturally replenished, is based upon the premise that the present biomass of fish and shellfish is satisfactory for current and future needs. However, it will be obvious to anyone who glances at the size frequency diagrams of pre-European Māori catches of fish in the past that the present-day inshore fishery is a pale reflection of the bountiful supply of former times. Moreover, the concept of imposing a minimum size limit on fish

caught as an additional conservation measure may be fundamentally flawed. Pre-European Māori certainly did not have this strategy, and it is arguable which is the more sensible approach.

Pre-European Māori may not have had a 'steady-as-she-goes' attitude either. Instead, they may have adopted a somewhat longer term view, more in line with their gardening activities. This involved shifting cultivations from time to time as soil became exhausted to leave them for a long fallow period. During this process, settlements needed to be re-located also, and in this way new marine patches would be exploited too. In this model, the environment is constantly going through a cyclical process of depletion and recovery.