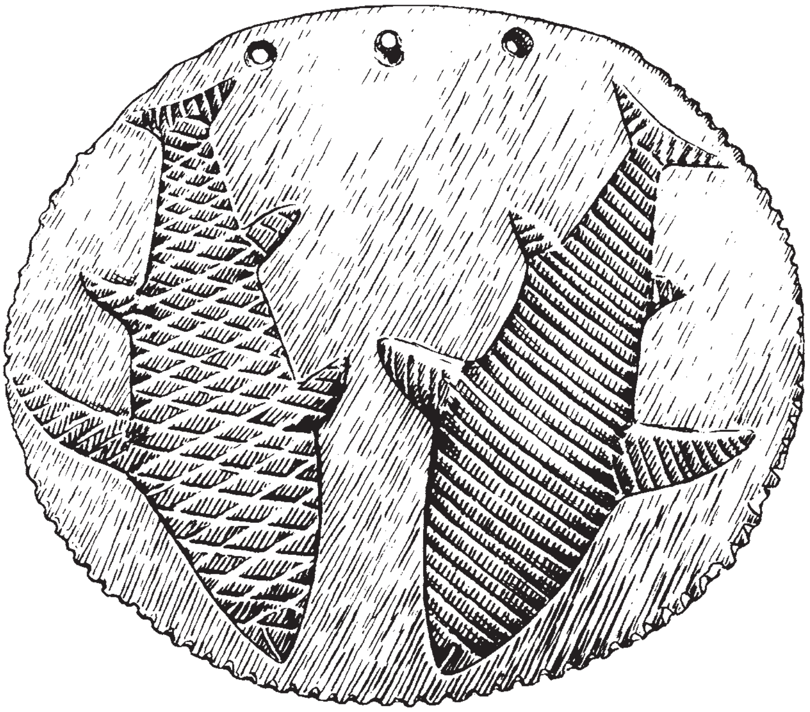
FISHING IN PRE-EUROPEAN NEW ZEALAND

Foss Leach



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Cover illustration: Slate breast pendant from Okain's Bay, Banks Peninsula (Thacker Collection), after Skinner (1974: 70–71). Skinner thought that the fish represented on this amulet could either be stylised bonito or albacore, or porbeagle shark. The body shape and fins are certainly strongly reminiscent of all three of the common mackerel sharks (Family Lamnidae) in New Zealand: *Carcharodon carcharias* (great white), *Lamna nasus* (porbeagle), and *Isurus oxyrinchus* (mako).

The Gods do not deduct from one’s life the hours spent fishing

Chinese ancient proverb

CONTENTS

ACKNOWLEDGEMENTS

The idea of writing a book describing pre-European fishing in New Zealand was first discussed in earnest by myself and Atholl Anderson in 1976, and the two of us collected material and worked together for a time on this project. We have both maintained a strong interest and commitment to this field of research since then, both on the sea as well as the land, and I would like to acknowledge Atholl's contribution to this work, which has been a very long time in coming to fruition.

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Illustrations are individually acknowledged in the captions and on page 330, but I would like to mention several colleagues who suggested or provided illustrations (including some that were not used in the end), or assisted me to obtain them: Jim Allen, Nigel Prickett, Melinda Allen, Eric Conte, and especially Yosi Sinoto.

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INTRODUCTION: WHY WE SHOULD BE INTERESTED IN ANCIENT FISHING

In the Annual Review of Anthropology for 1981, James Acheson of the University of Maine wrote a lengthy review of *The Anthropology of Fishing*. In this, he posed the question:

> What are the major contributions of maritime anthropology? Some anthropologists say there are none, and that such studies have nothing in common but water... . Bernard [1976].. , for example, argues that "maritime anthropology" is "far-fetched" in that it has no focus and has produced few "generalisations increasing our understanding of man." Studies in this field, he claims, could better be classified as "plain old ethnology, archaeology, linguistics, or physical anthropology with no loss of generality" (Acheson 1981: 275).

These are damning criticisms indeed; and clearly Bernard does not have much time for plain old ethnology, archaeology, linguistics, or physical anthropology, subject matter which I for one have always found interesting and which in my view has contributed quite a lot towards a better understanding of humankind.

Acheson went on to show that Bernard's view is extremely shallow and that there is considerable potential in the anthropological study of fishing. He drew from published literature on fishing from communities in such places as Canada, Sweden, Mexico, Sri Lanka, Ecuador, and Ghana; but apart from a passing reference to Malinowski's study of the Trobriand islanders in 1920, Pacific island fishermen[1] were essentially ignored in his scholarly review. The failure to incorporate marine resources and associated fishing behaviour in anthropological studies of human societies has been widespread. Similarly, it is only relatively recently that there has been discussion about, and recognition of, the importance of aquatic environments in hominid evolution (e.g., Roede *et al.* 1989; Morgan 1994, 1997) and of marine and freshwater resources in the emergence of *Homo sapiens* (Parkington 2001).

The New Zealand Māori, with whom most of this book is concerned, are Polynesian in their language, culture and heritage. They migrated from Polynesia between 800 and 1,000 years ago. The tropical Pacific is therefore the broader culture-historical context in which pre-European Māori culture is best understood.

It has always seemed to me somewhat odd that until quite recently anthropologists gave very little attention to fishing in the Pacific region. Fishing is amongst the most important of all aspects of modern and prehistoric[2] life in the Pacific, and to try to understand how a society functions on an

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[1] In Polynesian society generally, and Māori society in particular, there was clear division of labour. In the case of fishing, this was almost always the domain of men, especially activities that involved a canoe or use of fishing lines, hooks etc. Women's fishing activities were confined to foraging by hand in shallow water, and gathering shellfish and perhaps some small fish, and probably crayfish. For this reason therefore the term *fisherman* is consistently used throughout this book in recognition of this gender specific division of labour in fishing activities.

[2] The term 'prehistoric' has no emotive connotation amongst scientists, and has the technical meaning of human societies who do not have written historical records. Unfortunately, for the general public the term can have a somewhat derogatory sense of something inferior or outdated. To avoid giving unintentional offence, the term 'prehistoric Māori' or 'prehistoric Polynesian' is nowadays often replaced by the term 'Pre-European', which is an attempt at political correctness. Personally I prefer the term 'prehistoric', because its meaning is unequivocal, and to me the term 'pre-European' elevates the arrival of Europeans to an undeserved status, since it was so frequently accompanied by

(continued...)

atoll, for example, without fully appreciating the role of fishing is plain folly. The same is surely true for all Polynesian societies, including the New Zealand Māori. Yet the classic works of Pacific Anthropology, such as those by Malinowski and Firth, deal in great depth with many aspects of social organisation and ritual and scarcely at all with fishing behaviour. This makes it difficult for archaeologists studying fish remains to understand the wider social and cultural contexts in which fishing took place.

On the other hand, a modern anthropologist could possibly be forgiven for the relatively minor attention given to fishing behaviour. It is a subject field with certain difficulties — we are all familiar with the notion of the extravagant fish story in European society; indeed the very word *fish* itself is used to connote something unreliable or not quite right. Phrases like *fishy* and *odd-fish* or *fish-ball* spring to mind. Fishing is one of the most important domains of the apocryphal story, and it would be wrong to think that twentieth century European fishermen have a monopoly on fishy folk tales[3]. Baucke once remarked that the Moriori of the Chatham Islands excelled in the art of fishing for lobsters, and that:

> a diver who appeared with three — one in each hand, and one held by the antennae between the teeth, was acclaimed *tchim' tchakat' me' kye* (Baucke 1928: 360).

This curious phrase from the incompletely recorded Moriori language is thought to be equivalent to the Polynesian *tenei tangata mahi kai*, meaning a 'food provider of renown'. It stretches credulity to think that a Moriori was ever actually seen with a lobster in his mouth and one in each hand[4], but despite such an exaggerated claim there can be no doubt that fish is and has always been an important source of food for Moriori, Māori, and more generally for Polynesians throughout the Pacific world. The phrase *tenei tangata mahi kai* or 'food provider of renown' could equally apply to the fish as well as the fisherman.

Archaeologists working in New Zealand and the Pacific have been just as remiss as their colleagues in social anthropology in paying far too little attention to fishing in traditional Polynesian societies. One reason is probably the lack of comparative osteological material by which archaeologists can identify the types and quantities of fish which prehistoric people were catching. Fortunately, this problem has now been largely overcome. There are now good comparative collections of bones in archaeological laboratories at the University of Otago and the Archaeozoology Laboratory at Te Papa Tongarewa, the Museum of New Zealand.

Another reason for this relative dearth of knowledge about ancient fishing is that many archaeologists and anthropologists have focused on the artefacts of fishing at the expense of fish actually caught. Museums around the world have substantial collections of both ethnographic and

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[2] (...continued)
devastating effects on indigenous people. However, to avoid any disrespect, I liberally use the term 'pre-European' in this book.

[3] Evidently Benjamin Disraeli had no experience of fishing when he passed the immortalised comment that "There are three kinds of lies: lies, damned lies and statistics".

[4] It is interesting that Peter Buck (Te Rangi Hiroa) referred to this yarn in 1926. He states "Experts [he claims these were women] emerge from a dive with a crayfish in each hand, and some are said to come up with a third crayfish in the mouth, where presumably it had been transferred by hand" (Buck 1926: 629). Buck read this paper before the Auckland Institute 25 November 1924 (ibid.: 597), and Baucke originally published his observations about Moriori in the *Auckland Herald* in 1923 (Skinner 1928: 355).

ancient fishing equipment from New Zealand and the Pacific and these have contributed to an overemphasis on artefacts. Archaeological examples of fishhooks, particularly, have often been considered more important as types in chronological sequences than as actual pieces of fishing technology. A typical example is the series of excavations at South Point on the island of Hawai'i. The archaeological deposits consisted of dense midden refuse built up over a substantial part of Hawaiian prehistory. Fish bone is hardly mentioned in the excavation report, but considerable attention is given to pearl shell fishhooks, which were also abundant in the site. A chronology of Hawaiian prehistory has been proposed, based on these fishhooks. What people were actually doing with the fishhooks is curiously overlooked.

These two reasons, one a practical consideration and the other a matter of proclivity, still seem to me to be inadequate justification for paying so little attention to what I think is of paramount interest and importance to so many Polynesian societies. These people are fishermen. On small islands they are surrounded by the sea. There is no escaping the sound of the sea or its influences in everyday life. It is a major source of food and recreation. The forces of nature are made known to islanders through the sea. One can swim in it, dive into it, catch fish from it, paddle canoes over it, come to understand its diverse moods, come to know the boundless life it contains; just about the only thing one cannot do with it is drink it. For Polynesian people the sea is about as important as the coconut tree.

In the past few years the lack of European knowledge about how fish and fishing are integrated into life in the Pacific region has slowly been redressed with publications by people like Bob Johannes with *Words of the Lagoon* (1981), at long last revealing the full depth of folk lore and knowledge which Pacific people possess of life in the sea.

Why should we be interested in ancient fishing? Perhaps the most compelling reason is that fishing is amongst the most important things in the life of Pacific peoples. It is primarily the domain of men; if they are not actually out at sea fishing, they are likely to be found in the men's house or canoe shed talking about fishing, sharing stories and fish-lore, preparing fishing line, repairing nets, building canoes, or experimenting with new fish hook forms. When an archaeologist visits a remote Pacific island community and starts digging up old rubbish dumps, the local workforce normally take part with a sense of bemusement; however, as soon as it is pointed out that it is possible to shed light on what kind of fishermen their ancestors were, the whole attitude changes to one of intense interest and enthusiasm. If the descendants of the 'people who came before' think it is important to learn about ancient fishing, then that is a good reason for archaeologists to respond to this.

There are many other reasons too why we should be interested in this field. One is that it provides us with insight into the subtleties of human/environmental interactions. By studying trends in fish catches over long periods and teasing out the separate factors which combine to make up these changes, we can start to see the influence of human predation on marine resources. This provides an important baseline for modern marine resource management activities. Fish are also important bio-indicators. Fish remains from dated archaeological deposits may be able to contribute evidence about past climatic fluctuations. Better documentation of such events, in turn, may help to understand aspects of human migration and adaptation in the Pacific islands.

Archaeological evidence about ancient fishing activities is now being used to address the catastrophic state of the present-day world fishery. A programme of research called *Back to the Future*, based at the University of British Columbia, "seeks to solve the fisheries crisis by employing past ecosystems with sustainable, clean fisheries as policy goals for a restored future"

(Pitcher and Ainsworth n.d.: 1). They model biomass changes through time with a series of snapshots back to A.D. 1450 (ibid.: 3) using archaeological data provided by Heymans (2003). Heymans considers archaeological evidence back as far as 3,500 B.C. in his reconstructions. A larger, multi-disciplinary, 10 year project, *HMAP (History of Marine Animal Populations)* also draws extensively on archaeological data, particularly from Europe and North America. New Zealand has yet to follow these important initiatives.

Another aspect of this problem is that the quest to rejuvenate the past marine ecosystem has become strongly enmeshed in the politics of indigenous rights. Many indigenous peoples, whose past economy included significant exploitation of marine resources, are now experiencing difficulties because they are no longer able to maintain this aspect of their cultures. The deplorable state of the New Zealand fishery and the effect this has had on rights guaranteed under the Treaty of Waitangi have been the focus of much evidence presented to the Waitangi Tribunal. Although some redress has been granted relating to the commercial fishery, there has been little attention given to customary rights until now (Leach 2003). It is important to gather quality information about the fishery past and present to help resolve this issue.

In 1967 Fred Reinman attempted a summary of what was known about ancient fishing in the Pacific region with his publication *Fishing: an aspect of Oceanic economy, an archaeological approach*. He made the comment of New Zealand:

> Perhaps more digging has been done here than in any other area of Polynesia, but despite this there are apparently no published accounts of an analysis of midden constituents which can provide us with statistical data on the frequency and weight of food remains. Many of the reports contain an enumeration of the remains — often in the form of a list beginning with the most prevalent kinds to the least so [This evaluation is often a visual one, made by the excavator, rather than on the basis of excavated samples][5] — but these cannot be used except to make statements about the presence or absence of shellfish in the diet (Reinman 1967: 172).

This criticism could, 39 years later, still be levelled at a large number of archaeologists working in both New Zealand and the tropical Pacific. I take the view that each archaeological site is a precious gift from the past. It should be seen as a rare privilege to be given permission to disturb it, and if it is excavated then all the remains it contains should be studied with the best possible research tools currently available, because once it is taken apart the original integrity is lost forever. What started out as an ancient rubbish dump and a valuable source of knowledge has become an archaeologists' rubbish dump consisting of hopelessly tangled objects, removed from their original chronological and social context. If archaeological sites cannot be afforded the highest quality excavation and study, for whatever reasons of expediency, then they should be left alone.

The purpose of this present volume is to summarise what we currently know about fishing in pre-European New Zealand. In the last 30 years the fish remains[6] of a significant number of archaeological sites in New Zealand have been carefully studied, and in some cases re-studied. Not all of these collections were made with modern scientific techniques in mind, and they are therefore

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[5] Reinman added the sentence here enclosed in square brackets as a footnote.

[6] This volume is primarily concerned with bony fishes and cartilaginous fishes (sharks and rays), but in places some attention is also given to other marine animals, such as crayfish, sea mammals, and molluscs.

of variable quality. However, we do the best we can with such samples, and give special attention to those collections which are large and were extracted using unbiased sampling strategies.

CHAPTER 1: THE ARCHAEOLOGY OF FISHING

This chapter describes the various procedures followed by archaeologists studying pre-European fishing in New Zealand. It is important to understand something of these processes, before going on to consider the wealth of information they can yield. Fish remains are found in various kinds of archaeological sites, but excavation is only the tip of the iceberg. The material is recovered systematically from a site and brought back to the laboratory where it is sorted and as much as possible identified. Once this has been done, it becomes possible to work out the relative abundance of different kinds of fish in a site or occupation layer, and to reconstruct the sizes of the major fish species caught. This in turn enables us to look for variations from one region to another and, even more importantly, to search for changes through time in individual regions. The contribution of fish to the diet is also an important field of enquiry.

ARCHAEOLOGICAL SITES AND FISH BONES

The typical archaeological site containing fish bones in sufficient abundance for later study is most often found in New Zealand within a short distance of the coast[1]. Fish remains were transported to inland locations by pre-European Māori, but one seldom finds areas of concentrated midden[2] far from the coast. Native freshwater fish other than eels (which are discussed in Chapter 7) are small and very few remains have been reported from archaeological sites. This is probably mainly due to their being overlooked during recovery and sorting and deficiencies in comparative material. For example, no archaeological laboratory has a specimen of *Prototroctes oxyrhynchus* (grayling), which could reach a size up to 2 kg. In addition, in inland locations where freshwater species might have been more commonly caught, the soils are usually more acidic, and tiny bones may not survive so readily. In coastal sites, exposed to sea spray, the pH is usually close to neutral, which is more favourable for bone preservation. If fish bones are dumped in middens rich with shellfish remains this is also a very favourable soil chemical environment, because the calcium carbonate neutralises acid soils. The remains of crayfish very rapidly decay away, but their mandibles may survive in some environments. It has been noticed that archaeological soils rich in burnt shell or ash can contain crayfish mandibles.

More than 56,000 archaeological sites have been recorded in the New Zealand Archaeological Association Site Recording Scheme (Walter 2004: 82). In the computer database relating to this scheme, each site is given a single two-character code which most cogently describes what kind of site it is. The codes cover a very wide range of site types, such as fortified *pā*, stone quarry, terrace site, kūmara (sweet potato) storage pit, etc. Of the total sites, 32% are categorised as containing sufficient economic debris to warrant being classified as some kind of midden (Fig. 1.1). Of these, 22% are classed as middens, and the remainder as other kinds of site with associated midden deposits.

The New Zealand coastline is not plotted in this illustration, but the high density of archaeological sites in coastal areas makes the coastline visible even so. An unknown proportion of these midden sites, but certainly a great number of them, contain fish remains. As we will see in Chapter 4, fish remains have been studied at an acceptable level of scholarship at only 126 of nearly 18,000 sites

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[1] Most of these sites are within 50 metres of the shore, and they are seldom more than 500 metres.

[2] The word midden drives from the Danish word *kjøekkenmøedding*, meaning ‘kitchen midden’ or ‘kitchen rubbish dump’.

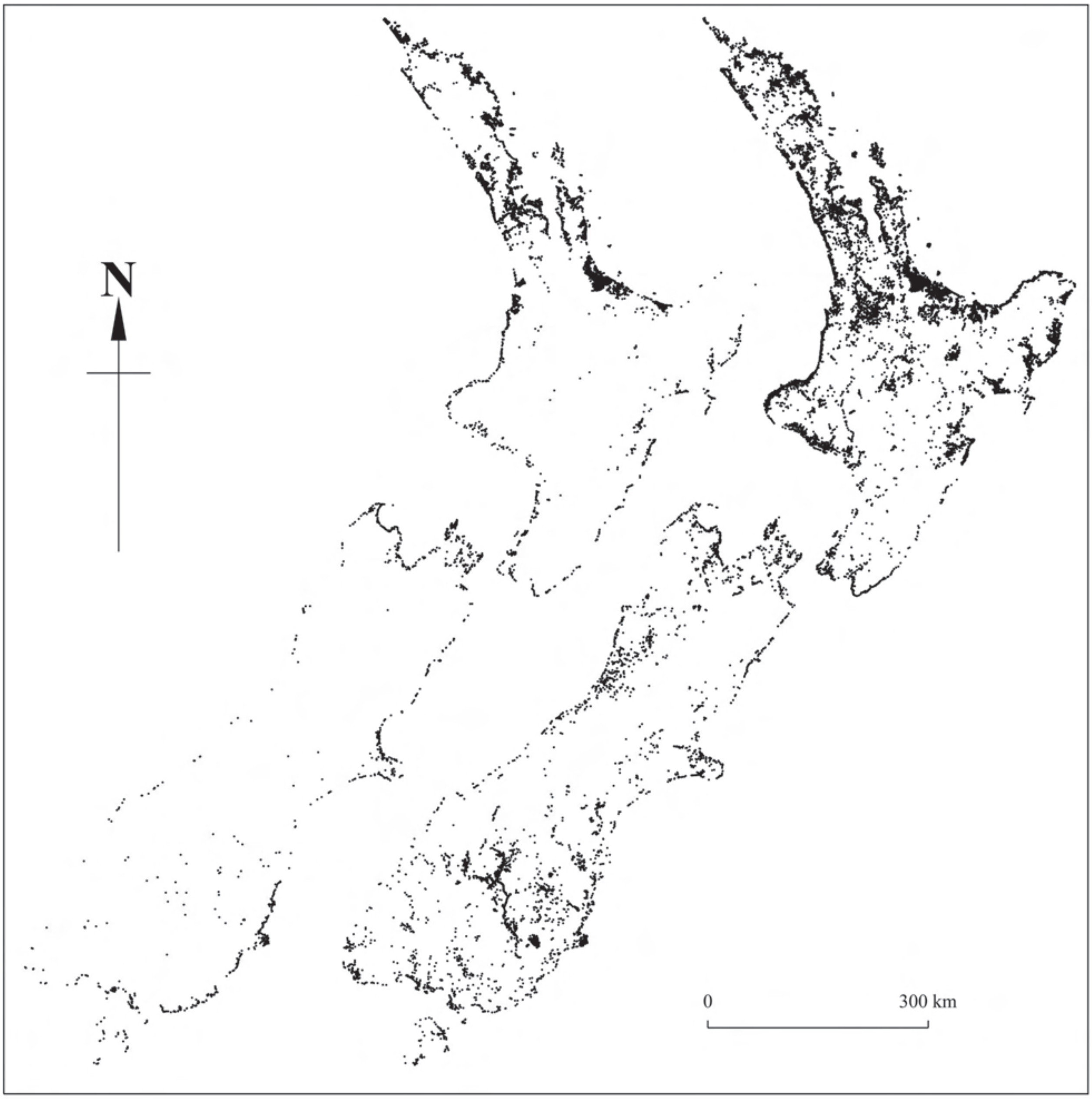

Figure 1.1: Of more than 56,000 recorded archaeological sites in New Zealand, those categorised as including midden deposits comprise 32% of the total. These are plotted on the left map. Other site types are plotted on the right hand side. The coastline is not drawn on either of these maps (Information from the New Zealand Archaeological Association Site Recording Scheme).

with midden recorded so far (Appendix 1[3]). It should also be noted that a large proportion of the sites not specifically classified as middens also contain economic debris including fish remains. The wealth of archaeological sites evident in this illustration shows that there are wonderful opportunities in New Zealand for studying the marine food quest. Two typical midden excavations are shown in Figures 1.2 and 1.3.

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[3] The 126 sites and abundance figures cited in Appendix 1 derive from the database maintained at the Archaeozoology Laboratory, Museum of New Zealand Te Papa Tongarewa. They relate to fish remains from 97 sites processed strictly according to methods employed in the Laboratory, and a further 29 sites which were processed outside the Laboratory, but which I consider to be trustworthy. In this volume I refer to 'The Fishbone Database' as a shorthand term for the data presented in Appendix 1.

Figure 1.2: The ‘Black Midden’ at Black Rocks, Palliser Bay, after excavation (Photo by Atholl Anderson).

These illustrate excavations carried out by Atholl Anderson in 1971 (Anderson 1973), which provided an important benchmark in New Zealand archaeology. The excavation strategy is therefore worth describing in some detail. Anderson carried out four excavations, two of 8 square metres and two of 2 square metres. In each case the aim was to excavate at least 10% of the volume of the midden, as far as it could be judged from surface features. The sites were quite shallow, and a total volume of 5.03 m^3 was excavated (ibid.: 59). The retention strategy employed is illustrated in Figure 1.4, and resulted in a reduction of the quantity down to about 1.5 m^3. That is, of roughly 6 tonne excavated, a little less than 2 tonne was removed to a laboratory for processing (Fig. 1.5).

These were small excavations by most standards, and the fieldwork operations were designed to maximise recovery, so that careful attention could be given to the midden in a laboratory

Figure 1.3: The ‘Crescent Midden’ at Black Rocks, Palliser Bay, during excavation (Photo by Atholl Anderson).

environment where research conditions are more favourable. Anderson’s study combined careful excavation, emphasising fullest field recovery, with a detailed marine survey of the local area at Black Rocks[4]. This made it possible to define the nature of prehistoric food collection strategies in the area. Fish remains were quantified, shellfish specimens were measured and size-frequency diagrams prepared and examined for changes through time. Admittedly, this research was labour intensive, but the rewards were manifold, producing a great deal of knowledge about how pre-European Māori gathered food from the sea. With a few notable exceptions, mainly in the South

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[4] Archaeological sites in this volume are referred to by their local name. Further details about these are provided in Appendix 1.

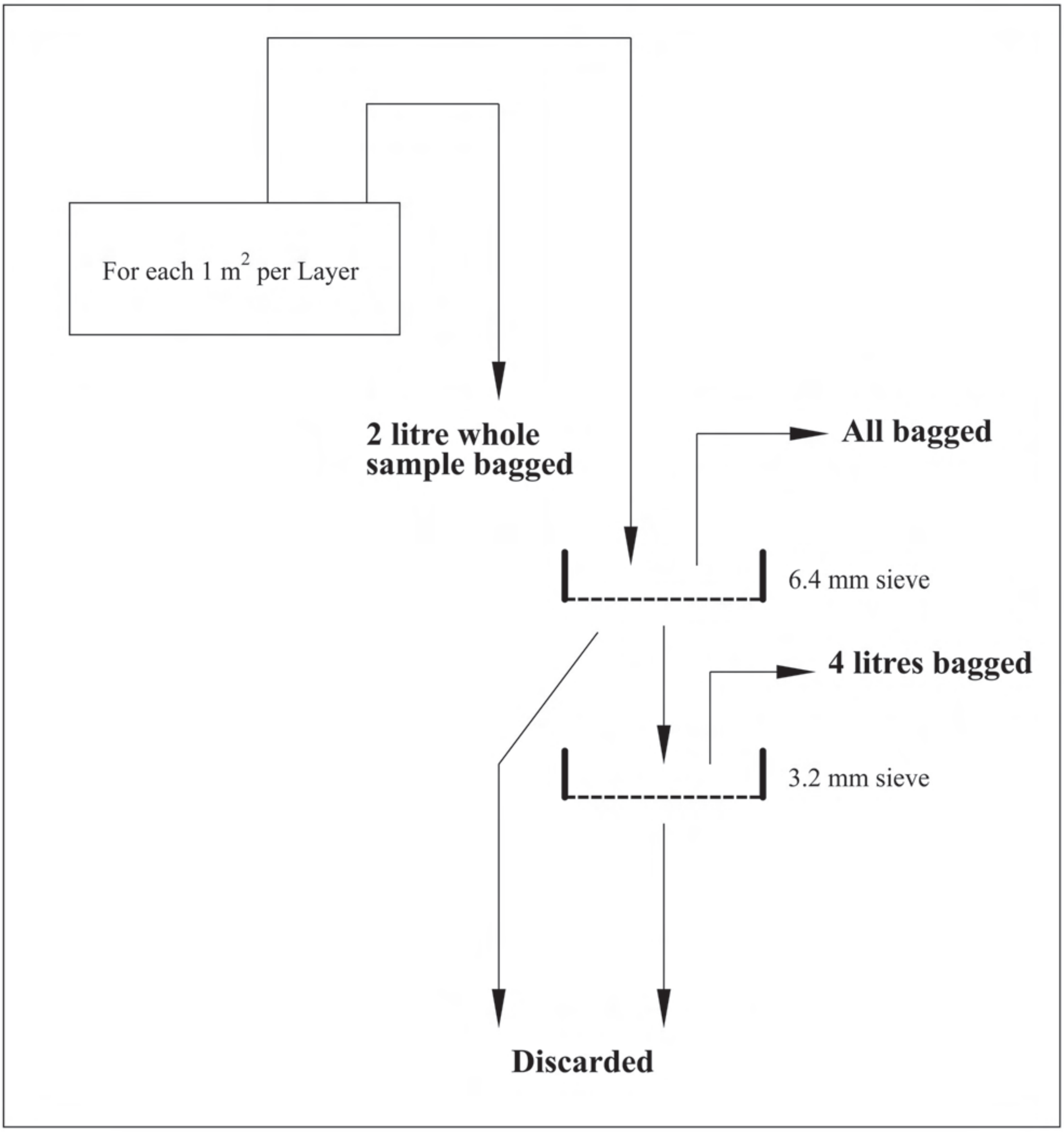

Figure 1.4: The retention strategy used by Atholl Anderson at Black Rocks, Palliser Bay (after Anderson 1973: Fig. 3).

Island, Anderson's trail-blazing example of what can be achieved with midden research in New Zealand has unfortunately not been followed. Midden sites are being destroyed in large numbers during various forms of public and private works, and only perfunctory attention is being given to them by archaeologists.

It is noticeable in the retention scheme described above that no attempt was made in the field to discard some remains as of no later analytical value. Some excavators in the past sorted material in the field into bones which were vaguely thought to be useful or not useful. This is a specialised task, and should not be attempted in the field. It is far better to retain everything above a certain

Figure 1.5: Atholl Anderson doing the preliminary sorting of a sample of 2 tonne of midden removed from the Black Rocks excavations in Palliser Bay. This sample is one-third of the midden excavated in the field (Photo by Foss Leach).

sieve size, and discard the rest. Anderson's excavations used rather large sieve sizes, and some may prefer to use finer mesh screens. This would, of course, have the effect of increasing the amount of material returned to the laboratory. Another criticism which might be levelled against the Anderson scheme is that the bulk samples are not very large. These types of samples are especially important for systematic collection[5] of otoliths (small dense bones from the ear), land snails, carbonised seeds, etc. An alternative to bulk sampling is to put all the soil passing through the sieve stack through special flotation equipment which will remove landsnails and carbonised remains. My preference is to keep much larger bulk samples (that is the soil passing through the smallest sieve), at least 100 litres, from each significant stratigraphic horizon in a site.

IDENTIFYING FISH BONES IN THE LABORATORY

When a collection of fish remains reaches the laboratory for study, the first task is usually to carry out re-bagging of the material before actually beginning analysis. Most excavation soils contain quite a lot of moisture, and it is preferable in the field to bag midden in paper bags rather than plastic ones, so that slow drying is facilitated. During the re-bagging phase, provenance details are checked and written on the new plastic bags in a much more uniform manner than is normally done in the field. Special pens are used which etch the plastic so that provenance details can never be lost. When re-bagging is completed for the whole site, each bag is then tipped out into a sorting tray

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[5] Unfortunately, such items have not always been collected and retained in a systematic manner, such as randomly, from sediments. This greatly limits their value for palaeoenvironmental or palaeoecological research.

with white background and gone through systematically with tweezers, sorting into major midden categories, such as bone, shell, artefacts, stone, charcoal etc. As this is completed, the material is then again re-bagged, but this time into the separate categories. This process of sorting and re-bagging goes through a number of separate stages, with more specialised tasks carried out at each successive stage. In my laboratory the bags of fish bones are first sorted into separate anatomical elements, in particular into parts of cranial anatomy which have been found over the years to be the best diagnostic elements of as wide a range of species as possible (Leach 1997). These bones are:

Dentary
Premaxilla
Articular
Maxilla
Quadrate
Special bones

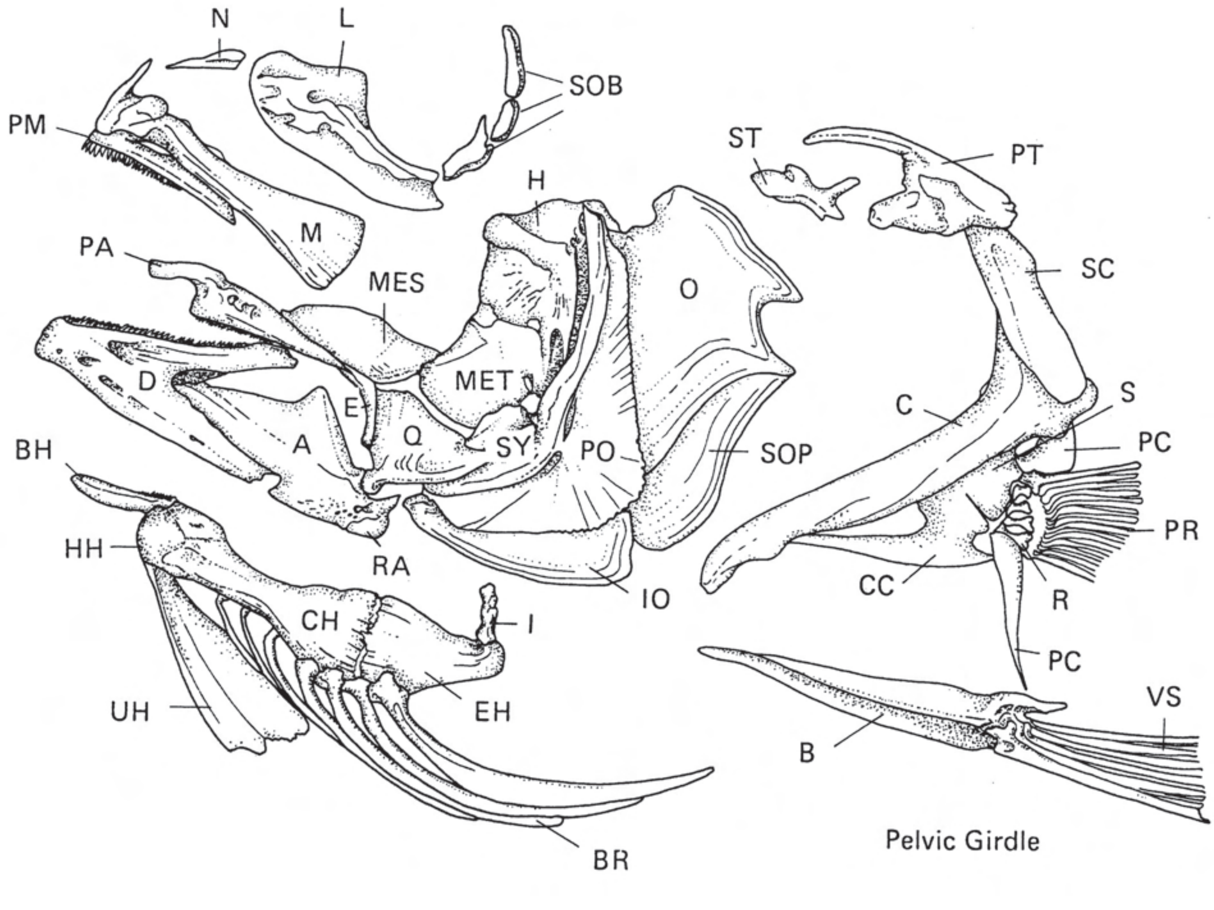

Figure 1.6: The main facial and appendicular bones of a typical fish (from Cannon 1987). A=Articular, B=Basipterigium, BH=Basihyal, BR=Branchiostegal, C=Cleithrum, CC=Coracoid, CH=Ceratohyal, D=Dentary, E=Ectopterygoid, EH=Epihyal, H=Hyomandibular, HH=Hypohyal, I=Interhyal, IO=Interopercle, L=Lachrymal, M=Maxilla, MES=Mesopterygoid, MET=Metapterygoid, N=Nasal, O=Opercle, PA=Palatine, PC=Postcleithrum, PM=Premaxilla, PO=Preopercle, PR=Pectoral Ray, PT=Posttemporal, Q=Quadrate, R=Radial, RA=Retroarticular, S=Scapula, SC=Supracleithrum, SOB=Suborbital, SOP=Subopercle, ST=Supratemporal, SY=Symplectic, UH=Urohyal, VS=Ventral Spine.

The last-mentioned are specialised bones which are characteristic of particular species, such as the dorsal erectile spine of trigger fishes (Balistidae). These bones are of great use in identifying particular species, and often there are only one or two of them per individual, which assists in the calculation of relative abundance of different fish types. The main parts of the cranial anatomy of bony fishes are illustrated in Fig. 1.6.

The question of which bones to use for identification continues to be a matter of heated debate. The potential for obtaining more information must be weighed against the time spent in analysis, the nature of specific archaeological deposits, and the purpose of the analysis (for example a biodiversity study, or economic research). In Europe, it is sometimes necessary to devote considerable effort to the identification of vertebrae, as other bones are rare. In New Zealand and the Pacific it has sometimes been found that a particular 'special bone', such as an otolith, provides the main evidence for a type of fish (Weisler 1993). In general, however, the bones listed here enable consistent and sufficiently detailed analysis.

When the fish bones have been sorted and re-bagged according to these standard items of cranial anatomy, each category is examined in turn, and the fish types present identified. It has been found that if one is only dealing with one part of the anatomy at any one time, identification of species is much easier. In any one bag of dentaries from a particular provenance, for example, one will usually have several specimens of varying size belonging to the same species. This system of identification has evolved in New Zealand over nearly 30 years, and is now at a highly organised

Figure 1.7: Foss Leach sorting archaeological fish bones for identification in the Archaeozoology Laboratory at the Museum of New Zealand. In the background are bays of shelves with fish bones mounted on display boards (Fig. 1.8) (Photo E.001124, courtesy of Museum of New Zealand Te Papa Tongarewa).

stage whereby many thousands of bones can be identified efficiently and accurately without undue difficulty (Fig. 1.7).

Of course in order to identify species, one must have a reference collection of modern specimens of fish. Since our identification system is based on working with one part of the anatomy at a time, the collection is organised in this manner too, with all bones of one type mounted on one board (Fig. 1.8). Although there are hundreds of species of fish in New Zealand waters, only about 50 of these occur in any abundance in archaeological sites, and 6 of these make up more than 80% of the fish so far identified (Fig. 4.1, Table 4.1). Consequently, it is not necessary to have enormous comparative collections for archaeological research. Even with excellent comparative material it is still difficult to identify some fishes to species level, and sometimes they cannot be identified to genus either. For the purposes of understanding ancient food gathering behaviour the inability to identify bones to a lower level than genus is not a serious handicap. For example, there are two species of freshwater eels in New Zealand, the short-finned and long-finned eel. The differentiation of these mainly relies on external features which are not preserved archaeologically. However, they occupy very similar habitats, and no significant information is lost when we identify only to the level of *Anguilla* sp.

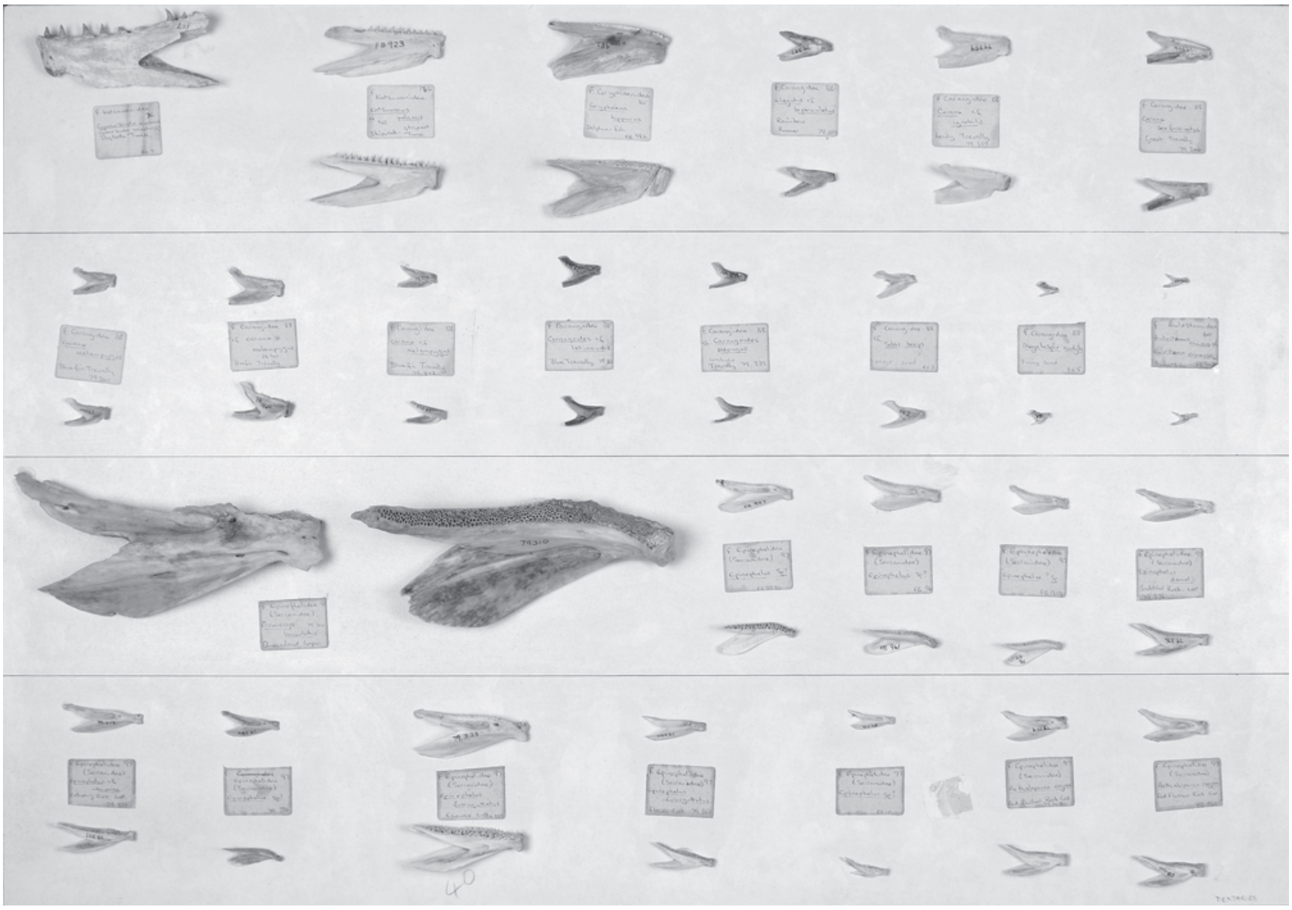

Figure 1.8: The reference collections of fish bones in the Archaeozoology Laboratory at the Museum of New Zealand and in the Anthropology Department at the University of Otago are organised by anatomy. On each display board is mounted only one part of the anatomy of the common inshore fishes of New Zealand and the tropical Pacific. This greatly simplifies and speeds up identification of bones to species. More than 300 species are mounted in this manner (Photo by Raymond Coory).

One particularly troublesome group of fishes in New Zealand are those belonging to the Labridae family (Leach and Anderson 1979a; Leach *et al*. 1999a). There are 16 species of this family in New Zealand, belonging to several genera. It would probably be quite useful to be able to identify these at least to genus level, but unfortunately (at the moment) we cannot. The different species do have different habitats, and valuable information about human behaviour is lost when only identifying to family level. To complicate matters, some parts of the anatomy are identifiable to a particular species, and others are not. For example, the dentary of the scarlet wrasse, *Pseudolabrus miles*, is perfectly distinguishable from the dentary of the spotty, *Notolabrus celidotus*. However, the maxillas of these two species are very difficult to distinguish. This may sound like a trivial problem, but it is not. In carrying out identification work on fish remains, the first objective is to work out the relative abundance of the different fish types (discussed in the next section). For one family of fish, say labrids, if we identified the maxilla bones to the level of family, the quadrates to genus, and the dentaries to species, it would be very difficult to put all this information together and calculate how many fish are represented in the collection. The way we get around this type of problem is by identifying all parts of the anatomy to family level in the case of labrids. The resulting numeric abundance is therefore a minimum, rather than an inflated figure.

In discussing archaeological fish remains common names can be just as useful as species names, and are often be used in this volume[6]. I have adopted a flexible approach. As already noted, bones often cannot be identified to species level. In New Zealand they can usually be identified to genus, but in the Pacific many can only be identified to family. When searching for statistical trends in time and space it is often necessary to use fish families as the unit of analysis before any trends can be observed. Moreover, to give a species name to archaeological bones can be quite misleading. Jack mackerel are a good case in point. The distribution of a South American species is known to be influenced by episodes of El Niño/La Niña, when it sometimes comes into New Zealand waters. This species is osteologically indistinguishable from a resident New Zealand species. It is clearly not warranted to give a species name to archaeological bones of mackerel. If we were able to identify the South American species from bones, this would provide useful evidence of past climatic events.

FIGURING FISH CATCHES — MINIMUM NUMBERS

As pointed out above, the first objective in the study of archaeological fish bones is to work out the relative abundance of the different fish types in a collection. This tabulated information provides us with the first glimpse of what all these bones meant to the prehistoric people who dumped them. It tells us which particular fishes were most important to these people, at least in terms of food value. That is, it defines the relative economic role in the society. A species of fish low down in the table of relative abundance may nevertheless have had great social significance in a society, even though its economic importance was low. This is certainly the case with tuna and bonito in Pacific Island societies. They were only rarely caught, but bestowed great social prestige when captured by an individual. In ancient New Zealand the same role may have fallen to the groper because, as we will see in Chapter 4, these fish were very seldom caught by pre-European Māori.

How then do we work out the relative abundance of each fish type? It is difficult to credit the amount of hot air and confusion which this issue has generated in archaeological literature. Quite a few different measures have been developed, and each has its devotees whose adherence borders on religious fervour. Advocates of weighing bones cannot see the point of counting them and vice

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[6] Common names and their scientific equivalents are given in Appendix 2.

versa. Some think that the Minimum Number of Individuals (MNI) is the best measure, and others that the Number of Identified Specimens (NISP) is better. Some like to multiply the MNI by the number of mis-matched paired bones to yield yet another yardstick. In short, there is no end to the number of choices here.

TABLE 1.1
Typical example of MNI calculation
Blue Cod from CHA Site, Chatham Islands

Anatomy	**Number of Bones**	
Left Dentary	499	
Right Dentary	503	
Left Articular	72	
Right Articular	55	
Left Premaxilla	525	
Right Premaxilla	**565**	MNI
Left Maxilla	461	
Right Maxilla	500	
Number of Bones	**3180**	

This is not the place to engage in extended discussions on the merits and demerits of the different techniques which have been proposed. My opinion is that if we focus on the phrase *relative abundance* and ignore *absolute abundance* a lot of the problems dissolve. I also think that so long as the bone collection is of reasonable size (number of bones > 500) the difference between the relative abundances yielded by several of the techniques becomes insignificant. A notable exception to this is the NISP. In my view a tabulation of relative abundance based on NISP is frequently absurd, assuming of course that the whole point of establishing the relative abundance curve is that it is meant to reflect the proportions of fishes caught by prehistoric people. The basic problem with NISP as a measure of relative abundance is that a fish has different numbers of bones for each part of the anatomy — there may be 60 vertebrae, whereas there are only two dentaries. Similarly, some fish species have up to 500 highly diagnostic spines, and another species has only one or none.

The NISP measure has a number of extremely useful functions in archaeological research, such as enabling us to identify patterns of butchering and preferential apportioning of different body parts to different social groups, but in my view it has little or no value as a measure of relative abundance of species.

The technique which I prefer is the MNI and a typical example of the calculation is given in Table 1.1. Actually, it is so simple it should not really be called a calculation. These are results from a site known as CHA in the Chatham Islands. There are 3180 bones identified as belonging to blue cod, a common inshore fish in these islands. This number is the NISP. The greatest number of bones identified for any one part of the anatomy is 565 bones of the right premaxilla. This is the MNI. To define this term in technical language:

> **MNI** = The smallest number of individuals which is necessary to account for all of the skeletal elements of a taxon in a faunal assemblage.

It should be obvious from Table 1 that the number of fish could not possibly be less than 565, but it could be more. For example, if one of the left premaxillas was a lot bigger than the largest of the right premaxillas, then the number of fish might have been 566. This is a case of what is termed increasing the MNI by taking into account size mis-matching. The type of MNI which I employ does not involve size mis-matching.

FISH SIZE RECONSTRUCTIONS

A second important objective in carrying out analysis of archaeological fish bones is estimating how big the original fish were. If most of the specimens of a species are of very similar size, this can be an important clue to the use of selective fishing activity or selective technology. Modern fishermen employ selective procedures, based on minimum legal size limits. Prehistoric people may have had notions on how best to conserve limited stocks of fish, and used similar types of prohibitions. In addition, some fishing methods are selective by size. A simple example of this is the size of baited hooks. A large hook will more frequently catch large fish, and hardly ever catch small fish. Conversely, a small hook can catch both small and big fish. Nets which are set in place and left for a time catch fish by entangling their gills as they try to swim through the net. So gill nets are selective by size. Seine nets, on the other hand, which are dragged through the water by hand, will capture everything which is in front of the net down to a certain minimum sized fish, which can get through the mesh.

Clearly the size of fishes caught by prehistoric people can tell us a lot about selective behaviour. However, this is not the only reason we are interested in fish size. Another, possibly more important objective, is that the study of fish sizes through time enables us to learn something about the impact which humans have on their local fishery over long sustained periods of harvesting. It is common knowledge that there has been massive over-fishing in the European era of New Zealand history, and that this has led to a lowering of the average size of fish. It is perfectly reasonable to assume therefore that if pre-European people had any impact on the fishery in earlier times, this would also have lowered the average size. It is easy to see how this line of thinking leads to a convincing scenario that when Polynesians first arrived in Aotearoa the fish were huge, and in the ensuing centuries of fishing by Māori, fish got smaller — perhaps not a lot smaller, but smaller all the same. Then, when Europeans arrived with more advanced technology such as steel fish hooks and motivated by unbridled greed, the fishery was stripped away so that now only tiny fish remain.

Scenarios like this, based on assumptions, no matter how plausible, are still just that: scenarios. We will see later in this volume that if pre-European Māori had an effect on the inshore fishery by their fishing activities, it may have been the exact opposite — an increase in the average size of fishes.

Needless to say, it is important for us to develop and use reliable methods which enable us to estimate fish sizes from the bones which we find in archaeological sites. This is easy to say and hard to do; not hard in the sense of being intellectually difficult, but in the sense of being labour intensive and extremely boring. It is achieved in the following manner. First we must collect 100 to 200 modern specimens of the species of interest, which, most importantly, cover the whole range of sizes we can expect to encounter archaeologically. This is not so easy, given the effect of the last 150 years of European fishing around New Zealand. Finding a good sample of large specimens of the main species of interest has been very difficult. We always keep an eye open in the summer fishing season for reports of large fish being caught by recreational fishermen. On one occasion we read of a possible claim of a world record snapper being caught in the Bay of Plenty. After contacting the person we found that the specimen had been given to a taxidermist for stuffing. After contacting the taxidermist we were able to borrow the head bones (which were needed in the stuffed specimen) for a period, long enough to make plaster casts of each, so we have a permanent copy of the specimen.

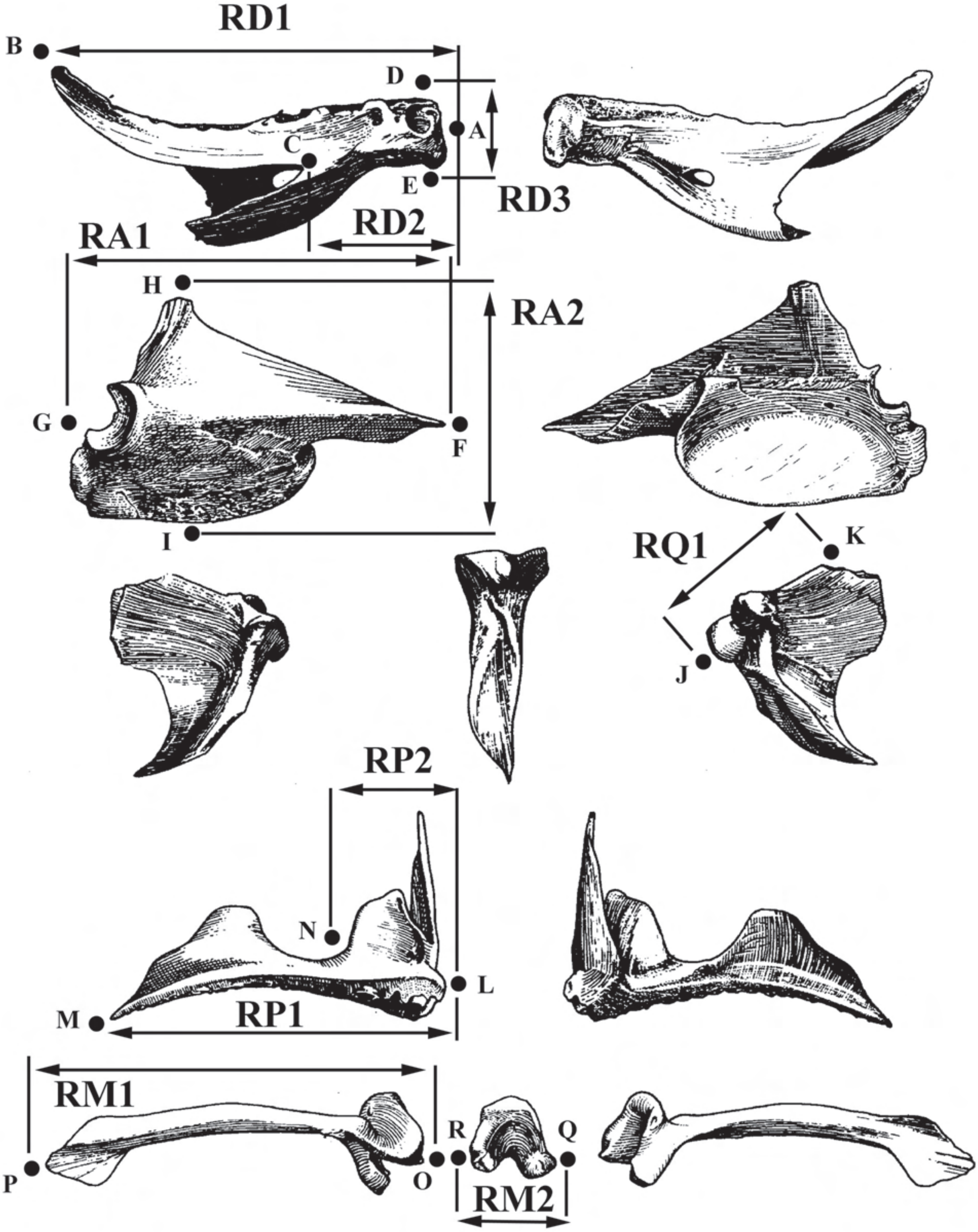

Figure 1.9: Measurements made on cranial bones of blue cod (from Leach *et al*. 1997b: 483).

When we have procured a large sample of modern fish, they are weighed (ungutted because the entrails of many species were considered good food in most traditional Polynesian societies), and the length measured. Then the head is cut off and boiled down to extract the five paired cranial bones mentioned earlier, and any special bones which are important to keep. These are then dried, each one numbered so as not to loose its original identity, and boxed. When all specimens are thus processed, the laborious process of measuring them begins.

A typical example of the anatomical landmarks used on bone specimens is illustrated in Figure 1.9. These relate to the blue cod fish, *Parapercis colias*, which is often found in New Zealand archaeological sites. Wherever possible, the largest dimension (such as the maximum length) is measured on an archaeological bone, but in many cases archaeological bones are broken, so it is desirable to have alternative measurements which are appropriate to fragments. This is why several measurements are defined for any one bone, as indicated in Figure 1.9.

The methods by which the live fork lengths and weights of a prehistoric fish catch are estimated from archaeological bones are described in a series of papers in which one species at a time is considered (Leach and Boocock 1995; Leach *et al*. 1996a, 1996b, 1997b, 1997d). When we plot a bone measurement against the original fish length (Fig. 1.10) it is evident that there is a clear

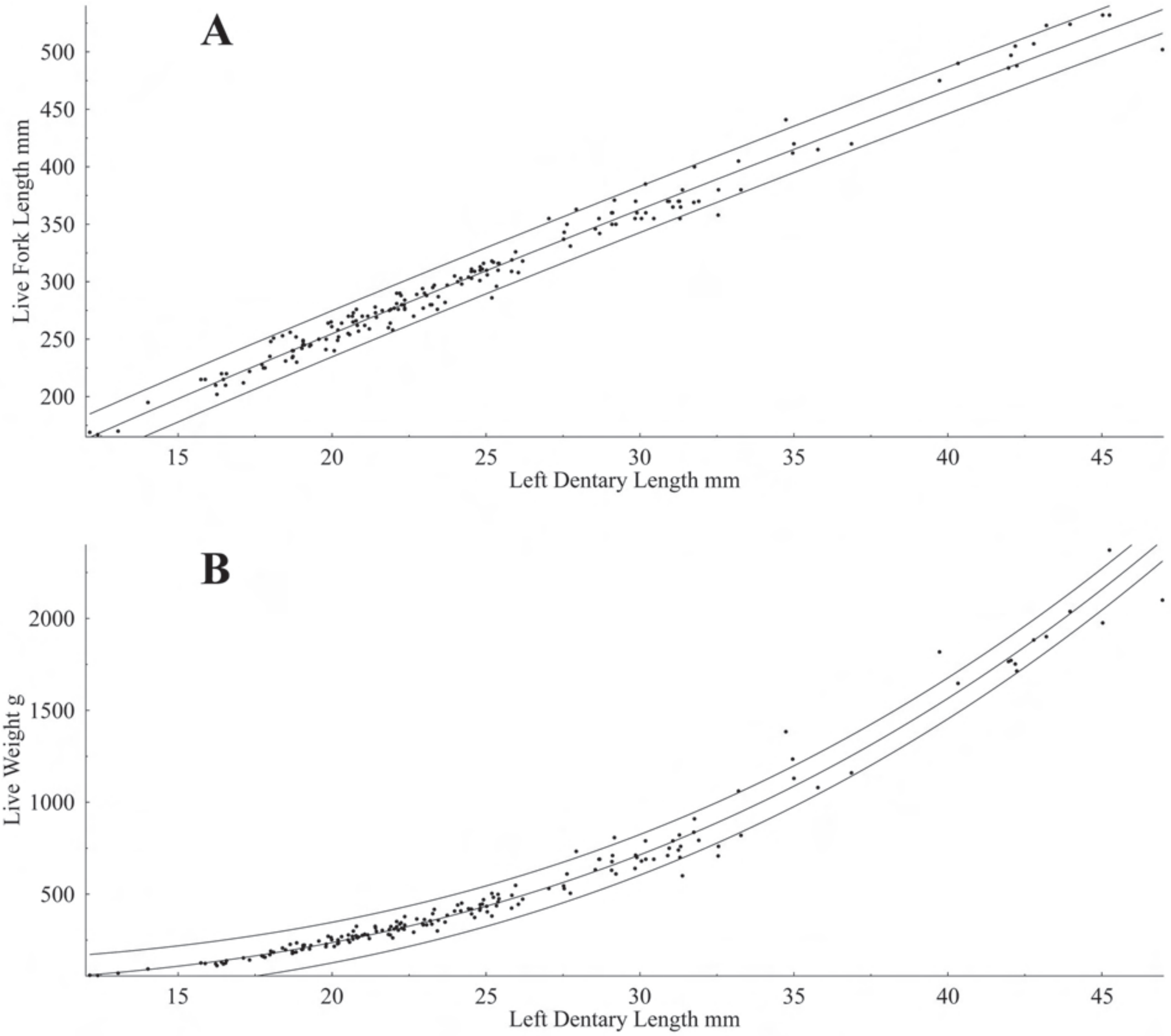

Figure 1.10: Bone measurement plotted against fork length (upper) and live weight (lower) for blue cod. The lines show the 95% confidence limits for power curve fits (from Leach *et al*. 1997b: 487).

relationship between the two measurements. In our work we use the least squares regression method to derive a power curve equation, and use this to estimate the original fish size from bone measurements.

It is instructive to follow a worked example of how we get from a bone measurement to an estimate of the original size of the live fish. In this example, we will take the measurements which relate to a modern specimen of blue cod of medium size from our comparative collection. This fish had a live fork length of 350 mm, and an ungutted weight of 610 g. The left dentary length was 27.63 mm.

The best fit equation for estimating fork length from the left dentary length bone measurement is a power curve fit as follows:

$$\text{Fork Length mm} = 18.63431 * \text{LD1}^{0.8729386} \pm 10 \text{ mm}$$

The best fit equation for estimating live weight from the left dentary length bone measurement is the power curve fit as follows:

$$\text{Weight g} = 0.0669148 * \text{LD1}^{2.727114} \pm 56 \text{ g}$$

By substituting the bone measurement of 27.63 into these two equations, we derive estimates for the fork length of 338 mm, and for weight of 571 g. The actual error in estimating the fork length is therefore 12 mm (350–338), and in estimating the weight 39 g (610–571).

With the aid of a simple computer program, large numbers of archaeological bone measurements can thus be converted into estimates of fork length and weight, and these in turn can be used to calculate statistical data such as mean and standard deviation. These data also provide the basis for reconstructing the size-frequency histogram which represents the prehistoric fish catch.

For example, at the archaeological site of Waihora in the Chatham Islands we calculate that the mean weight of blue cod caught by the prehistoric people there was 569 ± 3.8 g (Leach *et al.* 1997b). From this, we can calculate the total weight of blue cod, using the MNI value for the species. Smith (1985: 487–488, 2004: 8, 10) recommends using a figure of 70% for the amount of usable meat weight per total body weight for the common species of New Zealand fishes.

Mean Body Weight	x	MNI		Total Body Weight	Usable Meat Weight
569 g	x	2547	=	1,449 ± 10 kg	1,015 kg

At Waihora, therefore, we can estimate that blue cod amounted to about 1.0 metric tonne of fish meat. This information is an important first step towards understanding the contribution of various components of diet in the overall economic system of a prehistoric people.

We have found that archaeological bones are often from much larger fish than are easily caught today in New Zealand waters, and this poses special problems in obtaining a good comparative collection which covers the full size range available to prehistoric people. Snapper, *Pagrus auratus*, is a good case in point. Our comparative collection of measured snapper numbers 110 fish. Of these only 7 have a fork length greater than 400 mm. The average fork length of snapper from prehistoric catches is frequently above this value (for example: Twilight Beach 532, Kokohuia 467, Houhora 491, Galatea Bay 464, Cross Creek 400). Fortunately, we have one very large snapper in the collection (940 mm fork length), and until recently we have not had to extrapolate beyond this size

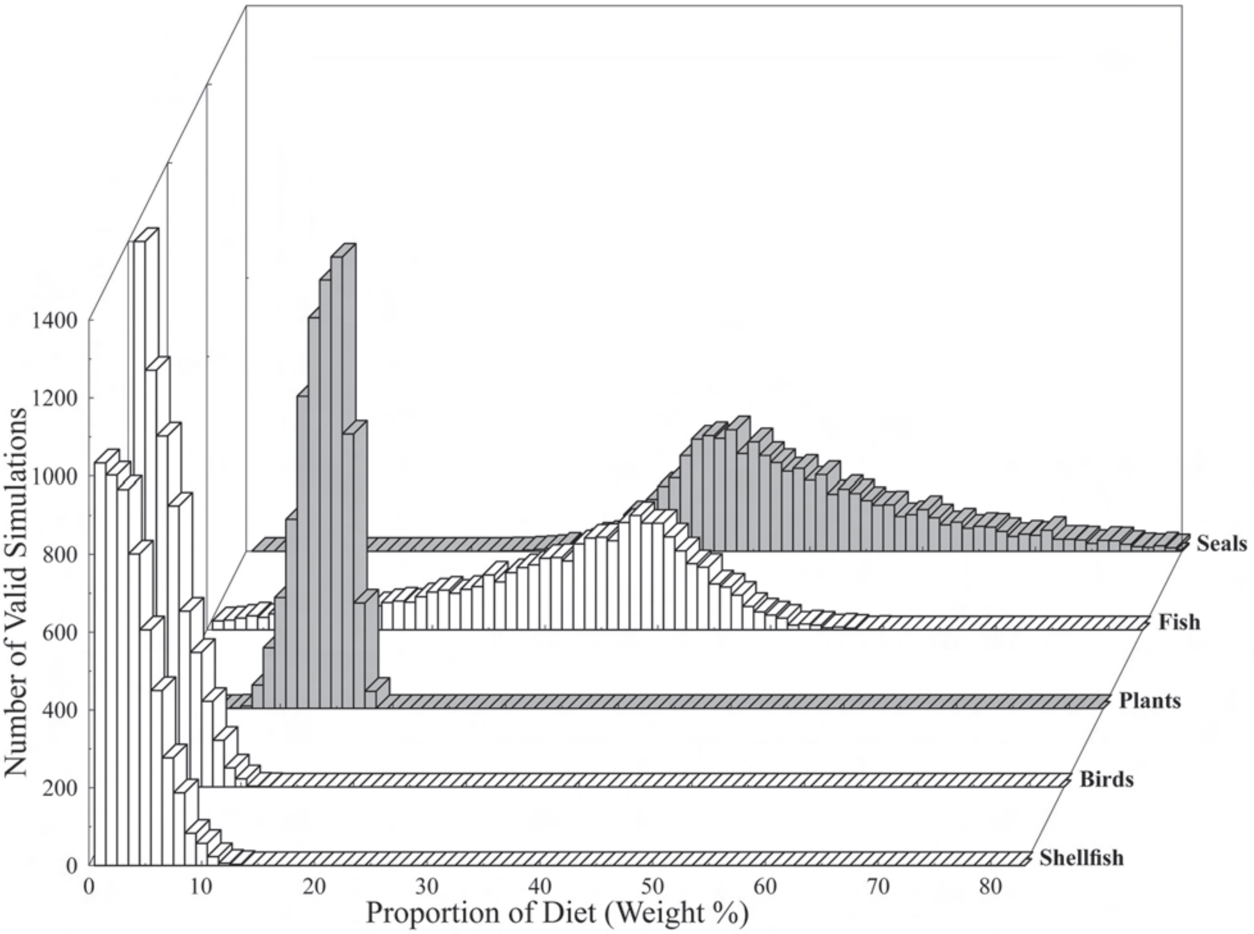

Figure 1.11: Contribution of the main food components to the diet of Moriori from isotope research (from Leach *et al*. 2003: 70).

with any archaeological bones; however, at the site of Houhora a snapper was estimated to have had a fork length of 1010 mm. The measurements on this bone were checked several times and it is certainly larger than the largest specimen in our comparative collection.

FISH AND ANCIENT DIET

Human dietary requirements involve three basic ingredients in various proportions depending upon the type of economy involved. These are protein, carbohydrates and fat. Unfortunately, one of these poses special problems for archaeologists when trying to quantify the relative contributions of each for a particular group of prehistoric people; that is, the dietary contribution of carbohydrates, which largely derives from plant foods. Archaeological evidence of food mainly consists of bones, which as can be seen from the foregoing are relatively easy to quantify. Quantifying the contribution of plant foods, and therefore carbohydrates, is much more difficult. So while we are able from bone evidence to make quantitative statements about the relative importance of various kinds of fish, birds, and mammals, the contribution of any one or all of these to diet as a whole requires additional knowledge of the role of plants.

This subject is explored in greater detail in Chapter 8, but it is useful to comment briefly on the matter here. It has been found that three isotopes, $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ fractionate in nature so that animals and plants from the sea contain different values than those deriving from the land. By analysing these isotopes in a tiny fragment of human bone belonging to a prehistoric person it is therefore possible to determine how much of their total diet came from the sea and how much from the land (Davidson and Leach 2001; Leach *et al*. 2003). The regular archaeological study of midden remains permits us to work out the proportion of food from protein sources which came from the land and the sea. From this information, it is possible to estimate the contribution of the various components of the diet, including plant foods from the land and fish, shellfish, and sea mammals from the sea.

An example of the process in action is illustrated in Figure 1.11, where the contribution of fish to the overall diet is shown to be about 32% by weight of all food consumed by the people inhabiting the southwestern corner of the Chatham Islands.

These results also permit us to estimate that 73% of the protein in the diet of these people came from fish, and that fish contributed 17% of the caloric energy in the diet.

CHAPTER 2: THE PACIFIC ISLAND BACKGROUND

From the perspective of New Zealand, situated in a temperate zone in the south Pacific, it is sometimes forgotten that the indigenous people, the Māori, had not always been Māori. They came to New Zealand from a tropical region much closer to the equator, and although they brought with them a long history of association with the sea, these original immigrants from the tropical Pacific knew and understood a world profoundly different from New Zealand. It is therefore useful to describe the world they came from as a background to their New Zealand experience.

THE EARLIEST FISHERMEN IN THE PACIFIC

It is of some interest to try and identify when marine fishing began in the Pacific region, because it may be related to the development of a maritime technology which ultimately led to the remarkable episodes of exploration and settlement of the vast oceanic world. The presence of fish bones in early archaeological sites does not necessarily mean that people had developed sophisticated canoe transport systems which would enable expansion beyond the large landmass of New Guinea, but it does indicate growing knowledge of the sea and its resources, and canoes would have been needed to capture certain types of fish.

Australia and New Guinea were part of a single landmass until 6,000 years ago, and were populated long before that, by at least 40,000 years ago. The discovery of human occupation on the island of New Britain at the cave site of Misisil dating to 11,000 years ago (Specht *et al.* 1981) was the first important evidence that humans had learned how to cross a significant sea barrier away from a large continental region and successfully colonise land across the sea during the Pleistocene. This discovery was eclipsed from 1985 onwards by a series of excavations in New Ireland and Buka, somewhat further out into the Pacific from New Guinea. These excavations were in a series of caves known as Matenkupkum, Matenbek, Panakiwuk and Balof 2 on New Ireland, and Kilu on Buka (Fig. 2.1).

These sites date well back into the Pleistocene (Allen *et al.* 1989: 550–551; Allen and Gosden 1996: 186; White *et al.* 1991: 49; Marshall and Allen 1991: 66; Wickler and Spriggs 1988: 703); some radiocarbon dates for them are given below.

Matenkupkum, New Ireland	35,410 ± 430 BP	ANU-8179
Kilu, Buka	28,740 ± 80 BP	ANU-5990
Matenbek, New Ireland	20,430 ± 180 BP	Beta-29007
Panakiwuk, New Ireland	15,140 ± 160 BP	Riddl-531
Balof 2, New Ireland	14,240 ± 400 BP	ANU-4848

These sites are important, not only because they document human colonisation well beyond the nearest continental region, but also because they contain clear evidence of the gathering of marine food, including fish. Much earlier fish remains have been found in some sites in eastern Zaire, in Africa. Three sites at Katanda within about 4 km of Lake Rutanzige produced abundant fish remains (more than 7,000 bones from the Kt9 site alone), belonging to at least 13 genera, and date to before 90,000 years BP (Brooks *et al.* 1995: 551; Yellen *et al.* 1995: 554). The Katanda finds are remarkable not only for the variety and wealth of fish remains but for the interesting range of bone tools such as spear points, which could have been used for fishing. The fish at these sites are of course fresh-water species, whereas those in the New Ireland and Buka sites are marine species, and this difference is probably quite important. The Pacific sites were occupied by people who somehow had traversed two significant permanent waterways, and therefore had already acquired some

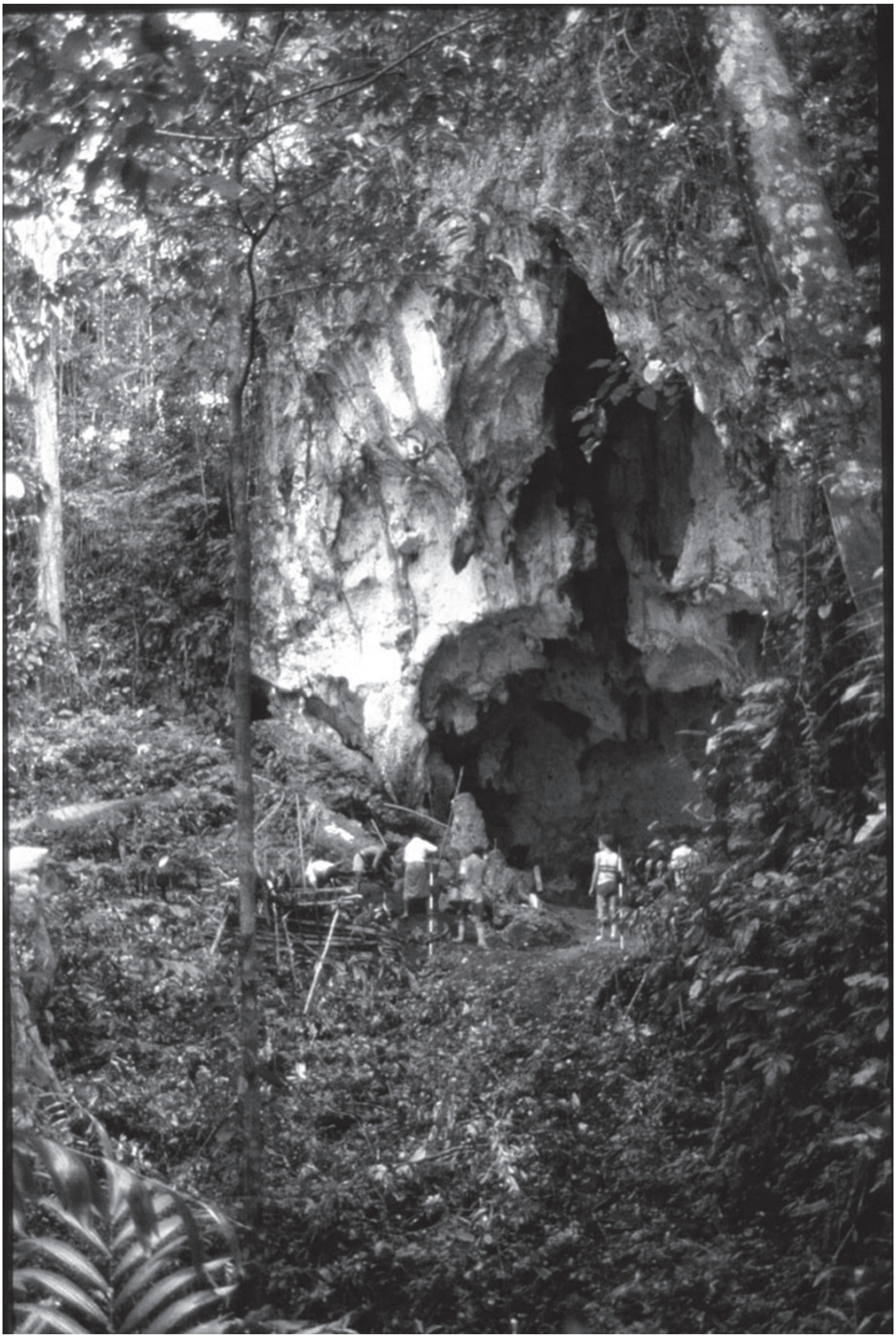

Figure 2.1: Early cave site known as Panakiwuk in New Ireland with marine fish remains (photo courtesy of Jim Allen).

mastery of marine transportation. The presence of marine fish remains is a further pointer to a developing association with the sea. This type of association is not necessarily the case at Katanda.

Unfortunately, little has been published yet about the fish bone from the cave sites in New Ireland and Buka. Our own analysis of the Balof 2 assemblage (White *et al*. 1991: 54) produced the following:

Taxon	**Family**	**NISP**
Teleostomi	? Family	22
Acanthuridae	Surgeonfishes	6
Elasmobranch	Sharks, skates, rays	16
Carangidae	Jacks and Pompanos	1
Balistidae	Triggerfishes	2
Scaridae	Parrotfishes	3

Allen and Gosden report that the four New Ireland sites all had

> "shallow-reef dwellers (Balistidae, Scaridae, etc.) while the elasmobranch fish remains include at least three species of tropical sharks. Fish bones occur in small numbers in the earliest levels of Matenkupkum and are relatively common in the earliest levels of Matenbek…. None of the fish species present are open-sea or deep-sea fish which would suggest line-and-hook capture. We therefore assume that the fish were taken either by netting, spearing, poisoning or, more likely, by the use of fish traps on the reef platform" (Allen and Gosden 1989: 552).

Marshall and Allen (1991: 76, 77) report Osteichthyes with NISP=37 and MNI=8 for Panakiwuk.

Obviously, these fishbone assemblages are not large, but they do serve to illustrate that maritime skills were being developed on the shores of the western Pacific near New Guinea well back in the Pleistocene.

The really major movement of people out into the remainder of the Oceanic world did not occur until much later than these first steps along the margins of Papua New Guinea and the Solomon Islands. This took place with the appearance of the Lapita cultural complex about 3,500 years ago (Kirch 2000: Chapter 4). This spread rapidly from the shores of the Bismarck Archipelago at the eastern end of Papua New Guinea all the way to Tonga and Samoa in the central Pacific. About the same time people explored and settled the northern islands of Belau, Yap, and the Mariana Islands. Finally, as much as 2,000 years later, there was a new expansion eastwards to the Cook, Society and Marquesas Islands, which in turn was followed by the colonisation of Hawai'i and the remote margins of the Pacific, including New Zealand, Chatham Islands, and Easter Island, by about 1,000 years ago.

THE PACIFIC ENVIRONMENT

The Pacific Ocean occupies about one-third of the surface of the earth and contains more than 20,000 separate islands (Darby 1945 (I): 5). These can be broadly grouped into two major geological zones, separated by what is known as the andesite line.

In the eastern and central Pacific, east and north of the andesite line, rocks are very restricted in variety — most are basic or alkaline in character, and practically the only rock useful to prehistoric people is basalt. This is the material commonly used for the manufacture of stone tools, particularly adzes. Another important rock, obsidian, occurs in the Tongan group and on Easter Island, and a form of basaltic glass is found in the Hawaiian islands and on Tahiti.

In the western part of the Pacific, in what is known as the andesite zone, there is a much wider variety of rocks, many of which are acidic in form, including granite. The andesite zone is a transitional region between the geologically rich continental areas which surround Oceania, and the geologically impoverished Pacific island world.

When people first crossed the andesite line in their eastward exploration and settlement of the Pacific, they entered a world with a number of important environmental restrictions, of which rock types are a typical example. Another important aspect of these restrictions relates to plant and animal life: the number of species of plants and land animals decreases markedly as one moves

Figure 2.2: Aerial view of Maiao, a typical small Polynesian high island, and associated coral reef (photo Teva Sylvain ©, Pacific Promotion Tahiti S.A., courtesy of Yosi Sinoto).

eastwards. Characteristic of some parts of the Pacific area is the coral atoll[1], although there are many volcanic or high islands as well. In voyaging to New Zealand, the ancestors of the Māori reached an area of much greater geological diversity than the islands of their tropical homeland.

The popular image of a Pacific island is a small volcanic island with a fringing coral reef (Fig. 2.2, but there are also some very large islands in the Pacific, such as New Guinea, Viti Levu (the largest island in the Fiji group), the main island of New Caledonia, and Bougainville in the North Solomons Province of Papua New Guinea. By way of perspective, it might be noted that New Guinea is three times the size of New Zealand, and nearly four times the size of Great Britain, as some comparative figures in Table 2.1 show.

TABLE 2.1
Some comparisons of total land area (source various)
NB: 300 people live on the tiny island of Touhou

Island/Island Group	**Area km^2**
New Guinea (including Irian Jaya)	828,100
Japan	372,300
New Zealand	268,700
Great Britain (including Scotland)	228,300
New Caledonia (La Grande Terre)	16,900
Viti Levu, Fiji	10,900
Stewart Island, New Zealand	1,750
Tahiti, Society Islands	1,040
Chatham Islands	965
Great Barrier Island, New Zealand	285
Hiva Oa, Marquesas	240
Easter Island	130
Ua Huka, Marquesas Islands	117
Huahine, Society Islands	86
Rarotonga, Cook Islands	67
Kapiti Island, New Zealand	22
Tikopia, Solomon Islands	15.6
Mana Island, New Zealand	2.17
Kapingamarangi, Caroline Islands	1.12
Touhou, Kapingamarangi	0.04

There is much debate about exactly where the first immigrants to New Zealand came from; my opinion is that there were several landfalls by groups from more than one island group. There is no dispute, however, that these immigrants were all from Eastern Polynesia. The most likely islands of origin are one or more places in the Society Islands, the Marquesas Islands, or the Cook Islands. There are problems in accepting any one of these as the sole source of New Zealand's pre-European population, so perhaps two or even all three were involved. Whatever the case, these three island groups have fairly similar marine environments and the range of fish species familiar to the people living on them is also similar. It is interesting to compare the sizes of some islands from which immigrants may have come. Rarotonga in the Cook Islands is somewhat larger than Kapiti Island in New Zealand, Hiva Oa and Ua Huka in the Marquesas are both smaller than Great Barrier Island,

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[1] Coral atolls have a rocky basement below sea level, inaccessible to early Pacific islanders.

and Tahiti is a little smaller than Stewart Island. New Zealand would have seemed enormous to the immigrant Polynesians.

Islands which have a fringing coral reef support very large populations of fish. Fishermen identify several quite separate zones for capturing different species, at various times of the day and night and according to tidal patterns. The shallow reef flats with coral heads are rich in small species and at high tide, when fresh sea water spills into these areas, marauding carnivores such as needlefish, sauries and half-beaks (families Belonidae, Scomberesocidae and Hemiramphidae, Fig. 2.3) will venture across them for easy pickings. At this time people will stealthily paddle a canoe across the still waters to spear such fish. The Māori name *ihe*, applied to the common piper or garfish in New Zealand (family Hemiramphidae), is one example of Polynesian ancestry; this name is used for other types of garfish in the Marquesas, Tahiti, the Austral Islands and the Tuamotus, and can be reconstructed to Proto Polynesian[2] (Biggs and Clark POLLEX 1996).

A large number of species of the families Scaridae and Balistidae are found in slightly deeper water, living among coral communities. The Scaridae or parrotfish (Fig. 2.4), which eat coral, have specially adapted jaws for biting off chunks and an elaborate grinding mill in the throat for crushing them up to release nutrients. This is an extremely diverse family of fish, of great importance to both prehistoric and modern Pacific Islanders. However, there are no parrotfish in the colder New Zealand waters, which do not support much coral. The Balistidae or triggerfish are omnivores, eating weeds, sea urchins, sponges, crustaceans and living coral. Once again, there are many species in the Pacific and the most common name is *humu* or *humuhumu*. The name *kōkiri* is given to these fish in the Tuamotu archipelago; in the Māori language the name *kōkiri* is applied to the leatherjacket, the only member of the Balistidae to venture so far south.

For many Pacific Islanders, the sea was an important source of raw materials as well as food. Large shells such as Tridacna were used for adzes, pounders and hammers; smaller shells were also used for adzes and chisels. Iridescent shells such as pearl shell, Trochus and Turbo species were ideal for fishhooks and many shells were suited for personal ornaments. Sea urchin spines and various kinds of coral provided files and other abraders. The New Zealand marine environment provided very few alternatives to these tropical resources.

Published accounts of Pacific fishes enumerate over 1,000 species, but the total number is bound to be much larger that this. The comparative collection in the Archaeozoology Laboratory at the Museum of New Zealand has bones of over 300 tropical Pacific species mounted for identification of archaeological bones, compared with only 50 species required for New Zealand.

The nature of the seasonal round in temperate New Zealand would have been in marked contrast to the previous experience of tropical Polynesian immigrants. In the island groups from which the ancestors of the Māori probably came, seasonal differences are relatively slight, the main contrasts being between a wetter and a drier season, and in the direction of the prevailing winds at different times. There is little variation in temperature year-round and very little difference in the number of daylight hours. Night falls swiftly throughout the year. Although there is some seasonal variation in the availability of pelagic fish such as tuna, inshore fish are available all year round, and in most island groups there is no time of the year when seas conditions are unsuitable for fishing or shellfish gathering for any length of time.

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[2] A reconstructed language, ancestral to all present-day Polynesian languages.

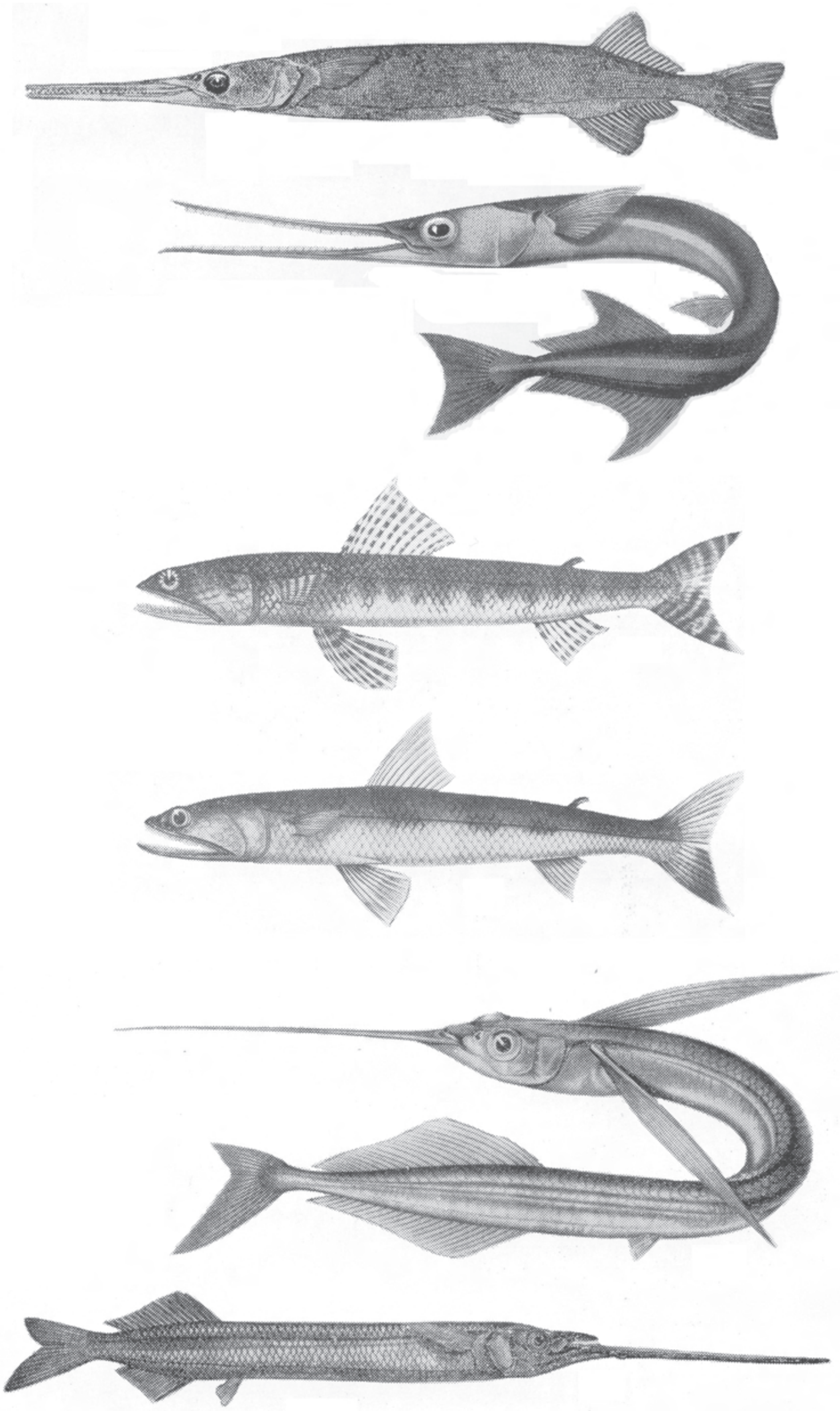

Figure 2.3: Needlefish, sauries and half-beaks (after Munro 1967: plates 7, 10, 11).

There is little regional diversity in the small islands of the eastern Pacific, although in larger islands, in Fiji and Hawai‘i, for example, there is a marked difference in rainfall between the wet and the dry side of each island. But these are minor differences compared with the regional variation in landform and climate within New Zealand. This led to the development of a range of subsistence economies, from predominantly horticultural in the warmer north to fully hunter-gatherer in the south. Whatever the nature of the subsistence base, these economies all followed a strongly seasonal round, with an emphasis on preservation of seasonally available foods for later consumption.

There are marked changes in the abundance of some species of fish in New Zealand. Barracouta, for example, are primarily summer visitors in the South Island. It will be seen later that these fish were of great importance to southern Māori, and their strong seasonal migratory behaviour meant that mass harvesting took place in the summer months and the fish were then preserved by drying in the sun so that stores were available for the lean winter months.

THE EMPHASIS ON FISHING IS PATCHY

Not all Pacific islanders spend a significant amount of time and energy engaged in fishing activities. The Pacific is such a diverse region geographically that it caters for an equally diverse range of

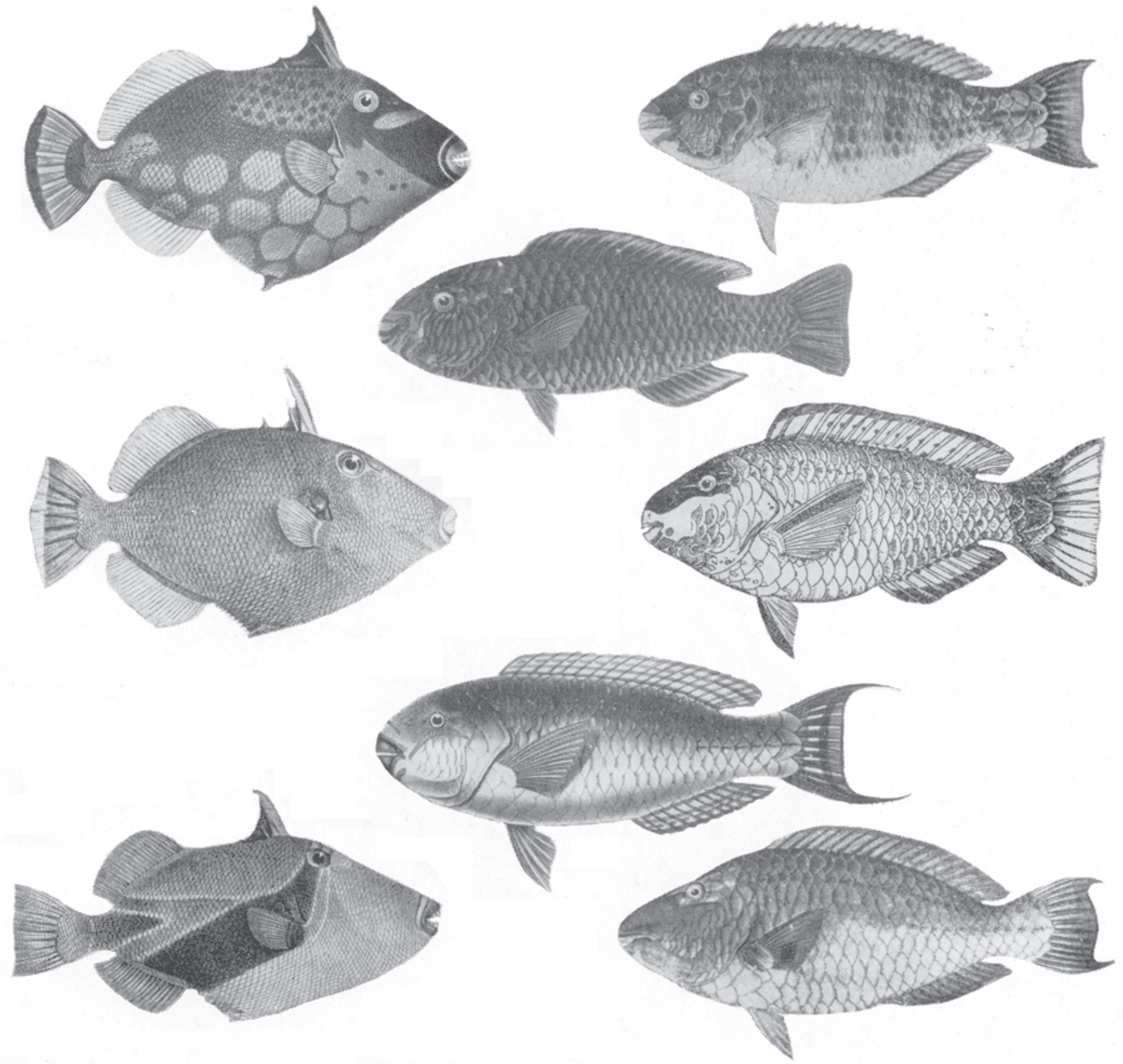

Figure 2.4: Parrotfish and triggerfish (after Munro 1967: plates 61 and 75).

human activities, particularly in subsistence economy. All island communities rely on gardening to a greater or lesser extent. Usually, only modest amounts of protein-rich food are consumed, even on atolls, but the amount of protein is adequate for nutritional requirements. On larger islands the types of vegetable foods grown can be quite diverse, but there is always one which is considered above all others to be a staple, and around which a great deal of daily activities revolve. It is interesting that the staple food varies a lot from one place to another, and it is not easy to find reasons for this. In some societies the yam is the most important plant by far, and a great deal of ceremonial attention is given to it as well. In other societies, the taro is supremely important, and in yet others it is the breadfruit, or the sweet potato.

One would expect that on atolls, fish would form a large portion of the food which people eat. This is probably not so, although it is hard to document this because there has been little quantitative research on Pacific Island economies. Fish meat is well known for its lean qualities, and although it is an excellent source of protein, humans require more than protein for healthy existence. Fats and carbohydrate are very important in diet too. Studies of the diet of early Canadian Indians and Arctic Eskimo have shown that during winter when animals are lean and there is no carbohydrate to be found, people will starve by eating lean meat alone. This is further discussed in Chapter 8. However, the combination of lean meat with a high intake of fat can offset starvation in cases where carbohydrate foods are rare. Consequently, even on atolls where there is a super-abundance of fish life in the lagoon and it is easy to catch, people cannot live on fish alone and must make gardens for carbohydrate food. These usually take the form of special man-made swamps in the centres of the small land areas along the periphery of atolls. Taro is grown in these swamps, which rely for water on the Ghyben-Herzberg freshwater lens which sits on top of the sea water under the gravels of atolls. Unfortunately, when a tidal wave hits an atoll these swamps may become brackish and can take a long time to recover. The brackish water kills the taro. During these times, people on the atoll starve, despite the rich marine life available.

Even on large islands where the threat of tidal waves is not an important factor, carbohydrate food can be scarce. It is noticeable that wherever pigs are kept they are always bred for as much fat as possible, and the fat is eaten by handfuls at feasts as a highly prestigious food. Fish cannot provide fat to anything like the amounts required for a healthy diet where carbohydrate foods are scarce.

With this dietary perspective in mind it is easy to see that in most circumstances it does not really matter whether there is a super-abundance of fish or not, because above a certain threshold there is no benefit to subsistence. The critical food for Pacific islanders is the tropical root and tree crops which provide carbohydrate. In southern New Zealand, where carbohydrate foods were extremely scarce, the critically important food to obtain was fat. Seals provided a ready source for this.

Drought is another major cause of periodic shortage and famine in some parts of the Pacific. In the early historic period, droughts caused failure of the breadfruit crop in the Marquesas, which led to starvation in some areas and outbreaks of warfare (Dye 1990). Fishing could not compensate for the failure of the breadfruit, which provided the staple carbohydrate food in the Marquesas. In recent years drought has caused extreme hardship in such diverse regions as the highlands of Papua New Guinea and parts of Fiji. When crops fail, pigs as well as people suffer.

It is not surprising that in the larger islands of the Western Pacific, there are groups of people who live inland and have little or no association at all with the sea. This is the case in some of the larger islands of the Solomons and Fiji, for instance. At the opposite extreme, it was also possible for people living on a very small island to become land-bound. By the late prehistoric period, deforestation on Rapanui (Easter Island) had reached the point where trees for canoe manufacture were no longer available, and marine exploitation was confined to the immediate inshore zone.

COMMON FISHING ACTIVITIES

Prehistoric Pacific islanders used a wide range of fishing techniques and equipment. These include netting, spearing, trapping, angling with baited hooks, trolling with lures or with baited hooks, harpooning, poisoning and general foraging. Fishermen in the Santa Cruz group of the Solomon Islands even used a kite to carry a line and hooks out across the water (Koch 1971: 40).

Direct archaeological evidence of past fishing technology is generally limited to finds of fishhooks and lures; in some areas the remains of stone-walled fish ponds and weirs are still to be seen in the shallow waters of the lagoons. A notable example is the group of weirs at Fauna Nui on Huahine in the Society Islands (Emory 1932). In Hawai‘i, fish ponds are believed to have been used to raise mullet (Mugilidae) and milkfish (Chanidae) in great quantities (Kikuchi 1976), although bones of these fish have been conspicuously absent from archaeological fishbone assemblages in the vicinity of the fish ponds (Leach *et al*. 1988a). This general dearth was noted by Weisler (1993: 132), who reported one otolith of mullet from an archaeological site in an area where fish ponds existed (Weisler 1993: 143–145). In the database at the Archaeozoology Laboratory at the Museum of New Zealand, with a total MNI of 13,704 fish, Mugilidae are present in small numbers in only six sites (MNI=31). Chanidae are represented by a solitary example from Sinoto’s excavation at Fa‘ahia on Huahine (Leach *et al*. 1984: 190).

In the case of stratigraphic layers dating close to the historic era, the fishing methods used by the inhabitants can be reconstructed to some extent by drawing on ethnographic accounts from the area concerned and on knowledge of fish habits and behaviour (e.g., Leach *et al*. 1988b). One has to be very careful in the use of ethnographic analogy in such cases though, to avoid assuming what one sets out to discover about the past. Numerous ethnographic accounts describe both widespread and more specialised fishing activities. Nets ranged from small scoop nets to huge, communally owned and operated nets used in major fish drives.

A specialised form of netting is the night capture of flying fish using a very large net with a handle, somewhat resembling a large butterfly net. This is held by a man standing in the front of a canoe in front of another man holding a light (now-a-days a lantern, formerly a flaming coconut leaf torch), which attracted the fish (e.g., Buck 1927: 288). This kind of fishing is widespread in Polynesia.

A good description of communal fishing with a very large net on the Polynesian outlier of Nukuoro was provided by Kubary, a nineteenth century German ethnographer. The net, known as the upena tonu (*gubenga donu* in modern orthography), was said to be up to 200 m long and 30 m deep. It actually consisted of six to ten separate nets, each of which was loaded on a canoe. These were joined at the fishing ground as the net was lowered into the sea. The entire population of the atoll took part in this activity. The canoes formed a long line and the net an arc which gradually drove the fish towards the shore where they were taken with hand nets, spears, or by hand. Because of the size and depth of the net, large sharks and turtles would be taken as well as many kinds of bony fish. The catch was divided in the centre of the village amongst the entire population of the atoll. A more common activity involved a smaller net about 20 to 30 m long and 2 m deep, used by about ten men in several canoes to surround large fish. Such nets were owned by individual fishermen who invited others to accompany them and share the catch (Davidson and Leach 1996: 186).

Figure 2.5: Typical examples of fishing equipment and some personal ornaments made from bone and shell from the Marquesas Islands (photo courtesy of Bishop Museum and Yosi Sinoto).

Fishhooks varied considerably in size, form and material, from tiny one-piece hooks of shell to very large wooden hooks. Not only wood and shell, but bone, turtle shell, coconut shell and even stone were used for hooks in Polynesia. Further west, materials included thorns, spider web, and parts of insects. Trolling lures also varied in size from small examples with shell shanks only a few cm long and correspondingly small turtle shell points to massive examples from Tonga which had a whalebone shank lined with an iridescent pearl shell plate on the bottom surface, and a large turtle shell or bone point (Anell 1955).

Spearing was probably not an important fishing method in the Pacific before the advent of underwater goggles and later masks, although spears were certainly used during fish drives, as described above for Nukuoro. There was a variety of traps, ranging from examples very similar to modern crayfish pots to elongated, funnel-like examples.

Most Pacific communities used a variety of fishing methods. The actual combination used by any one community varied according to the local marine environment, raw materials available, cultural preferences, and so on (Fig. 2.5). Some islands have very extensive reef flats; others, such as the Marquesas, lack a fringing reef altogether. Pearl shell, a preferred material for fishhooks and trolling lures, is very unevenly distributed; some lagoons had an apparently inexhaustible supply within easy reach, whereas in other islands, accessible pearl shell was completely lacking. However, such differences provide only part of the explanation for the variation in fishing practice; some communities chose to indulge in more exciting but dangerous offshore fishing activities, while others did not.

The commonest and most widespread form of fishing involved netting on the inshore reef areas. Analyses of fishbone assemblages from sites of various ages and from all over the Pacific have consistently produced evidence of fish catches in which reef fish predominate. This is typical of Lapita sites (Green 1986) and of many more recent sites. However, examples of much more adventurous fishing behaviour are also encountered.

SPECTACULAR FISHING ACTIVITIES

There is a popular belief that Pacific Island fishing was centred around the exciting pursuit of tuna and other pelagic fish. This required use of canoes capable of going outside the protected reef areas into oceanic waters where these fish are normally found (Fig. 2.6). This commonly held view of the Pacific fisherman probably owes much to the accounts of Tahitian fishing by Nordhoff (1930). Certainly fishermen in many Pacific islands spend a lot of time talking about tuna and other game fish, but analyses of the bones of fish actually caught often lead to the conclusion that “while much dreaming of these fish may have taken place in the past, far more were probably caught in the men’s house than ever in a canoe” (Leach and Davidson 1988: 4). However, there are some well documented archaeological examples of prehistoric fishing for tuna and other game fish.

People in the Marquesas and Society Islands 1,000 years ago or more enjoyed fishing offshore for tuna and the like. In the Marquesas, at least, they continued to do so throughout the prehistoric period, although the proportion of tuna in their overall catch declined. Archaeological evidence of more recent prehistoric fishing in the Society Islands is lacking, but Nordhoff’s account suggests that there was probably continuity in this aspect of fishing behaviour into recent times.

At Hane on Ua Huka in the Marquesas, tuna dominated the archaeological fish catch, comprising 25% of the total MNI. The next most important fish were cod/groupers (16%), which would have been taken with a baited hook, and trevallies (12%), taken, like tuna, on a lure. Although there was some fluctuation in proportion in the four successive layers at the site, tuna were consistently the most important fish (Davidson *et al*. 2000). Several other archaeological sites in the Marquesas have produced similar results (Leach *et al*. 1997c; Rolett 1998: 133, 141).

Tuna were also important at the site of Vaito‘otia/Fa‘ahia on Huahine in the Society Islands, although here there was more variation within the site. In one area, tuna dominated with 18% of the catch, followed by trevallies (16%), parrot fish (12%) and cod/groupers (9%), but in another, parrot fish dominated with (27%), followed by cod/grouper (11%), trevallies (10%) and tuna (7%) (Leach *et al*. 1984; Davidson *et al*. 1998). It is unusual to find such variation within a single site, and several explanations could be put forward. However, it is worth noting here that even 7% of tuna in a catch is high compared with most other Pacific island fish assemblages studied. This emphasis on tuna fishing should not be taken as necessarily typical of Eastern Polynesia. There is so far no evidence of any comparable activity in the Cook Islands, for example.

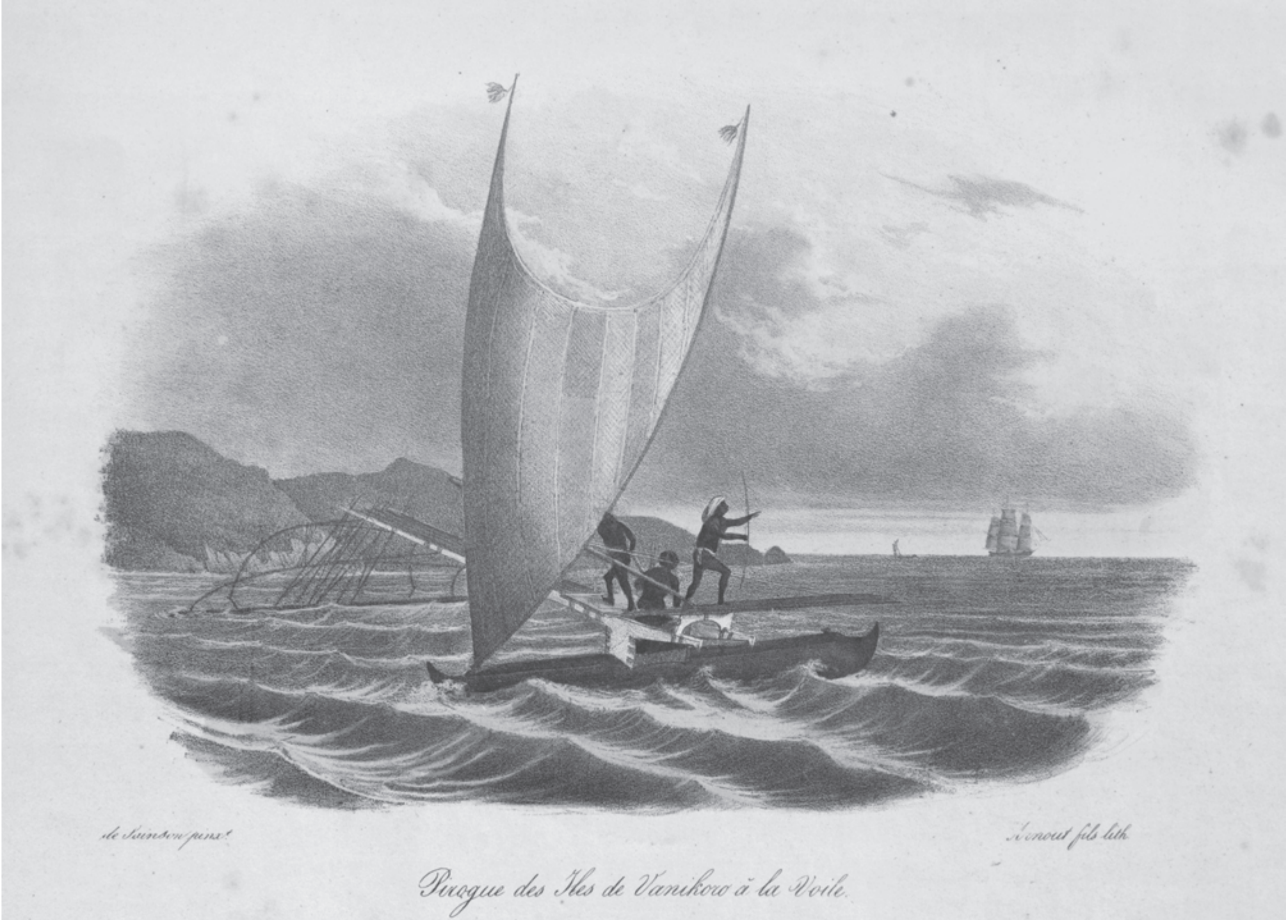

Figure 2.6: A small sailing canoe from Vanikolo, Solomon Islands in 1828 (Dumont D'Urville 1833: plate 184).

The most spectacular evidence to date of game fishing in the Pacific comes from the Mariana Islands, far to the west. These people were adept at catching dolphin fish and marlin or swordfish. Analysis of fish remains from Mochong, on the island of Rota, revealed that fish taken in the open sea accounted for 24% of the total catch. Dolphin fish (family Coryphaenidae) contributed almost 12% and marlin or swordfish (families Istiophoridae and Xiphiidae) 3%. This last figure included at least ten individual fish from different parts of the site, suggesting that this was not the opportunistic eating of a stranded fish, but systematic capture, which must have been extremely dangerous for the fishermen (Leach *et al*. 1988b). Of course the large size of these fish means that their significance to the economy was greater than the simple number count would indicate.

Records of the Marianas in AD 1602 left by Zamora (Driver 1983) describe the capture of large fish and the importance of flying fish as a target of their fishing.

> "the first flying fish is eaten raw; the second is baited on a large hook attached to a line that is cast over the stern of the boat. Many dorados [mahimahi; dolphin fish; *Coryphaena hippurus*], agujas paladares[3] [possibly blue marlin, or *Makaira nigricans* [sic, *nigricans*]], and other large fish are caught in this manner" (Driver 1983: 208).

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[3] The Spanish term 'aguja paladar' is old Andalusian for swordfish, but was extended to cover other species in foreign waters (Arturo Morales 2005: pers. comm.).

The social importance of these large fish is also recorded by Zamora, and he describes various aspects of associated ceremonial behaviour and salting of the meat for preservation. One interesting story, reminiscent of Ernest Hemingway's tale of the 'Old Man and the Sea', is recounted as follows:

> "...a very large blue marlin [aguja paladar] took the hook. His line was very thin and, as he did not want to break it, he hesitated to pull it in. Yet he was very anxious to land the fish; therefore, he very cautiously began playing and tiring it. This took a long time. Meanwhile, a large shark appeared and attacked the blue marlin in the midsection of its back. In order not to let go of his line, the indio allowed his boat to capsize. Then he tied the end of his line to the capsized funei, followed the line through the water to the shark, and diverted him from his catch. Then he brought the blue marlin back to his boat, righted the craft, and sailed home, flying a woven mat as a banner from the masthead. Once ashore, he began to tell us what had happened and, like a person who believes he has accomplished a great feat, very proudly strutted pompously along the beach" (Driver 1983: 209).

CONCLUSIONS

Polynesian immigrants to New Zealand were heirs to a very long history of fishing in the Pacific. For as much as 40,000 years, Pacific people had caught marine fish. Their skills in fishing had probably developed together with their knowledge of maritime technology and ability to traverse large tracts of empty ocean — skills which led eventually to their discovery and colonisation of New Zealand.

The vast Pacific Ocean and its numerous islands of many different sizes and types offered a wide variety of fishing environments. People developed a great range of techniques for, and preferences about, fishing. The immediate homeland of the Māori was in one or more of the island groups of Eastern Polynesia. These groups are characterised by small volcanic islands with limited geological resources and terrestrial plants and animals, but with abundant marine resources. The inhabitants of these islands used a variety of fishing techniques and in the Society and Marquesas Islands, at least, fishermen were adventurous, going off-shore in search of tuna, as well as exploiting the safer inshore environments.

CHAPTER 3: THE NEW ZEALAND FISHERY

INTRODUCTION

When the first Polynesian settlers arrived in New Zealand, the new marine environment would have been quite a shock. People in the Pacific world had been confronted with essentially the same marine environment for some 35,000 years. The accumulated knowledge resulting from such experience could not have forewarned the first immigrants to New Zealand of what to expect in this southern corner of the Pacific. The sea conditions and marine foods in these southern temperate waters are so different from those of the tropical Pacific that it is hard to get an adequate perspective on the experiences of the new arrivals.

It is by no means certain that New Zealand was settled only once from the tropical Pacific, so the experience of new discovery may well have been repeated several or many times. In fact, it is still happening today, as people from the Cook Islands, Niue, Tokelau, Samoa and Tonga come to New Zealand. They too explore the marine environment around the cities they live in. It would be interesting to study the behaviour of modern immigrant Polynesians in the New Zealand marine environment and their attitudes towards it. This would be bound to uncover some clues as to what it was like for people arriving here in the pre-European period.

In putting together some comments about the New Zealand fishery environment, I am conscious of the fact that this will be from a quite different perspective than that which would be meaningful to the people who lived here in the pre-European era. The entire conceptual framework would be different, not only the names of fish and how they relate together taxonomically, but the ideas relating to fishing zones, seasonality and tidal patterns. The sources of information are the same, but the knowledge derived from them is different. Some may think that this merely states in polite language that ancient people were ignorant savages; nothing could be further from the truth. Having had some experience with fishermen in remote corners of the Pacific I can state with conviction that the knowledge of all aspects of the fishery is profound amongst Pacific island peoples, but it is a different form of knowledge from European scientific knowledge, which is different again from European common knowledge.

MĀORI TAXONOMY AND THE FISHERY

Europeans are prone to believing (without giving it a second thought) that their methods of classifying the world are the only sound ways of doing so. It is perfectly natural to think like this: Polynesians think exactly the same way — that their taxonomy (classification of plants and animals) is the only sensible one. Examining a different system of taxonomy, such as Māori fish names, can be a challenge to one’s entrenched way of thinking.

As a young person learning the vocabulary of the natural world through the spectacles of the European scientific tradition, I was exposed to nothing except the Linnæan binominal system for classifying the natural world using a formal system of names[1], and did not realise that there were alternative, equally valid, systems. This experience is no different to any other form of enculturation; religion being a good example. If I had been born in Thailand, I might today be a Buddhist. Linnæus did a lot of people a huge favour by introducing order amongst chaos, by proposing

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[1] The binominal system assigns two names for an organism — genus and species — using predominantly Latin and Greek words. Species names are usually referred to as binomials, because they have two parts.

something neatly logical and systematic. But it would be wrong to think that the Linnæan system has a monopoly on what is right and correct — there are numerous alternative systems which can be described as logical and systematic. In short, when it comes to classification of the natural world, there is no such thing as right and wrong in an objective sense. This merits a little further explanation.

Numerous attempts have been made to introduce objectivity into classificatory systems, and many consider that the best approach lies in numerical taxonomy (Sokal and Sneath 1963; Sneath and Sokal 1973). Scientific literature is now replete with various forms of this, applied to an ever increasing range of classificatory problems, not just animals and plants: types of rocks and fossils (Miller and Kahn 1962: 245 ff.), detecting time series in the morse code (Kruskal 1971: 124 ff.), classifying the works of Plato (Boneva 1971: 173 ff.), the classification of diseases (D'Andrade *et al*. 1972), type of human cultures (Doran and Hodson 1975: 161 ff.), biological populations of humans (Constandse-Westerman 1972; Rao 1952: 357 ff.).

These all suffer from the same underlying problem: how the specimens finally group together depends entirely on which characteristics are chosen to depict them. Numerical taxonomy helps to give us confidence that two different researchers will get the same results, assuming they have chosen the same characteristics in the first place, but the idea that this is the one and only objective view of reality is an illusion. The results of such analyses are seldom any more than statistical verification of what was blindingly obvious at the outset. Contrary to this, organisms can be more or less identical in outward characteristics, yet qualify as different species using genetic markers:

> The problems of classification have been compounded over the past 25 years by the introduction of biological and molecular techniques demonstrating that biological and genetic divergence is not always accompanied by morphological change. Thus they may demonstrate that two genetically distinct populations meriting recognition at a species level may be identical in their appearance (Tyler 1991: 164).

This type of problem led to the development of another classificatory system known as cladistics (Kitching *et al*. 1998). In contrast to classifications based on morphological characteristics (phenetics), in cladistics, groupings do not depend on whether organisms share physical traits, but on their evolutionary relationships. Thus, the emphasis is not upon the presence of all shared traits, but upon the presence of shared derived traits. Indeed, in cladistic analyses two organisms may share numerous characteristics but still be considered members of different groups. A cladistic relationship is one expressing recency of common ancestry. In Sneath and Sokal's words: "the term cladistics is used here to mean a study of the pathways of evolution; that is, how many branches are there, which branch came off which other branch, and in what sequence?" (Sneath and Sokal 1973 :29). Thus it can be seen that the world view in cladistics is focused entirely on evolution. It would be foolish to claim, however, that the cladistic view is the only valid view of the natural world. An experienced hunter might classify animals in terms of their behavioural characteristics because that is what is important when hunting for them. This is a valid world view too. In short, judging an alternative method of classifying nature using the rules of your own world view is not very fruitful.

Some years ago I thought it might be interesting to compare the types of fish found in archaeological sites on Nukuoro, with the fish-hooks that had been used to catch them in the same sites. This was a case where we had several different methods of classification in front of us: the Linnæan system for identifying the different types of fish, the Nukuoro people's system of identifying the hooks they used to catch those same fish, and metrical analysis of the hooks followed by numerical taxonomy techniques (Davidson and Leach 1996). There was no useful correspondence between the outcomes of the three systems. Each is valid within its own set of rules.

One problem that has been noted about so-called ‘scientific classifications’ is that they are constantly being revised. In this respect, Paulin and Stewart made an interesting observation in the foreword to their book *A Checklist of Fishes in the National Museum* that:

> ...it has been shown that common names carefully chosen can be more stable than scientific names. For example, Gilchrist (1902) listed common and scientific names of South African fishes but today most of the scientific names are obsolete whereas the common names are still in use [citing Smith 1975] (Paulin and Stewart 1985: 5).

This suggests that fishermen, those mainly responsible for allocating common names, might have a better idea of how to classify fish than scientists. As Doak has pointed out:

> The science of taxonomy, sorting fish into related groups and individual species, has long been plagued with difficulties arising from lack of direct observation and precise studies. Until the advent of scuba, the fish scientist was sometimes remote from the sea. He could not easily observe closely allied species in their environment and often identified separate species by characteristics which vary with age and maturity (Doak 1972: 97).

An example of over-zealous ‘scientific’ classification is with the Labridae family in New Zealand. Some species have considerable sexual dimorphism and polychromatism, so that many taxonomists mistakenly classified individuals into discrete species, which were in fact merely sexual phases of the same animal. Examination of the animals in their natural habitat by scuba divers (Doak 1972: 75) revealed this astonishing conclusion. Although all marine zoologists would agree that this was an error, it is only an error within the system of classification that they are using.

In another system of classification, this may not be considered an error at all. Once again this highlights the central issue of classification: that the results you get are dependent on what characteristics are chosen because they are thought to be significant. This was brought into sharp relief in a famous paper by Ralph Bulmer entitled *Why is the cassowary not a bird?* (Bulmer 1967)[2]. Bulmer wrote a number of similar papers which are though-provoking challenges to western European taxonomy. He commented:

> The continual revision of criteria employed by egg-head classifiers, whether biologists, ethnologists or the intellectual sophisticates in ‘primitive’ or folk societies, does not permit them to evade recognition of the *contextual* [emphasis mine] objectivity of animal species... (Bulmer 1970: 1090)

The Karam people, whom Bulmer studied, classify animals using a consistent system where gross morphology and two-dimensional habitat (horizontal and vertical) permit everything in nature to be accommodated without difficulty. But, as Bulmer points out:

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[2] I could not explain in a few sentences why the Karam people of Papua New Guinea classify the cassowary separately from birds; instead I leave the reader to explore this fascinating subject themselves by reading Bulmer’s paper. However, I will say that the Karam classification makes perfect sense to me.

> It is not surprising that the result shows little correspondence either to the taxonomy of the professional zoologist, which reflects the theory of evolution, or, for that matter, to our modern western European folk-taxonomies (Bulmer 1967: 6).

This term ‘folk taxonomy’ has been used when referring to systems of classifying plants and animals in small-scale societies, such as in Polynesia or amongst the New Zealand Māori. This term is suggestive of something slightly quaint, and has a patronising ring to it. There should be no need for any negative connotations here; such systems are just as valid as the Linnæan binominal system. It may surprise some readers to learn how extensive the scientific literature is on the subject of ‘folk taxonomy’. Conklin prepared a bibliography with 5,000 entries in 1972, arising from students courses and seminars in the Department of Anthropology at Yale University (Conklin 1972). In Māori taxonomy all animals and plants, including humans, are linked together by descent (*whakapapa*) from one of several supernatural deities, and therefore possess spiritual qualities. This in turn “emphasises to humans the fact that their environment and its resources are both ancestors and kin... a relationship based on respect and reciprocity” (Roberts *et al*. 2004: 4). Such a relationship is very different to that of western Europeans, whose taxonomy stresses phylogenetic ancestry in which humans are usually considered to be the most evolved species. Respect and reciprocity are not features of the Linnæan binominal system.

The ancestral homeland of the Māori is in eastern Polynesia; it is hardly surprising therefore that the taxonomy and nomenclature of fishes in New Zealand find close parallel in tropical Polynesia. A good example is provided by the word *tuna*. This is the Māori name for freshwater eels. This word occurs in many parts of the Pacific, also referring to freshwater eels. In New Zealand there are numerous Māori terms for eel, recognising far more varieties than in modern European zoological taxonomy. They are all nevertheless encompassed by the word *tuna*. This just goes to show that Māori taxonomy of the natural world is rich in clearly understood levels of grouping, in much the same way that Europeans recognise Order, Sub-Order, Family, Genus, Species, Sub-species, and so on. The subject of *tuna* is further discussed at a later point in this book.

‘Naming the land’ is often seen as an integral part of the process of becoming familiar with New Zealand when humans first settled here. However, we should realise that coming to understand the fishery also required naming. It would be useful to know a great deal more about this than has currently been investigated from early historical records of Māori marine taxonomy. Regional differences in naming the fishery may provide clues about the origins of different immigrant groups. Possibly of greater importance, however, such research would provide insights into how Polynesians classified this part of a temperate environment, using a tropical world as a reference point. Biggs (1994) has explored this in some detail for some other aspects of the New Zealand environment, including Māori names for plants. He suggests three ways of naming the features of a new environment — coining new words (which he thinks was unusual), assigning new meanings to old words, and borrowing words from other languages (which was not an option for the Māori colonists of New Zealand). He cites the example of *tio* (oyster) as a case where a feature of the New Zealand marine environment, although not the same as in tropical Polynesia, was sufficiently similar to be given the same name without needing qualification.

The process of exploring the New Zealand fishery should not be thought of as a cold and miserable experience with dismay at the lack of familiar foods. On the contrary, there would have been intense interest and excitement too. Although hardly any fish species in the new environment were the same as ‘back home’, the early immigrants certainly recognised fishes that were to some extent familiar and gave them names which reflect this.

Hooper (1994) has identified 147 fish names which are widespread in Polynesia and can, in most cases, be reconstructed as part of the vocabulary of Proto Polynesian (a reconstructed language, ancestral to all modern Polynesian languages). Fewer than 40 of these words have been recorded for Māori. Some, such as *mangō* (shark) and *whai* (ray), represent broad categories of fish and were further qualified in Māori and other languages (e.g., *whai manu*, eagle ray). The Proto Polynesian term **tanifa*[3] has variants in many languages, usually meaning a particular fierce or dangerous kind of shark, and sometimes also a sea monster. In Māori, *taniwha* was used for sea monsters and for sharks generally, but also as a qualifier referring to a particular kind of shark. *Mangō taniwha* is a white pointer (great white).

Occasionally, a Māori name described a fish that was identical or very close to a species found in tropical Polynesia. For example, variants of the Māori *kanae* (grey mullet) are found throughout Polynesia for the same species (*Mugil cephalus*), or another species of the same genus. For some of their most commonly caught fish, however, Māori adopted a name that had previously been used for a different fish, one not present in New Zealand, although usually there was some general similarity in appearance or behaviour. Examples include *tarakihi*, *hāpuku*, *pātutuki* (one of several Māori names for blue cod) and *tāmure* (snapper). The case of barracouta is interesting. The Māori chose to name it *mangā*, which in the Cook Islands and other parts of Eastern Polynesia is the name given to the snake mackerel, rather than *ono*, a very widespread Polynesian name for members of the Sphyraenidae family, which are also very similar in appearance to the New Zealand barracouta.

FISH ZONATION AND OCEAN CURRENTS

As might be expected, the broad ecological zones of the New Zealand fishery depend to a great extent on the basic physiographical structure of the underwater environment around New Zealand (Fig. 3.1). The edge of the continental shelf is normally taken to be the 200 m depth contour, and this identifies seven distinct regions around New Zealand: the main New Zealand landmass, the Mernoo Bank northeast of Banks Peninsula, the Chatham Islands, Bounty Island, the Pukaki Rise between Bounty Island and Stewart Island, the Auckland Islands and Campbell Island. This contour line conveniently separates the inshore or neritic zone and the offshore or oceanic zone (Fig. 3.2).

As one moves away from the continental shelf the sea floor slopes steeply downwards, increasing by about 100 m for each 1.5 km. This area is known as the continental slope. At a depth of about 3,000 m it merges with a more or less level abyssal plain. The upper part of the continental slope from about 800 m to the edge of the continental shelf is a rich fish habitat. Upwelling of nutrient-rich waters from greater depths occurs in this region, and this promotes plankton growth and therefore fish populations. As can be seen in Figure 3.1 there are several notable areas of sea bottom between 200 and 1000 m around New Zealand , such as the Challenger Plateau, the Chatham Rise, the Bounty Platform, and Campbell Plateau. For unknown reasons the Challenger Plateau carries only limited fish stocks (Armitage *et al*. 1981: 15). The main deep water regions with large fish stocks are the Chathams Rise and the Campbell Plateau. The Chathams Rise lies under the same relatively warm subtropical water as the main New Zealand shelf, while the Campbell Rise is covered by cooler subantarctic water.

The richest areas of the continental slope occur along the subtropical convergence (Fig. 3.3). This is a zone where two bodies of cool and warm waters mix together (Ayling and Cox 1982: 17).

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[3] Historical linguists use the form **tanifa* for a word they have reconstructed as the probable form in a proto language. *Taniwha* is an actual word in Māori and other modern Polynesian languages; **tanifa* is the hypothetical ancestral form.

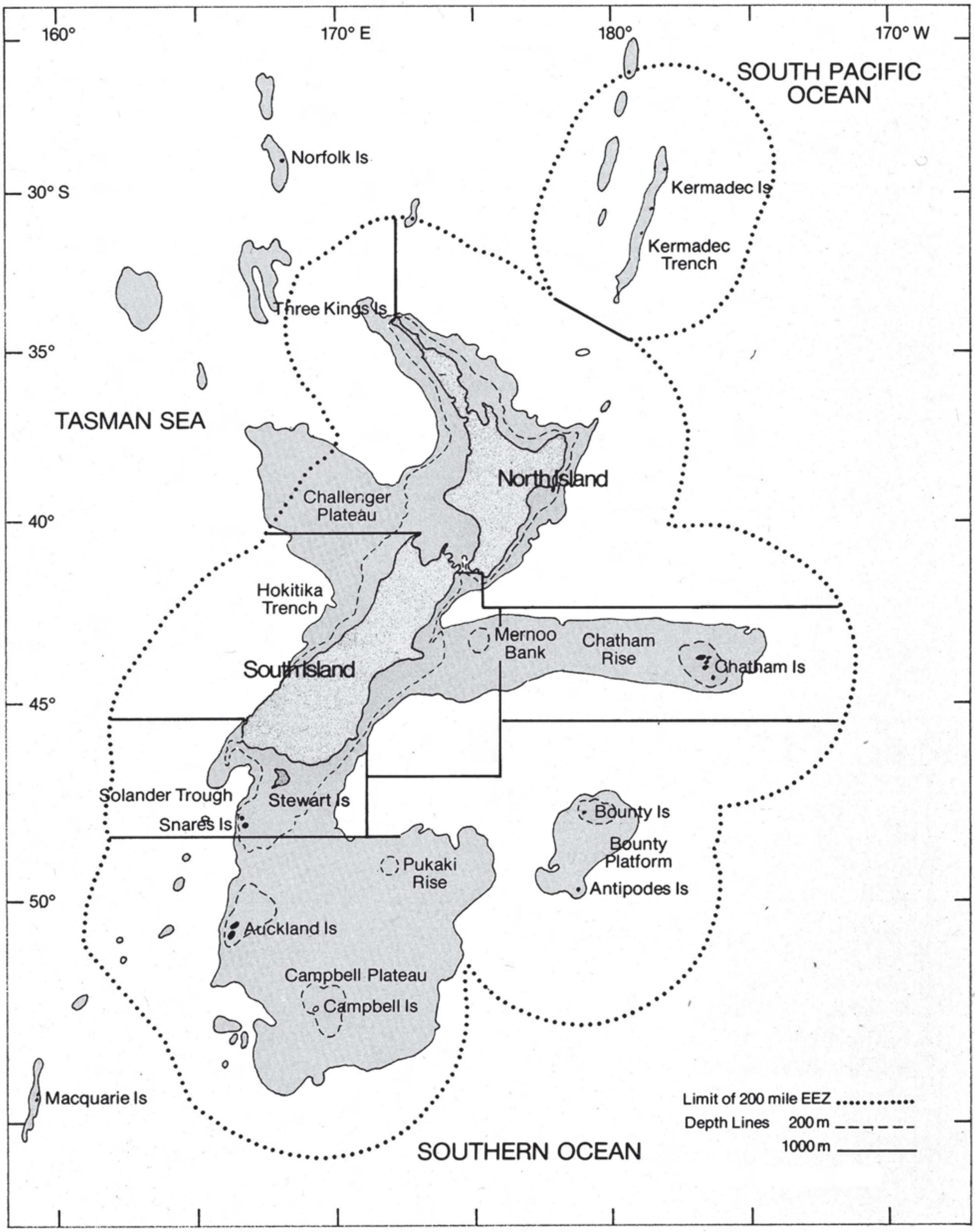


Figure 3.1: The main physiographic features of the New Zealand benthic environment (after Armitage *et al*. 1981: 9, courtesy of the New Zealand Seafood Industry Council).

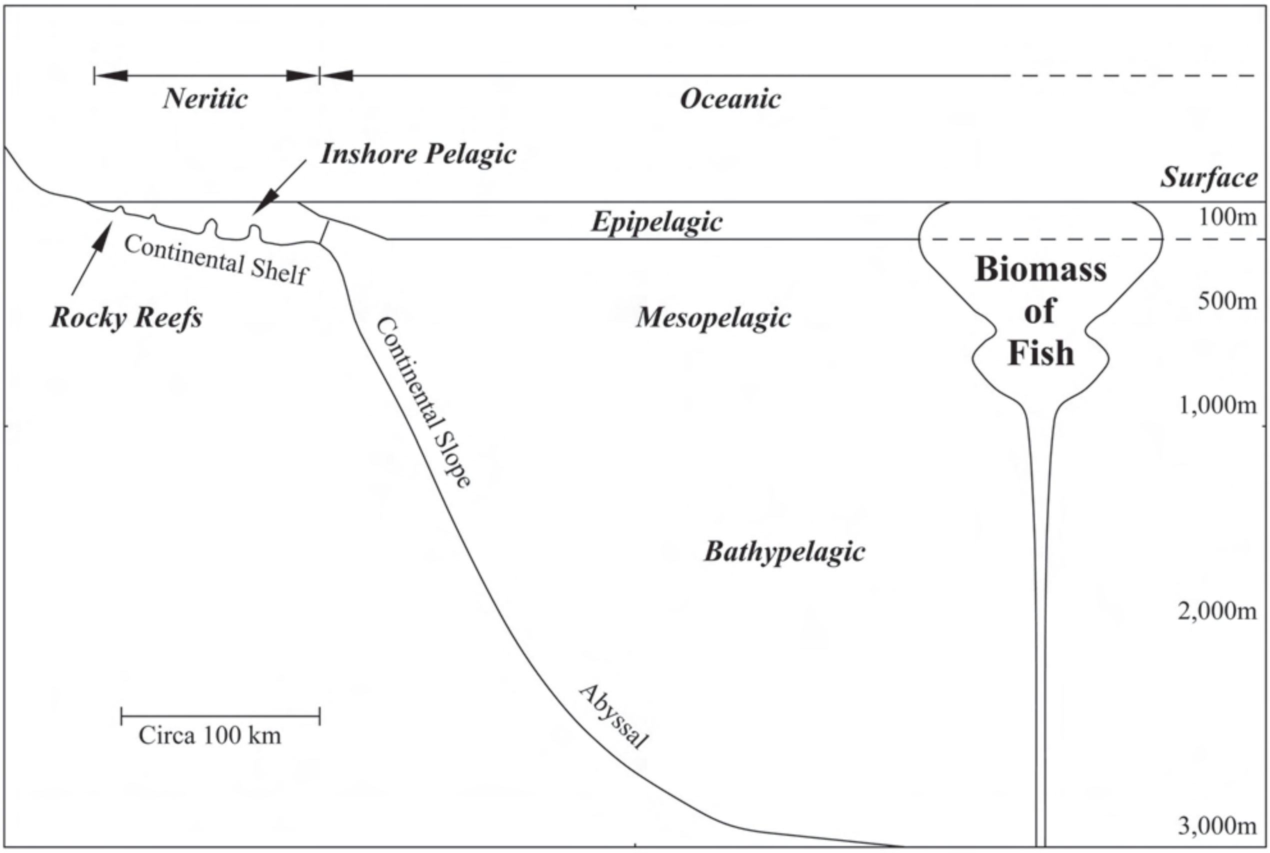


Figure 3.2: Major fish habitats (based on Ayling and Cox 1982: 16, courtesy of Tony Ayling).

A broad mass of tropical water drifts southward along the eastern part of Australia and forms the East Australian current. When this reaches Tasmania it is deflected towards the east by a body of sub-antarctic water which flows in a north-easterly direction. This deflected water becomes the South Tasman current, and when it reaches New Zealand, it swings northward to reach beyond Cook Strait. Some of this water passes through Foveaux Strait and up the coast of Otago (Fig. 3.4).

In like fashion, the southward drifting tropical water, when it reaches New Zealand, is deflected down the east coast, and is known as the East Cape current. When it meets the sub-antarctic water coming up from the south it turns eastward towards the Chatham Islands. No doubt part of this deflecting process is caused by the shallower sea bottom between Banks Peninsula and the Chatham Islands, known as the Chatham Rise (Doogue and Moreland 1966: 34).

These currents and the subtropical convergence have a major influence on the presence and abundance of different species of fish in New Zealand waters. Doogue and Moreland record that in February 1951 the East Cape current penetrated as far south as the Otago Peninsula, and in the same month flying fish were seen off Banks Peninsula. Swordfish and marlin are regularly reported off the southern fiords (south west South Island), where they have probably been riding the South Tasmanian current. The subtropical convergence would represent a cold water barrier to them. The southern bluefin tuna is a temperate water species commonly found in the vicinity of convergence water, appearing in South Westland and Foveaux Strait in October and November, and again in autumn. It is believed that this movement is influenced by the north-south seasonal movement of

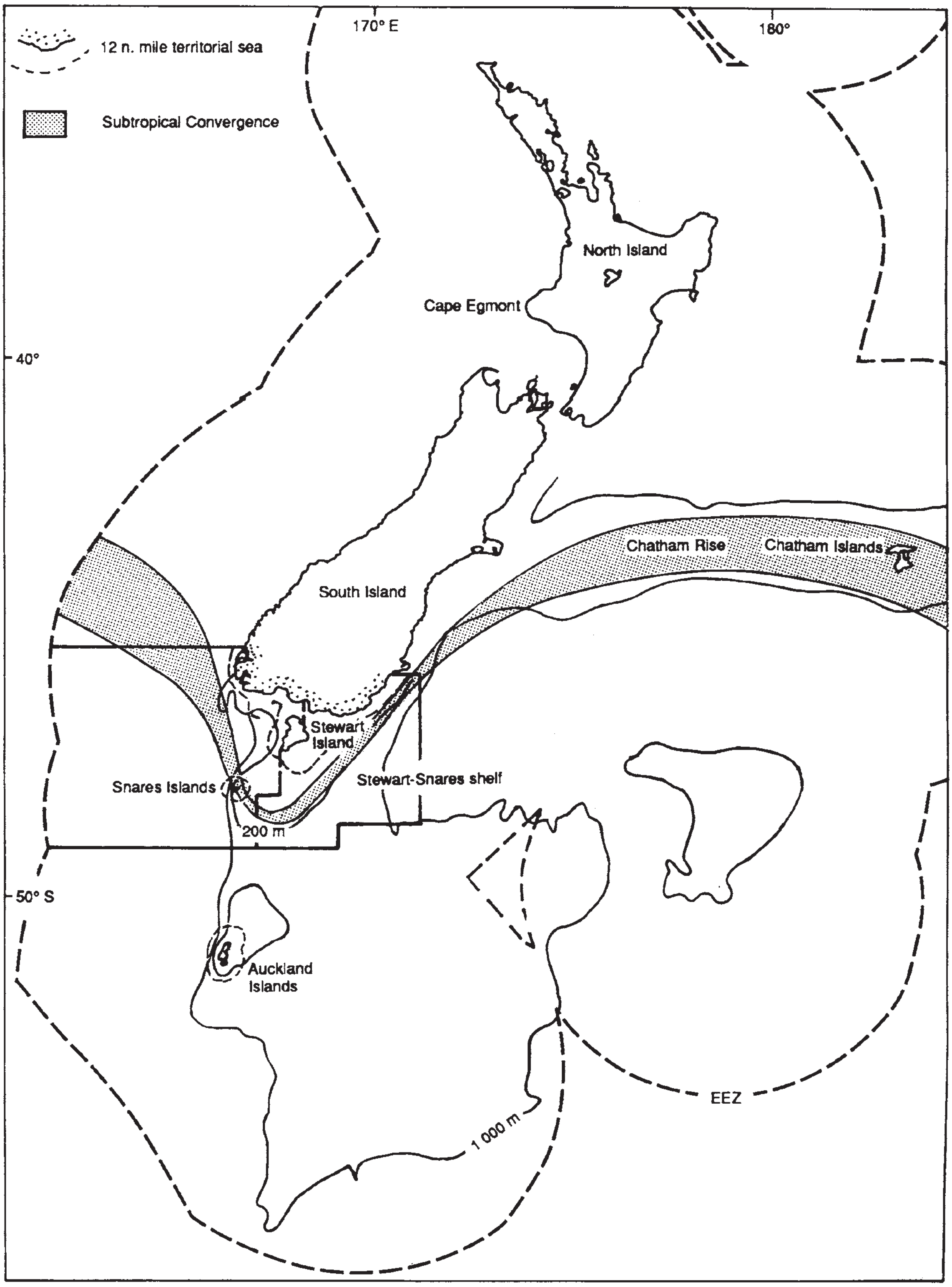


Figure 3.3: Subtropical convergence in New Zealand (from Hurst *et al.* 1990: 6, courtesy of Ministry of Fisheries).

the convergence. Doogue and Moreland also note that snapper and yellowtail kingfish, primarily northern species, extend their ranges during summer months south of Kaikoura and beyond, and that the subtropical convergence again marks an effective barrier for these fish. In the winter, they range only as far south as the western part of Cook Strait (Doogue and Moreland 1966: 34).

These seasonal effects and the overall position of the sub-tropical convergence can be expected to have had an important influence on prehistoric fishing activities. For instance, even slight changes in the climate regime in New Zealand over the past millennium would have had repercussions in the sea, certainly in surface sea temperatures and possibly in the positioning of the convergence too. This may explain why, as we shall see in Chapter 7, snapper are found in early archaeological sites in the Cook Strait region, but are rather rare, and in some cases absent, in sites later in time.

Figure 3.2 indicates the relative biomass of fish in the different zones. This shows that by far the bulk of fish are to be caught in depths above about 300 m, and especially on the continental shelf at less than 200 m. There is another major concentration of biomass in the upper reaches of the continental slope between 1000 and 500 m. This zone was almost certainly beyond the reaches of fishing equipment brought to New Zealand by Polynesians. However, having said that, it must be noted that there is ambiguous early historic evidence of deep water fishing in the Pacific for the *Ruvettus* (oil fish), or *palū*, as it is widely known. This is not the place to embark on a discussion about the problem of *palū* fishing, except to say that deep-water fishing (over 200 m) is essentially a modern phenomenon in the Pacific region with the spread of nylon lines and steel fish-hooks.

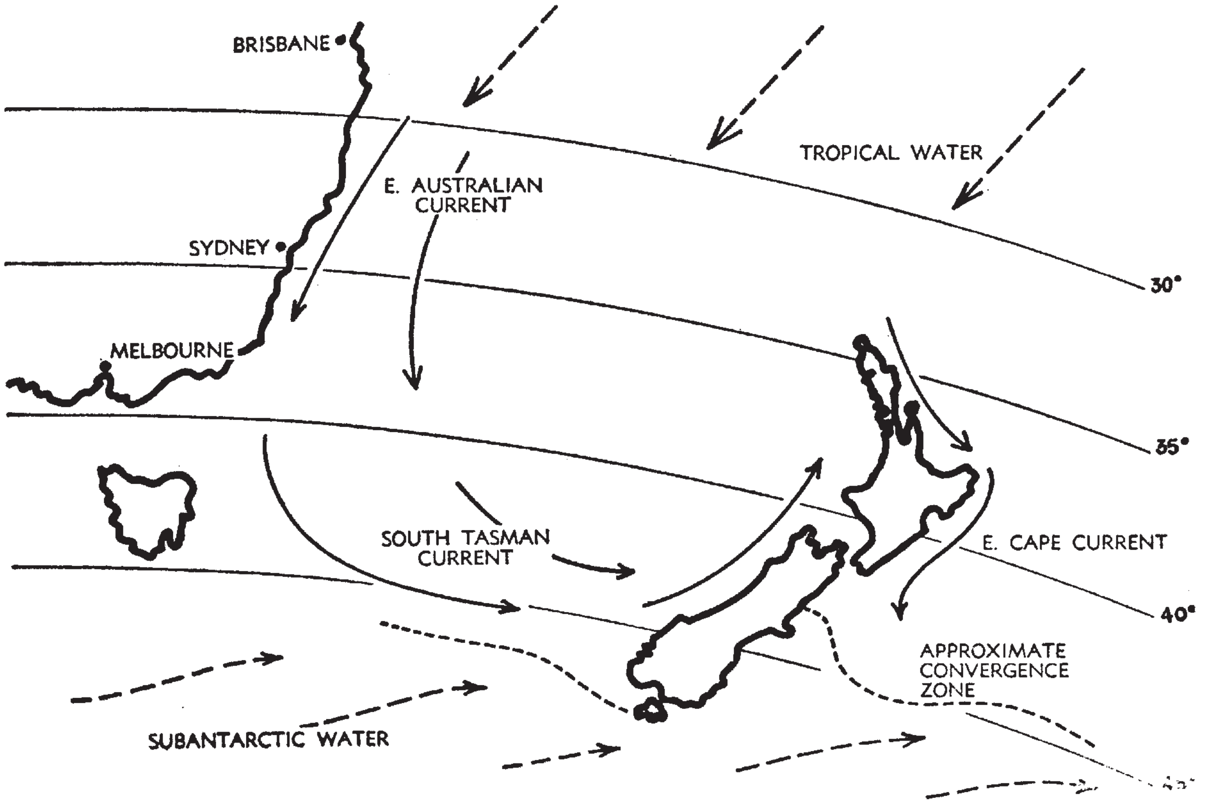


Figure 3.4: The main ocean currents which are responsible for the subtropical convergence in the vicinity of New Zealand (from Doogue and Moreland 1966: 34, courtesy of Eric W. Heath).

Commercial fishermen and fisheries scientists recognise a series of ecological zones around New Zealand waters, each with its dominant mix of species and other characteristics. Water depth is an important part of this. These zones are summarised in Table 3.1.

TABLE 3.1
Commercial Fish Distributions (after Armitage *et al.* 1981: 13 ff.)
See Appendix 2 for scientific names of fishes

- **Fresh water**: eels, whitebait
- **Shallow water** (near the shore, harbours, etc.)
  - **pelagic**: grey mullet, yellow-eyed mullet, garfish (piper)
  - **demersals**: sand flounder, yellowbelly flounder, school sharks, rig (seasonal occurrence), greenbone
- **Coastal water** (near the shore to 200 m depth)
  - **pelagic**: kahawai, yellowtail kingfish, blue mackerel, pilchards, sprat and anchovy, trevally, jack mackerel, barracouta (also deeper waters)
  - **demersals** **clear open bottom**
    - **northern**: snapper, john dory, leatherjacket
    - **southern**: red cod, moki, monkfish, blue warehou, spiny dogfish, elephantfish, sole, lemon sole, turbot, brill
    - **widespread**: tarakihi, red gurnard, rig, school shark, skates
  - **rough bottom/coastal reefs**
    - **widespread**: blue cod, hāpuku, bass groper, bluenose, conger eel
- **Oceanic waters** (200 to 1400 m depth)
  - **pelagic**: skipjack, albacore, southern bluefin
  - **demersals**: southern blue whiting, hoki, ling, silver and white warehou, hake, orange roughy, oreo dory, gemfish, frostfish, sea perch, orange perch, alfonsino, lookdown dory, ribaldo, silverside, ghost shark, grenadiers

With the exception of the last zone (Oceanic demersal), all these regions were available to the Polynesians who inhabited New Zealand in the pre-European era. Some of the deep water species, such as frostfish, occasionally come into shallow water and wash up on beaches. These species of course became known to the New Zealand Māori through such incidents. However, the main part of the fishery which was exploited by Māori was confined to coastal waters less than 100 m deep. This is an important point, of considerable interest to modern Māori seeking to assert mana (authority) over the sea and its resources, and will be returned to later.

SEA TEMPERATURES

The surface sea temperature around New Zealand is one of the principal variables which controls the presence or absence of seasonally mobile species, and also the rate of recruitment of juveniles. This is further discussed in Chapter 4 where snapper recruitment is considered. The interest in this matter for archaeologists is twofold. Firstly, the strong seasonal character of fish presence in inshore waters has important implications for the type of economic system which pre-European Māori could sustain. Secondly, any trends in surface sea temperatures over hundreds of years would have had important implications for people living in New Zealand.

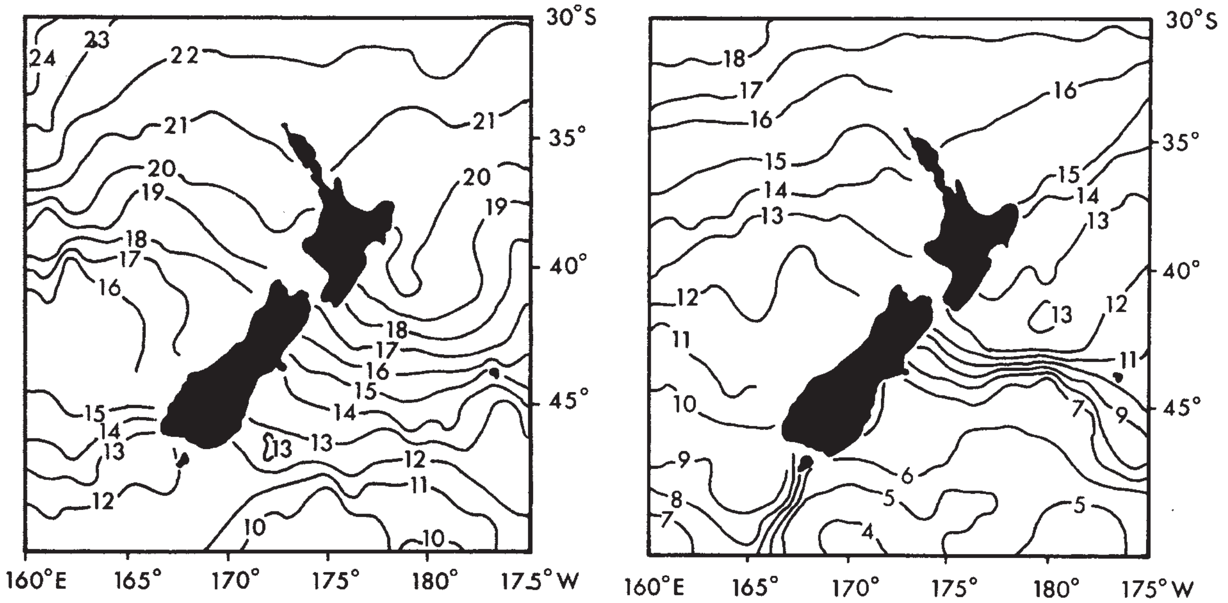


Figure 3.5: Surface water sea temperatures for New Zealand. These plots are close to the extreme values for summer (left) and winter (right), being obtained 8 March 1977 and 21 September 1976 respectively (from Eggleston and Paul 1978: 78, courtesy of Ministry of Fisheries).

The plot of summer and winter surface sea temperatures in Figure 3.5 shows the approximate boundary line for the sub-tropical convergence, in summer along the 15˚C contour, and in the winter along the 10˚C contour. In general terms, seasonal changes in water temperature around New Zealand are represented by a 5˚C change from mid-winter to mid-summer. This may not sound very large, but it represents a very large latitudinal shift in temperature contours. For example, on the east coast of New Zealand, the 16˚C contour in summer lies about the level of Kaikoura and Chatham Islands, or 44˚ south latitude. In winter, on the other hand, the 16˚C contour lies mostly above North Cape at about 33˚ south latitude. In other words, the shift is 11 degrees of latitude. Fish are very sensitive to temperature changes, some more so than others, and this large latitudinal shift is an important driving force for migratory movements of fish — species tolerant of cold water moving north in winter, and species intolerant of cold water moving south in summer.

It has been found that coastal surface sea temperatures follow coastal air temperatures quite closely. The daily fluctuations in air temperature are much more marked than those in the sea, as one might expect since the sea acts like a large heat sink, absorbing rapid local changes. However, the two temperature regimes follow each other, as shown by Greig *et al.* (1988: 393) in their study of 16 stations between Bluff and the Leigh Marine Reserve north of Auckland. They found air temperatures to be slightly cooler than the sea on average, and short-term fluctuations of air temperature to be 3–4 times the standard deviation of surface sea temperatures.

The temperature of shallow bays and gulfs reflects the local climate very closely; the primary influence here is direct solar gain and winds passing over warm or cold land or sea. In these cases, the dominant influence is atmospheric. On the other hand, oceanic temperatures follow the thermal patterns of large water masses and currents as well as long-term and large-scale climatic events. The surface sea temperatures of coastal waters between these two extremes are influenced by both atmospheric and oceanic events (Paul 1978: 70). In an analysis of historical trends in surface sea temperatures, Paul found evidence of cyclical patterns repeating every three or four years, and that

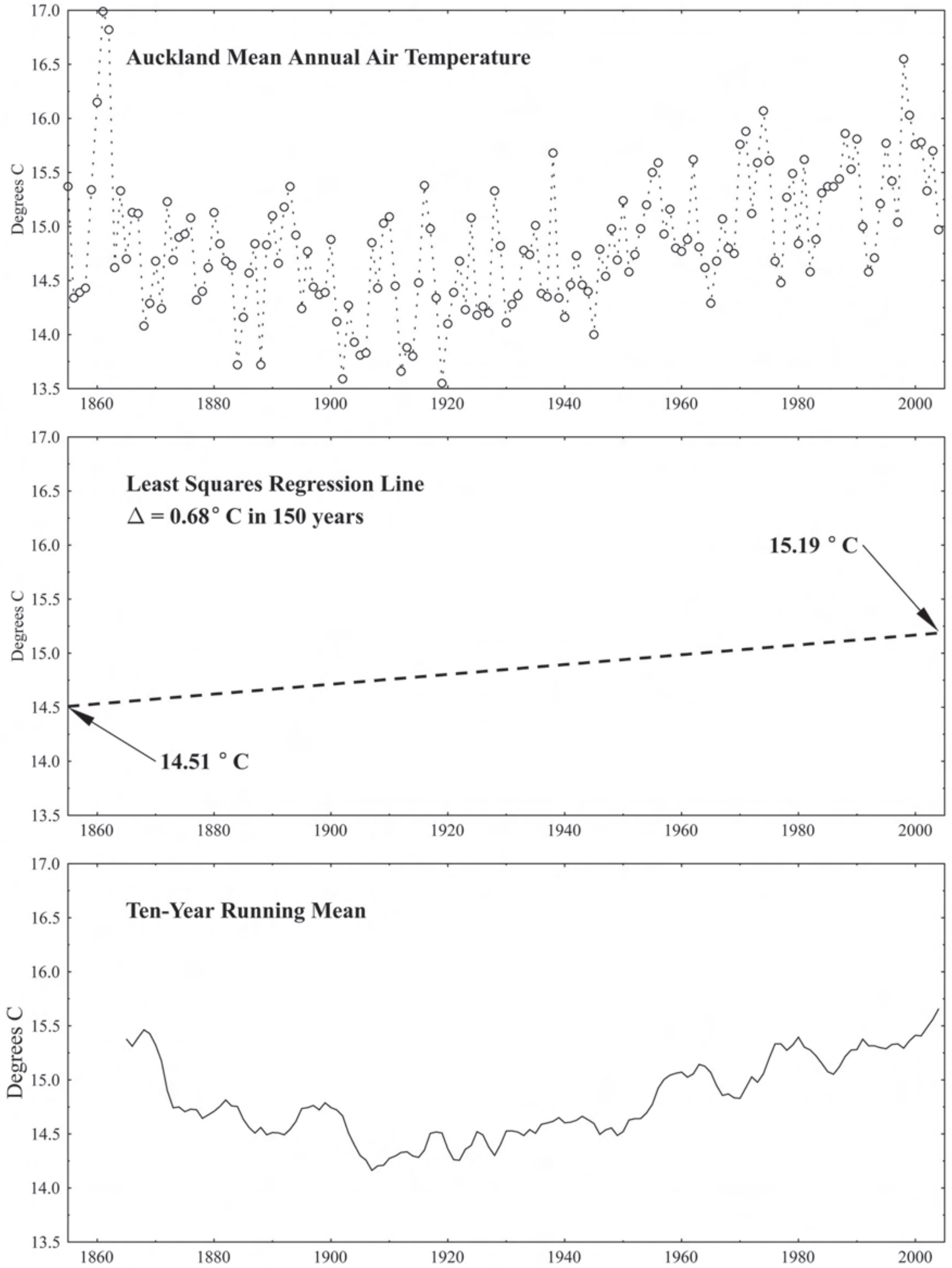


Figure 3.6: Historical trend of mean annual air temperature at Auckland (10 year running mean). An overall rise of more than 1°C has occurred over the period 1910 to 1996 (based on data provided by Paul 1997: pers. comm.; see also Paul 1978: 72–73).

"coastal air temperatures in northern New Zealand, when considered in terms of months and years rather than days, are a reasonable measure of sea surface temperatures" (ibid.: 71). Since there are far better historical records of air temperature than sea temperature in New Zealand, Paul examined these records as a guide to possible long term changes which might have prevailed in coastal waters (Fig. 3.6). His analysis shows an overall rise of more than 1˚C from 1910 to 1977, with somewhat higher temperatures before that. In Figure 3.6, the data range has been extended to 1996, and when least squares analysis is carried out on this, it shows that there has been a rise in temperature of 1.41˚C over this period. Folland and Salinger conclude that nearby ocean surface temperatures have warmed by about 0.7˚C since the beginning of the 20th century (Folland and Salinger 1998: 1195. See also Salinger 1991a, 1991b). Such a change will have influenced abundance figures for various fish species over the same period, but the historical details of this are not well studied.

Unfortunately, there is very little direct evidence of sea water temperatures for any part of New Zealand for the pre-European period, but there is information about changing air temperatures from both speleothem studies and patterns of glacial advance and retreat. This is discussed further in Chapter 7, but it can be noted here that there is increasing evidence of significant changes in climate during the last thousand years, and these changes would have had an effect on surface sea water conditions, and in turn the abundance and recruitment rate of different fish species.

SEA CONDITIONS

When Polynesians arrived in New Zealand they experienced sea conditions quite different from those of their homeland, and these would have influenced fishing activities. One important difference is the disadvantage that underwater visibility is much less than in the tropics. This is very important for people used to diving and spearing underwater. It is also important when spearing surface predators from a canoe, or using a hoop net amongst seaweed. A less obvious advantage, however, is the possibility of using stationary set nets or gill nets in New Zealand. Before the advent of nylon, such nets were effectively absent in the Pacific region. In fact, some Pacific islanders visiting New Zealand and seeing a local fisherman place a set net simply do not believe that it could ever catch fish, until of course the net is retrieved full of fish, captured by the gills. Nets made from sennit (coconut fibre) in the topical Pacific are highly visible under water and fish simply swim away from them, rather than trying to swim through them and getting caught by the gills. The concept of gill net selectivity therefore may not have been part of the fishermen's pool of knowledge when they arrived in New Zealand. Set nets, which capture by the gills, are commonly used in New Zealand for a number of species, and were fully effective when cotton line was employed in their manufacture. They are even more effective with nylon. It is an interesting issue to try and establish when gill nets developed during the course of New Zealand prehistory. Before this time, seine nets would have been employed to capture fish by dragging them through the water and essentially trapping the fish with the net.

Greatly reduced underwater visibility is not the only change from the tropical regions. Although islanders in the tropics experience conditions of large swell and occasional violent storms, the temperate waters around New Zealand have far more days per year when it would be difficult or impossible to put to sea in a small craft such as a canoe. The main factor here is surface swell, caused by local winds. This varies throughout New Zealand, but on the whole sea conditions progressively deteriorate towards the south. In Cook strait, there is nearly always a slight sea running, and even in summer, calm periods seldom last for longer than 10 days (Anderson 1973: 96). After a detailed analysis of the modern marine environment and local midden sites at Black Rocks, Palliser Bay, Anderson concluded that fishing and shellfish gathering on the nearby exposed coastal waters must have been confined to about 120 days per annum (ibid.: 120). Turbulent sea conditions constitute the principal limiting factor. These are caused by frequent local winds and also by the dominant southerly oceanic swell, which can be generated from far afield. Thus, poor sea

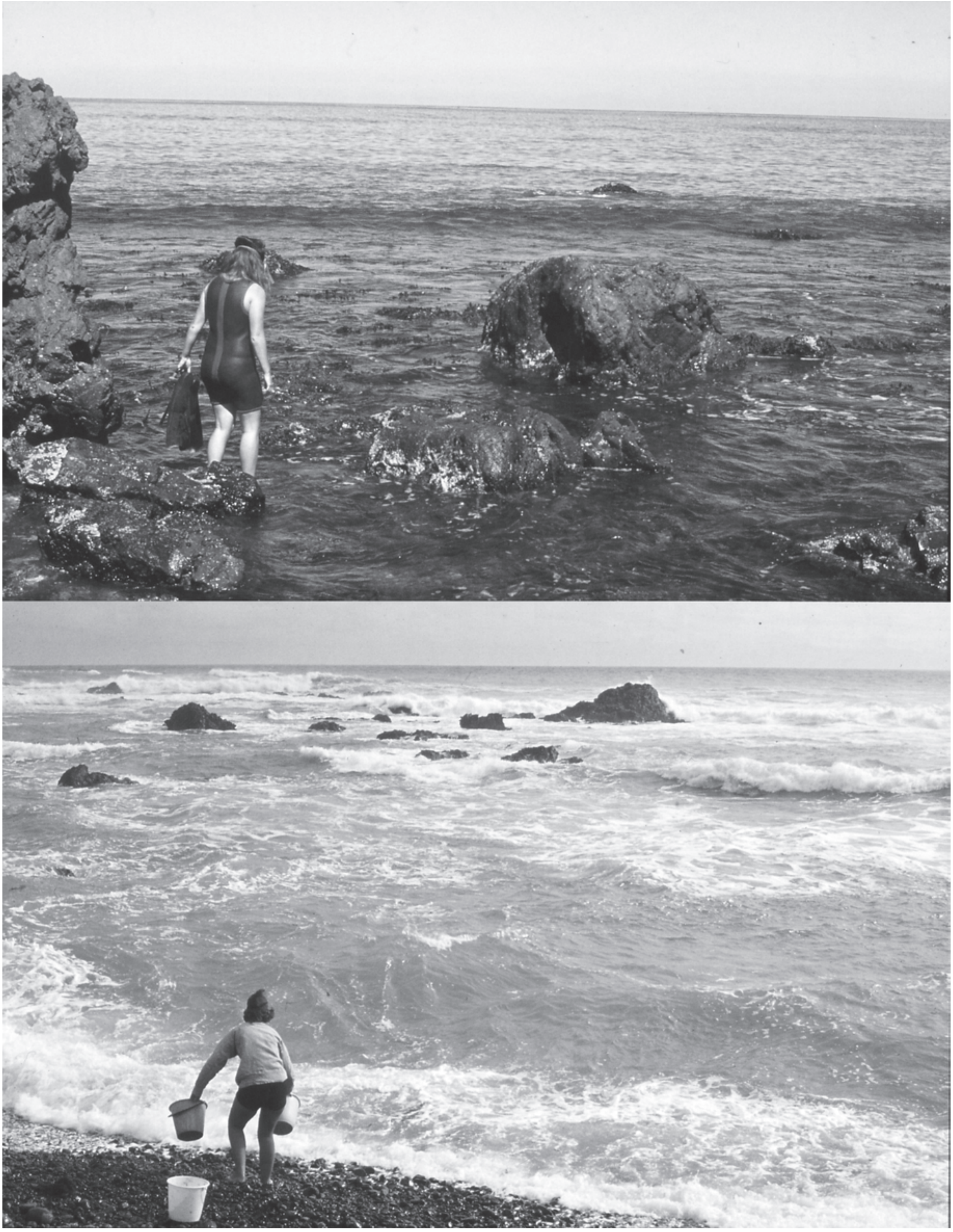


Figure 3.7: Black Rocks in Palliser Bay showing the contrast between a calm sea (upper) and during a typical moderate southerly blow (lower). It is impossible to put to sea in a canoe in such windy conditions, which might last for weeks on end (courtesy of Atholl Anderson).

conditions can prevail during periods of locally fine weather (Fig. 3.7). This severely limits the ability to procure marine foods for at least one third of the year.

Although people living near sheltered bays would not be hampered in the same way as those living at Black Rocks, such a situation is by no means confined to Palliser Bay. Much of the east coast of New Zealand is unprotected from these wind-generated swells. On the west coast, the prevailing northwest wind has a similar effect. This is particularly hazardous in the Northland region where numerous sailing ships were wrecked in the nineteenth century, unable to keep to windward. Captain Cook, with characteristically good seamanship, kept well away from the Northland coast when he travelled down the west of the North Island.

It has been noticed that there is a positive correlation between the general storminess of coastal waters in different parts of New Zealand and the relative abundance of labrid fishes in archaeological sites, and an inverse correlation with the relative yield of kūmara crops (Leach and Anderson 1979a: 11). This suggests that in places where there is the greatest pressure to harvest marine resources, and where it is most difficult to do so, labrids become important in the local pre-European economy, because they can be caught from the shore even in the most adverse conditions.

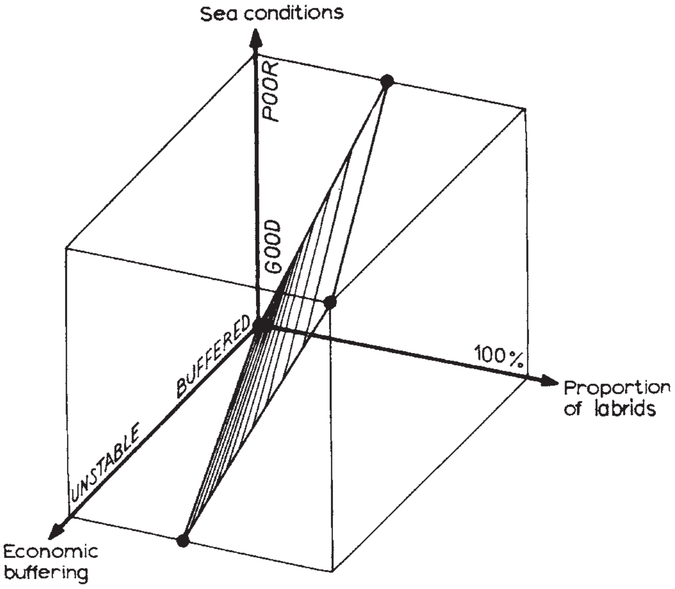


Figure 3.8: Labrid fishes are particularly abundant in archaeological sites in places where people experienced adverse sea conditions (from Leach and Anderson 1979a: 12).

However, as will be seen in Chapter 8, people could not maintain a healthy diet on fish alone. In the far north, where kūmara were more plentiful, people did not have to rely on labrids in bad weather to anything like the same extent (Fig. 3.8).

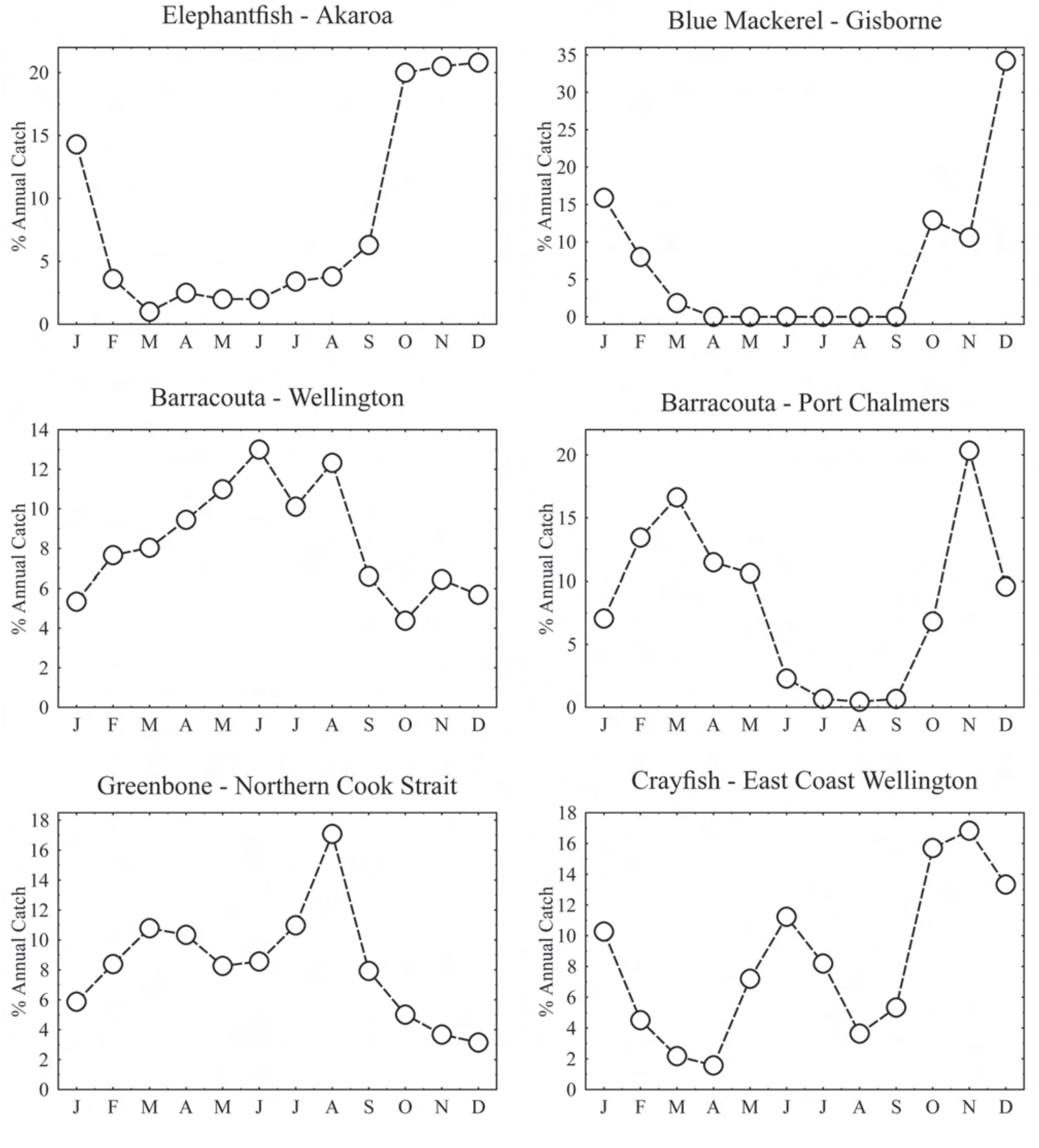
Not all of New Zealand is subject to poor sea conditions by any means. There are numerous sheltered bays with excellent fishing. Notable areas with intensive human settlement in the pre-European period are Parengarenga harbour, the Bay of Islands, Whangarei Harbour, and Hokianga Harbour (Fig. 3.9), all in the far north. It is interesting that neither Wellington Harbour nor the myriad of protected areas in the Marlborough Sounds appear to have had large populations of people. This region marks the boundary between groups of people in the north who had a successful horticultural economy, and those in the south who were hunter-gatherers. Cook Strait is a transitional zone in many respects.

Figure 3.9: The entrance to Hokianga Harbour in Northland with somewhat hazardous waters to negotiate. The inner harbour during pre-European times would have been a rich fishing ground. The outer area has some rocky headlands and excellent coastal fishing too (courtesy of Geosmart Ltd. Negative #27126, White's Aviation).

SEASONALITY

The seasonal change in sea water temperatures is one of the main driving forces for the movement of various fish species into and away from shallow inshore waters, and also from one part of New Zealand to another. These movements are very complex, partly depending on spawning requirements and partly on the quest for food. Generally speaking, the best time to go fishing in New Zealand is in the summer, but fish can be caught all year round. During the summer months a number of species come into shallow waters to spawn and they may then be caught in large numbers. Snapper is a good example of this. However, there are many species which inhabit rocky weedy areas and are present all year round, such as labrids, blue cod, solitary snapper, greenbone, etc.

As an example of changes in seasonal abundance, the commercial landings of blue mackerel and elephantfish are shown for different months of the year in Figure 3.10. These show a preponderance during the summer months. One has to be careful about how one interprets these commercial catch figures, which after all document fishing behaviour, not fish behaviour. However, in the case of these two species there are other observations which reinforce the change in abundance suggested by Figure 3.10. Large numbers of mackerel are seen in late spring and summer near Whangarei and Auckland. The fish apparently undertakes coastal migrations southwards in October and northwards in April and May (Leach 1979a: 116).


Elephantfish - Akaroa

Blue Mackerel - Gisborne

Barracouta - Wellington

Barracouta - Port Chalmers

Greenbone - Northern Cook Strait

Crayfish - East Coast Wellington

Figure 3.10: Some New Zealand fish are more abundant in inshore waters in the summer and others in the winter. These graphs show the commercial landings of several species (from Leach 1979a). The greenbone figures reflect fishing behaviour, not fish behaviour.

Elephantfish is primarily a southern species, and large numbers are caught in the Canterbury Bight, but it is sometimes seen as far north as the Bay of Plenty. It very rarely takes a baited hook since it feeds on crustaceans and shellfish, and it has specially adapted mouth parts for crushing these animals. It can be obtained in beach seines in the Canterbury area. The fish appears to migrate into deeper water when cold weather sets in, and during these months very large specimens can be hooked well offshore. At one time they were plentiful in Otago Harbour in summer from November through March. The change in abundance illustrated in Figure 3.10 shows a summer peak in catches.

Greenbone has been mentioned as a species present all year round. The information about this species is somewhat ambiguous. Fyfe (1982: 175) states "They are only to be found in shallow water during warm months between November and April, leaving before the water cools. They frequently die as a result of sudden temperature changes". Although Graham (1956) is not cited as the direct source of this observation, it does appear to derive from this book. What Graham actually said is:

> Greenbone only came into the Otago Harbour at intervals during warm weather. They were the first fish to suffer from a sudden change or lowering in the temperature which is sufficient to kill them, when they could be picked up on the shore. When a gale in the harbour caused the water to become muddy they soon died. This reaction to cold was also apparent in the aquarium when the temperature of the incoming sea water had to be brought up several degrees in temperature if Greenbone were to be kept alive (ibid.: 268)

These observations should not be interpreted as implying that greenbone are not present in coastal Otago waters or coastal waters elsewhere in New Zealand at times other than summer. Graham is describing greenbone coming inside the Otago harbour, which would not normally be a favoured

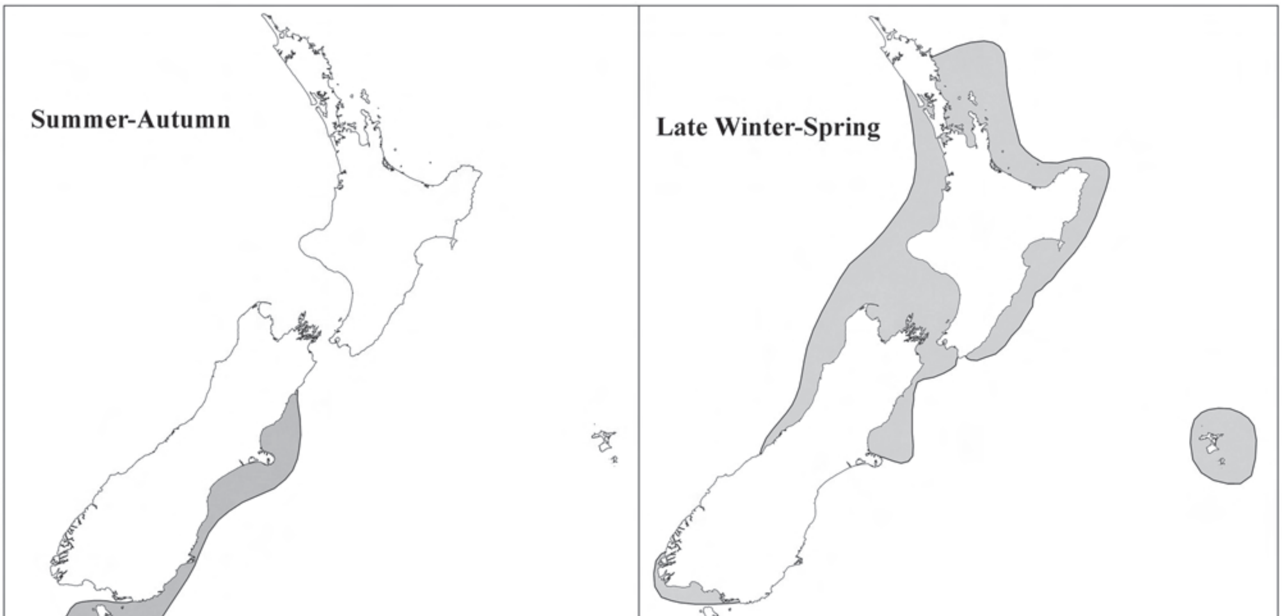


Figure 3.11: The general seasonal pattern of barracouta catches in New Zealand waters (based on Hurst 1988: 38, courtesy of Ministry of Fisheries).

habitat for greenbone, in the summer. The areas at the entrance of Otago Harbour are rich in seaweed and therefore provide suitable cover and food for this species, which are present all year round. Fyfe's comments about the seasonal movement of this species only concerns this special harbour occurrence. Greenbone occur throughout New Zealand, but are more common south of East Cape. The marked seasonal pattern of catches, evident in Figure 3.10, illustrates that fishermen leave them alone in preference to far more profitable returns from rock lobster fishing. The low point in the rock lobster catch in April is due to the mating, and the second low point in August is when they are moulting (Armitage *et al*. 1981: 189).

Also illustrated in Figure 3.10 is the pattern of catches of barracouta for two ports of landing. The seasonal habits of this species are discussed in further detail in Chapter 4, but it is noted here that the pattern shown for Port Chalmers of a strong summer appearance in the commercial landings is a fair reflection of their relative abundance in inshore waters at that time of year in the Otago region. The apparent winter predominance of catches landing in Wellington may also fairly represent a higher abundance at this time of year in the Cook Strait region. Hurst notes that the pronounced seasonal peaks in late winter to spring are based on known spawning areas. Most of the spawning appears to take place between August and December around the North Island and north-east and west coasts of the South Island (Fig. 3.11). The fishing patterns, evident in this figure, suggest that there is a southward movement in early summer to feeding areas in the Canterbury Bight and around

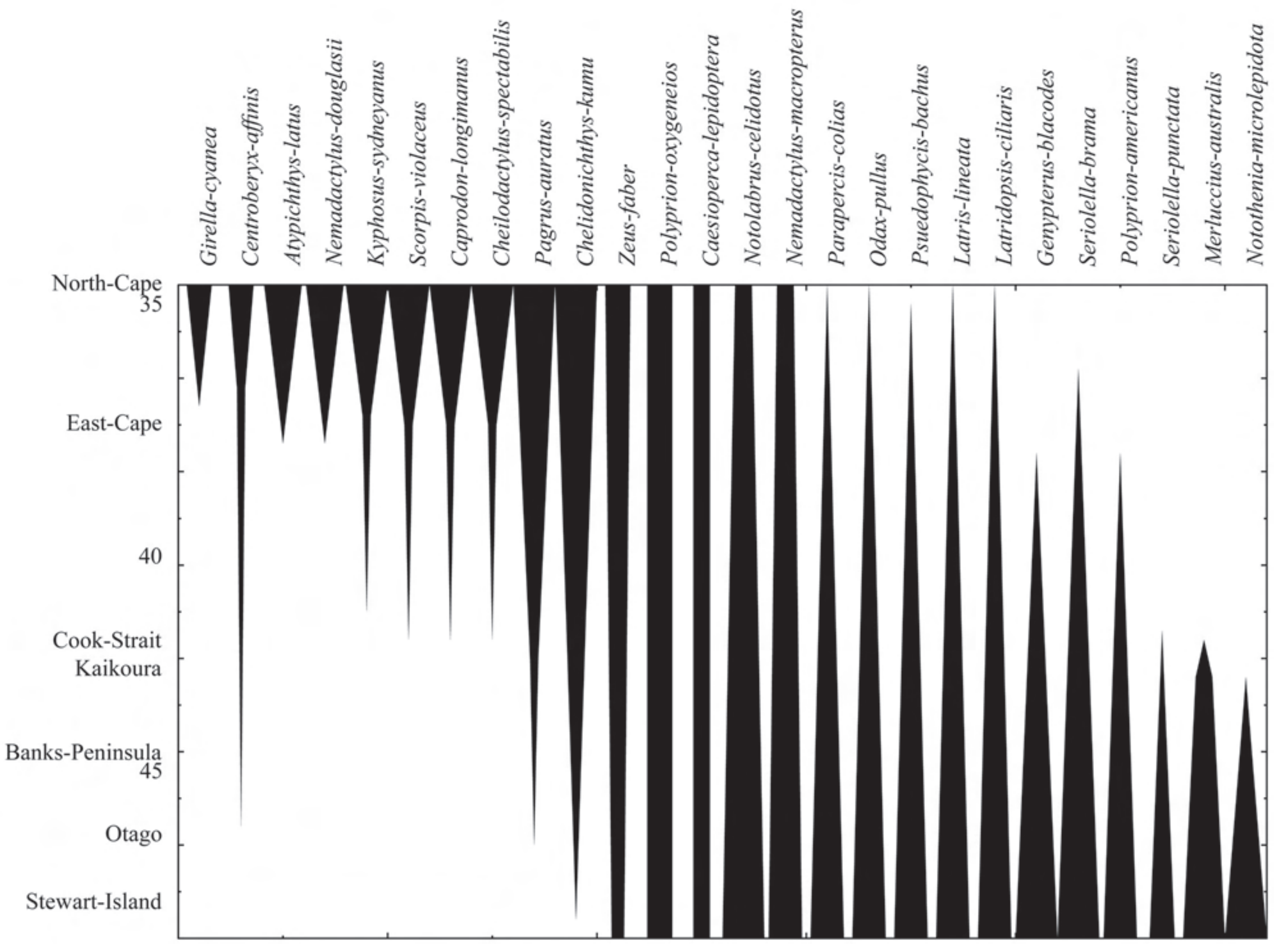


Figure 3.12: Distribution of common New Zealand fishes (after Leach and Anderson 1979a: 9, based on data from Waugh 1973: 257).

the Snares Islands. There is some evidence to suggest that barracouta are scarce in northern areas outside the spring spawning season (Hurst 1988: 36).

MARINE REGIONS

The islands of New Zealand are distributed across nearly 1600 km from north to south, and there are therefore substantial differences in climate and marine environment associated with this spread. The far north is sub-tropical and the far south is sub-antarctic. With such diversity of climate it is hardly surprising that pre-European Māori had completely different life-styles and economic systems at the two ends of the country. In the far north the people had an economy rich in horticultural produce, able to build and sustain large populations. In the far south, however, the people were hunter-gatherers, with low population density.

The types of fishing which could be carried out in different parts of the country were also determined by the large latitudinal spread of the New Zealand coastline.

The latitudinal ranges of common New Zealand fishes are indicated in Figure 3.12. This shows a steady loss of some species as one moves progressively southwards, and the steady appearance of different species at the same time. A few species, such as groper, spotty, tarakihi, and butterfly perch, have ranges which cover the whole of New Zealand. Even these appear in reduced abundance at one end of New Zealand or the other. We should therefore expect that pre-European fishermen in different parts of New Zealand would harvest the sea by somewhat different techniques and that their catches would vary as well. This is discussed in more detail in Chapter 6.

These latitudinal ranges raise the subject of whether there are significant groupings of species into marine regions or provinces. The most useful discussion of this is by Francis (1996), who carried out an analysis of the geographic distribution of reef fishes in New Zealand waters. He divided the region into a series of 16 areas as follows:

1	Norfolk Is.
2	Kermadec Is.
3	Three Kings Is.
4	NE North Is.
5	NW North Is.
6	SE North Is.
7	SW North Is.
8	Chatham Is.
9	NE South Is.
10	NW South Is.
11	SE South Is.
12	Fiordland
13	Stewart Is.
14	Snares Is.
15	Auckland and Campbell Is.
16	Macquarie Is.

He found that reef fish diversity (number of species) dramatically decreased with latitude, ranging from 228 species in Norfolk Island to only 6 species in Macquarie Island. There are four outliers, departing from a linear relationship with latitude, all of which have considerably less than the expected number of species. These are areas 2, 3, 5 and 10. It is interesting that the Kermadecs should be depauperate in species, even compared with the northeast North Island of New Zealand. Scheil *et al*. (1986: 532–533) suggest that this is a product of geological history and isolation, noting that no major currents flow through these islands, and that most of the landform probably appeared as recently as the Pleistocene. The other three areas with lower than expected diversity run down the west coast of New Zealand from the Three Kings Islands and the northwest North Island to the northwest South Island. Francis suggests that the exposure of this coastline to the prevailing westerly wind and swell results in little sheltered reef habitat, and that this is probably the reason for low species diversity (Francis 1996: 43).

In an attempt to identify groups of species which share similar distributional patterns, Francis used principal components analysis, and found seven clusters of 375 species represented. The regional distribution of these is shown in Figure 3.13. This shows a steady change southwards as one might expect. For example, in Otago waters (region 11), 83 reef species are present. Of these, most are from the 'Cool Temperate' cluster, slightly fewer from the 'Widespread' cluster, and a few from the 'Subantarctic' cluster. The list of species occurring in each cluster is provided by Francis in an appendix (Francis 1996: Appendix 1).

Francis also examined the distributional information to see if significant groupings of the original 16 regions could be found. Once again, principal components analysis was employed. This yielded eight clusters as follows (original regions in brackets):

I Norfolk Island (1)
II Kermadec Islands (2)
III Three Kings Islands and NE North Island (3,4)
IV West coast North Island and East Coast North Island south of East Cape (5,6,7)
V Chatham Islands and all of the South Island (8, 9, 10, 11, 12, 13)
VI Snares Island (14)
VII Auckland and Campbell Islands (15)
VIII Macquarie Island (16)

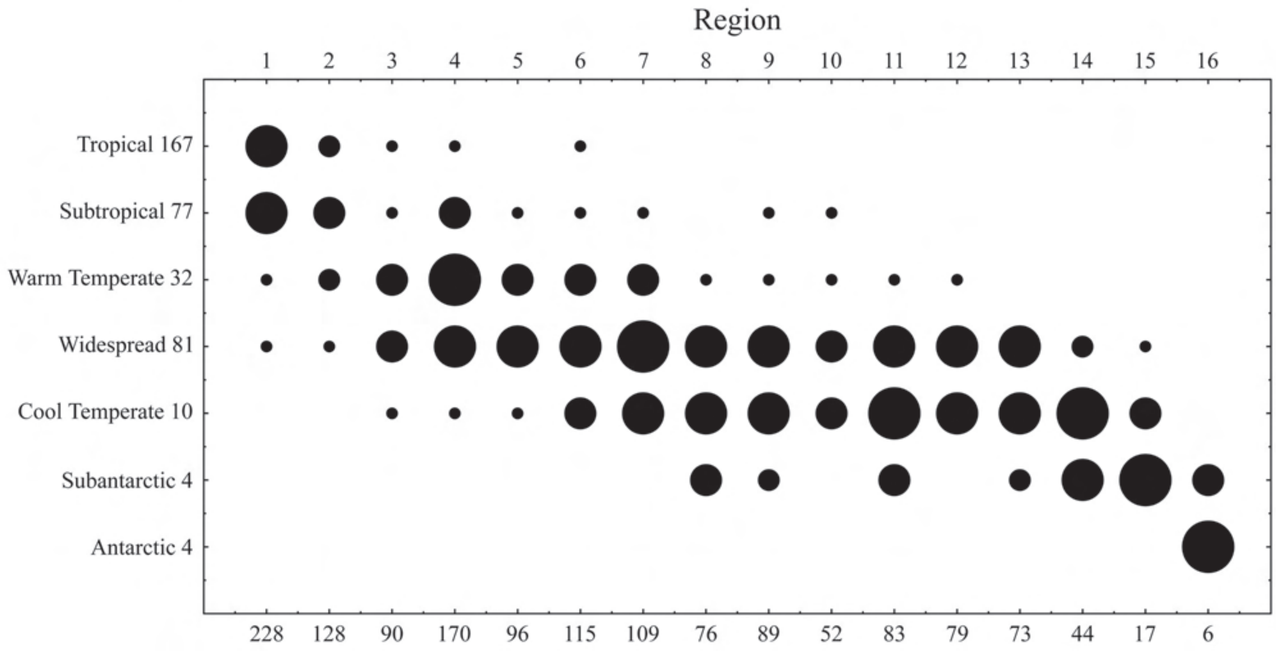


Figure 3.13: The reef fishes in the New Zealand region can be grouped into seven clusters which share similar regional distributions. The number of species in each cluster and region is indicated by the figures in the column on the left and along the bottom of the graph. The size of each circle indicates the percentage in each cluster occurring in each region (based on Francis 1996: 39).

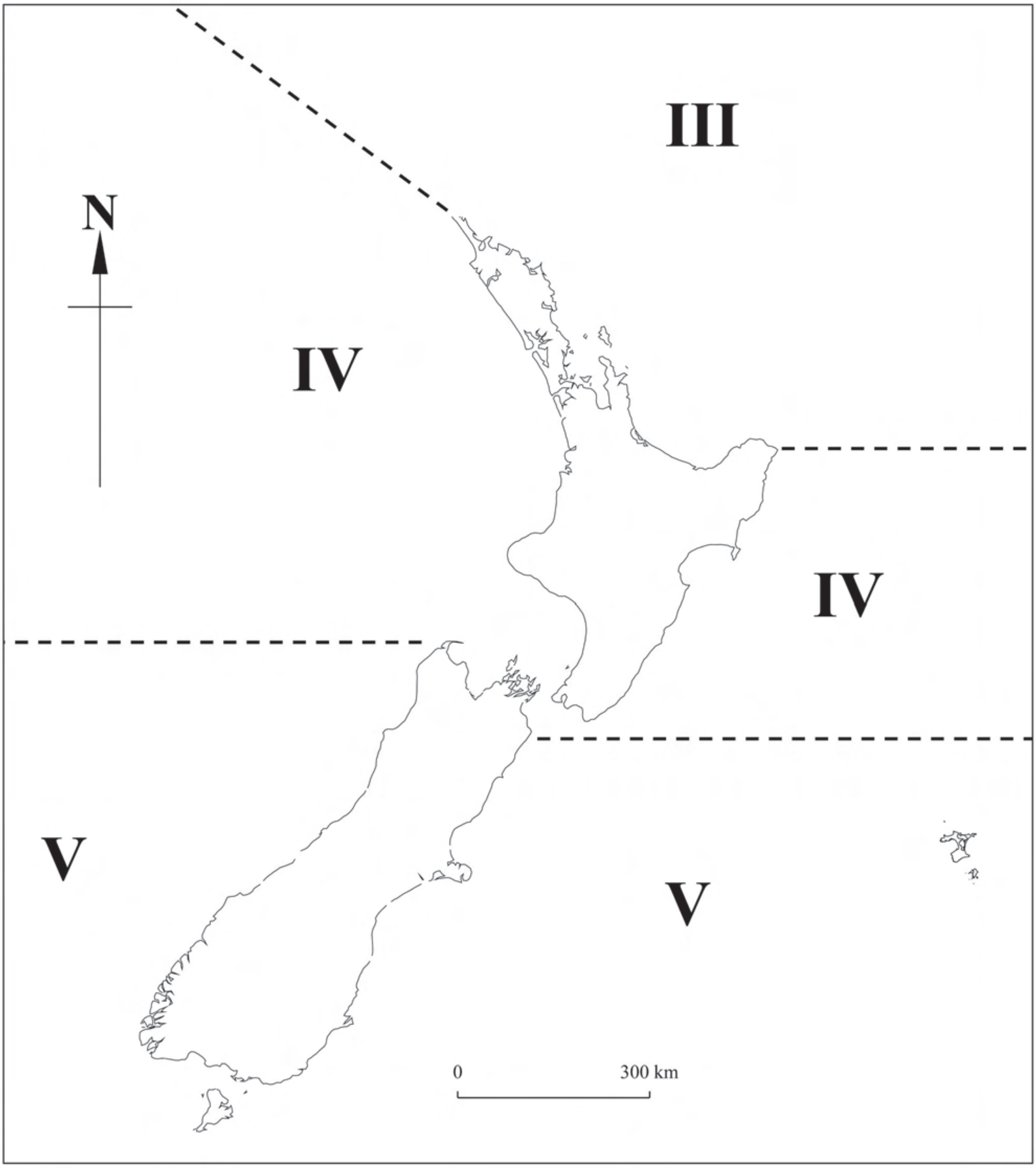


Figure 3.14: Eight regions can be identified in the vicinity of New Zealand which contain similar groups of species. Three are shown in this illustration. The other five are to the north or south of this map (based on Francis 1996: 40).

The groups which are appropriate to coastal mainland New Zealand are shown in Figure 3.14. The high diversity of fishes in region III is due in part to the presence of tropical and subtropical species, deriving from the warm East Auckland current. East Cape is also confirmed as an important biogeographical boundary, something which has been proposed many times previously. Francis notes that the reason for the existence of this boundary is not so easy to detect. He also identifies Cook Strait as the southern limit for many warm temperate water fishes, and the northern limit for several cool temperature species. However, unlike the East Cape boundary, in this case there is considerable overlap, and it is therefore not such a marked boundary.

Francis' paper is an important step forward in identifying clusters of New Zealand reef fishes and regional groupings; however, he falls short of naming these natural groupings as biogeographical provinces, partly because apart from the North Cape and East Cape boundaries he sees the lines as blurred rather than sharp distinctions (Francis 1997: pers. comm.). He has expressed similar reservations in his study of fish distributions in the southwest Pacific (Francis 1993: 148). Despite this reservation, the regions identified in Figure 3.14 are convenient areas against which to view the archaeological data on fishing.

CHAPTER 4: THE DOMINANT FISH IN PRE-EUROPEAN CATCHES

INTRODUCTION

In a detailed published list of New Zealand fishes, approximately 750 species were recognised (Paulin and Stewart 1985). Many of these are either very rare or so small that they would not be considered food unless they were mass harvested in the manner by which New Zealanders gather whitebait or anchovies. Although this large number of species is important when considering issues of biological diversity, the health of ecosystems, and animal taxonomy and evolution, it is not at all important when considering matters relating to human economy and diet. Published literature describing Māori knowledge of fish life lists numerous named taxa, possibly exceeding the figure of 750 mentioned above. These taxa are not the same categories as those used by European marine biologists. For example, Māori recognised 167 different types of eel with separate names (Best 1977: 95–100). These include freshwater eels, conger, lamprey and blind eel. This would cover fewer than 20 species recognised by European taxonomists. Far from indicating that either Māori or European are ignorant when it comes to eels, this discrepancy shows a gulf between the sociological importance of eels in the two societies. In a classic anthropological study of the Nuer people of Africa, Evans-Pritchard paid particular attention to a phenomenon whereby the number of words in a society for a category signals its relative cultural importance (Evans-Pritchard 1940: 41 ff.). The Nuer recognise several hundred types of cattle, clearly signalling the importance of cattle in their society. Likewise, the marked disparity between European and Māori names for eels indicates a profoundly greater importance in one society compared with the other. However, one should not leap to the conclusion that this necessarily implies economic importance. In point of fact, eels did not figure prominently in early Māori diet. This apparent contradiction will be explored further in Chapter 7, but it can be noted here that this interesting phenomenon concerning eels occurs in a number of parts of the Pacific, as well as other parts of the world.

In this chapter I am concerned with the economic importance of different types of fish in pre-European New Zealand. I stress that this is not necessarily the same thing as their social or cultural importance, as perceived by Māori who lived at the time, or indeed as perceived by their modern-day descendants. Once again, a simple analogy might serve to underline this important different perspective. In modern New Zealand, the elephantfish has a considerable economic role, particularly in the South Island where it is one of the dominant species used for fish and chips. However, the average urban South Islander, if confronted with a fresh whole specimen in a fish shop would very probably view it with disgust and buy something else. This is not merely a matter of unfamiliarity with the original source of a packaged item of food (a piece of fish enclosed in batter in this instance), it is also a question of changing social attitudes towards food. For example, one of the most prestigious and expensive fish foods in New Zealand supermarkets and fish shops today is the greenbone or butterfish, *Odax pullus*, yet this species was unpopular in the fish market in the 1930s (Graham 1956: 262); and people were prejudiced against the green colour of the bones. The fish may have been believed to be rotten, whereas the green colour is actually a sign of iodine precipitation. These fish are vegetarian, have a high iodine content in their flesh, and are very nutritious. Anthropologists refer to such attitudes as *food avoidance behaviour*. There is no dietary reason why people disdain to eat such a food, but there is a strong culturally transmitted distaste even so. As we will see in Chapter 7, eels were subjects of food avoidance behaviour in pre-European New Zealand, in common with many of the Pacific Islands. Eel avoidance is not confined to Polynesians; the Scots disdain eels, whereas the English are fond of them.

One more example might be mentioned to highlight the difference between economic and social importance. Fishing for tuna in the Pacific is a very important activity and occupies much of the attention of fishermen on small islands. Men sit in the men’s house for hours at a time discussing the habits of tuna, where to catch them, how to catch them, particularly important catches, feats of individual tuna fishermen, myths about tuna, songs, dances and chants about tuna, and so on. Anthropologists and ethnographers have collected numerous stories about tuna fishing in the Pacific. Based on this, one would be forgiven for thinking that tuna were amongst the most important foods of all Pacific Islanders; but nothing could be further from the truth. Tuna features very rarely at meal-time in the Pacific, but this is not an example of food avoidance behaviour. Tuna are very hard to catch using small canoes and there is adventure and danger in hunting them in the open sea. It is a prestigious activity, but not often successful. It is like pig hunting in the highlands of Papua New Guinea, and elephant hunting by the Pygmy people in Africa. Hardly any tuna, or pigs, or elephants are ever caught and killed, even though a lot of attention is given to the search for them. In point of fact, the common fish foods in the Pacific are much more mundane species, easy to catch and to fill bellies with.

At the risk of over-stating the obvious I therefore note that bones in archaeological sites tell us about what people ate; they tell us about human diet and economy. The presence of bones of a particular type of fish does not by itself tell us anything about the social importance of the fish, or anything about food avoidance behaviour. To reach conclusions about these matters, to some perhaps far more interesting, we must explore the remains from archaeological sites with greater cunning and insight, addressing questions, for example, as to why some taxa appear to be under-represented compared with their relative abundance in nature.

Although fish remains are very common in New Zealand archaeological sites, few have been studied intensively to yield basic lists of abundance of fish types. Almost all of the studies have been carried out either at the Museum of New Zealand or at Otago University.

These studies show that only a small number of species had a particularly strong role in pre-European Māori diet. The relative abundance of different fish types is summarised in Table 4.1 and Figure 4.1. Only six feature in archaeological sites listed in Appendix 1 with a numeric abundance of greater than 7%[1]. These are barracouta, blue cod, snapper, spotty, red cod and greenbone. These six types of fish account for nearly 85% of all fish caught. Because of their great importance in the economy of the pre-European Māori, they are discussed in some detail in this Chapter.

The focus here is on the fish themselves and their habits. I discuss their distribution in archaeological sites and give an indication of the kind of information we may be able to find out about them using archaeological information. I show how we construct size frequency distributions for archaeological catches, and how we estimate the live weight and edible meat weight of the fish. Archaeological findings are presented in more detail in Chapters 6 and 7, which deal with regional and chronological changes.

At the outset it must be admitted that our knowledge of fish behaviour, general abundance and ecology suffers from a basic problem of unknown degree of distortion and bias because it is derived from observations collected during the historic era. By using modern historical sources of information we are tacitly assuming that there has been no change in these characteristics either during the pre-European period, or during the historic period. For example, we are assuming that fish zonation and habitat preferences are basically the same now as they were 1,000 years ago.

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[1] The percentages given are weighted mean values, calculated from Appendix 1. That is, they are weighted in proportion to the size of an assemblage. This prevents very small assemblages from unduly influencing the averages. The figures have been pooled according to family, and given a common name appropriate for the dominant fish species. For example "barracouta etc." refers to barracouta and gemfish (NB: the total MNI of gemfish in the Fishbone Database = 5).

Although this is a very poor assumption, in many cases it is unavoidable. However, it should not be taken as a starting point but used as a last resort.

TABLE 4.1
Relative abundance of fish caught by pre-European Māori

Percent	**Fish Family**
25.1	Barracouta etc.
16.6	Blue cod
15.8	Snapper
10.6	Spotty etc.
9.2	Red cod etc.
7.4	Greenbone
2.5	Tarakihi etc.
1.8	Ling
1.8	Leatherjacket
1.5	Trevally etc.
1.3	Scarpee etc.
1.2	Kahawai
1.2	Blue moki etc.
0.79	Maori chief
0.59	Groper
0.48	Yelloweyed mullet etc.
0.48	Conger eel
0.42	Red gurnard
0.35	Other bony fishes
0.33	Freshwater eels
0.12	Marblefish
0.097	Spiny dogfish
0.087	Ghost shark
0.085	Eagle ray
0.072	John dory
0.067	Flounder etc.
0.065	Blue mackerel etc.
0.055	Blue warehou
0.052	Elephantfish
0.027	Parore etc.
0.022	Hoki
0.022	Estuarine stargazer
0.0099	Giant stargazer
0.0075	Porcupinefish
0.0050	Sting ray
100.2	**Total**

In Chapter 7, when I discuss change over archaeological time, it will be clear that pre-European Māori certainly did affect fish zonation by denuding the inshore area of larger specimens (blue cod on Mana Island). Moreover, fish are highly sensitive to the presence of humans and they do change their behaviour over quite short periods, learning from older individuals. Nowhere is this more clear than in their biting behaviour towards sharp, baited hooks, as they become increasingly hook-shy. This is further described in Chapter 5. I can recount one instance of a similar change from first hand

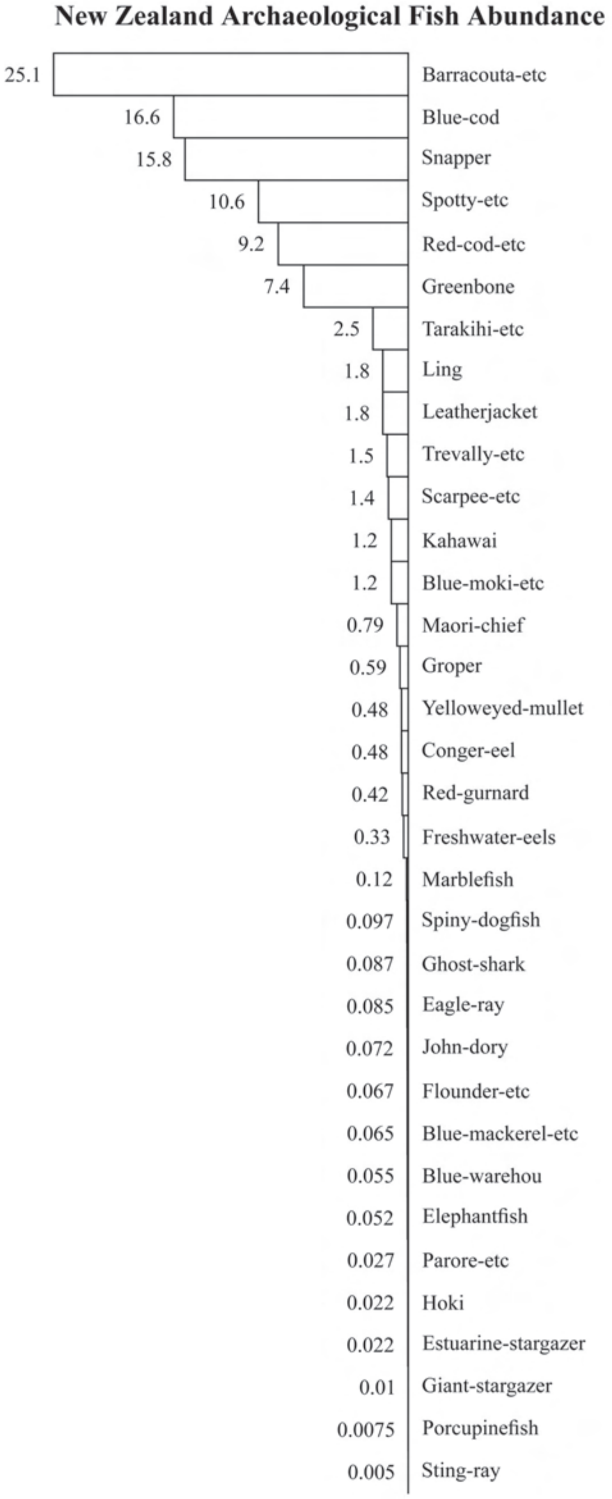

Figure 4.1: The relative abundance of different types of fish in the sites in the Fishbone Database. The figures given are mean percent of MNI, weighted according to size of assemblage. The fish types have been grouped into families for simplicity.

experience in the tropical Pacific. On the island of Kapingamarangi, one of the commonest methods of catching fish today is with a spear gun. Visitors to this island are astonished at the length of the spear guns which these Polynesians use. Old men are adamant that fish have learned to keep further and further away from humans underwater, necessitating the guns to increase in length over time. If fish behaviour and ecology cannot be regarded as pristine at the end of the prehistoric period, it is far worse to make this assumption after 150 years of European commercial fishing. In spite of these misgivings, this chapter represents a useful starting point, with the strong caveat that there could be a movable baseline here.

BARRACOUTA

This fish has the European binomial *Thyrsites atun*, and is classified by zoologists as a member of the family Gempylidae (sometimes Gemphylidae), known as the snake mackerels (Fig. 4.2). The common Māori name is *mangā*[2]. It is of interest that this name is not as widespread in the Pacific as the name *ono*, which is a term applied to various fishes which Europeans call barracuda, and which are classified as belonging to the family Sphyraenidae. This may sound slightly confusing, and indeed it is. Anatomically, the bones of fishes in the two families are not easy to distinguish, and although the external appearances are distinctive, one would be perfectly justified in thinking they were close relatives. The term *ono* refers not only to barracuda, but in some places to the wahoo (*Acanthocybium solandri*), and in others to swordfish (Biggs and Clark POLLEX 1996).

Pacific Islanders would never have seen the New Zealand barracouta before coming to this region. The New Zealand species is found in southern hemisphere temperate waters in South Africa, southern Australia, New Zealand and southern South America (Paul 1986: 120). It is found northwards to latitude 20° off the west coast of South America, corresponding to the northwards sweep of colder waters along this coast. However, there are several other species in the same family (Gempylidae) which are found in the tropical waters of the Pacific. For example, the species *Promethichthys prometheus* is widespread and known by the same name as the New Zealand barracouta, *mangā*, in both Rarotongan and Tuamotuan (Biggs and Clark POLLEX 1996). The same fish name is recorded in the Tongan language (ibid.), although the species is uncertain. It is worth

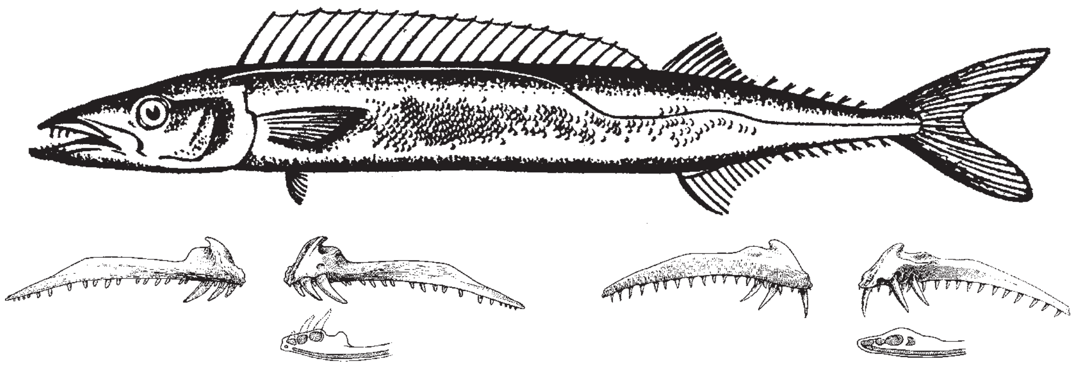

Figure 4.2: Barracouta, *Thyrsites atun*, *Mangā* (Māori) (after Doogue and Moreland 1966: 279, courtesy of Eric W. Heath). Below (left) is the right premaxilla bone of barracouta, with the right premaxilla of frostfish (right) for comparison (from Leach 1997: 67). Barracouta bones are very difficult to distinguish from both frostfish and gemfish.

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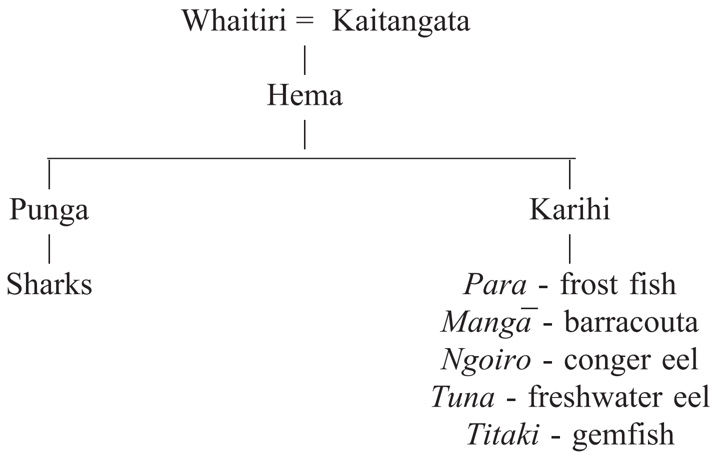
[2] This should not be confused with *mangō*, which is a generic name for sharks of various kinds (the term mako is derived from this).

noting that *Promethichthys prometheus* is generally smaller than the New Zealand barracouta, averaging about 380 mm length, and is found in deep water between 150 and 800 m (Munro 1967: 207; Tinker 1978: 337). The first immigrants to New Zealand must have recognised the New Zealand species of barracouta as a cousin of the rarely seen deep water tropical species, *Promethichthys prometheus*, and gave it the same name, *mangā*. Imagine their surprise when it turned up in abundance in inshore waters, unlike its oceanic counterpart.

Best notes that the Ngati Kahungunu people of the Eastern North Island told him that both *mangā* and *haku* (yellowtail kingfish) were sometimes taken on shell-lined lures (Best 1977: 51). This probably refers to the lure called *pā kahawai*, widely thought to have been specifically made for capturing the kahawai fish, and well known in museums in both New Zealand and abroad. This is not surprising because barracouta will bite almost any moving object in the water. When fishing over rocky bottom for blue cod, one occasionally feels a bang on the line while hauling up a fish. When it is taken on board it usually has just the head left, with the body neatly cut off on the way up by a barracouta. One can often see a barracouta swimming along with a fish being brought up from the depths. If one stops pulling the fish in momentarily, the barracouta will immediately lose interest and veer away. The slightest attempt to pull the fish in again captures the attention of the barracouta once more. What this shows is that movement is a major attractor principle for the barracouta, and almost any kind of lure in the water will do. However, a shiny material is even more effective, and red coloration also appears to be especially attractive. The most common lure used by pre-European Māori was known as *pohau mangā* and consisted of a piece of wood with a single bone point, often made from the jaw-bone of a dog, set into the end. These lures may seem primitive, but were perfectly effective. When metal came to New Zealand along with European people in the 18th and 19th centuries, the bone point was replaced with a bent nail. Museums have many of these artefacts. According to Best (1977: 51), Māori recognised three kinds of barracouta:

mangā ripo	a deep sea fish
mangā tutara	not eaten
mangā ahuone	the one commonly taken

Unfortunately, it is no longer possible to identify precisely what these terms refer to, but it can be noted that other species in the same family, which occur in New Zealand waters, have different names again. Given the importance of these fish in prehistoric catches, one might have thought that there could be several names for different age grades, or shoals turning up at different seasons. Perhaps there was, and the information about this has now been lost. Some hints of the Māori taxonomy relating to barracouta is provided in a depiction of the mythical origin of several fishes by Best (Best 1977: 56):



Gemfish was added to this mythical genealogy by Best (Best 1977: 56).

Best also provides an interesting translation of an account from a South Island Māori about fishing (Best 1977: 53–55, 239–241) in which the following observations were made about barracouta:

> Barracouta-fishing commenced in the seventh month — about November — and continued until April, when it ceased. The principal thing in connection with this fish is that it is not fished for with hooks in the ordinary manner, but is taken by means of a *pa*. This *pa* consisted of a piece of beech wood, in the end of which a bird-bone, or some other strong and suitable bone, was inserted; the length was 6in., the width 1½in. One end of a cord was fastened to this, and this cord was also secured to a carefully fashioned rod, one end of which was curved so as to be suitable for forcing to and fro in the water. Such was the form of lure used in taking that fish. When fishermen went out in their canoes to take barracouta with this implement, on seeing a school of the fish this implement was thrust into the water and dashed violently to and fro. This method is known as *kaihau* or *kaihau mangā*. A canoe would stay with the school until many fish had been taken by this *kaihau* method.
>
> The canoes would return to land, and women would clean the fish and cut off the heads, which were thrown away. The fish were cut up, the flesh dried, the outer part hung up on racks; the dried portions were cooked in a steam-oven (a *puna*) when required. These fish were cooked in the same manner that *kauru* was [the fibrous, fecula-containing interior part of the trunk of *Cordyline australis*]. The oven-fires were kindled when the morning stars rose. When day was well advanced the carefully arranged stones were well heated; the time allowed for cooking was the same as with *kauru*. When cooked they were taken from the oven and suspended on racks, and so dried. The inside fat of the fish was separated from the flesh when hung up for drying. Such was the process followed in dealing with barracouta until the end of the season (Best 1977: 54–55).

There are several interesting things about this passage. It must be remembered that it relates to South Island conditions, though where in the South Island is unknown. Firstly, it suggests that there is a strong seasonal pattern to barracouta fishing, from November until April. This accords with their known seasonal movements inshore at this time of year. Secondly, fishing from canoes is described. These fish may be taken from rocks casually, but by using canoes, people could chase shoals and harvest barracouta in large numbers. Thirdly, the method described is focused on surface waters, no more than the length of the wooden rod. Barracouta are now known from deep-water commercial trawling to be in deep water during winter months. Whether Māori knew this or ever caught them in deeper water is not known, but for a number of reasons it is unlikely. Fourthly, the removal and discarding of guts and head does not conform with many other accounts of the fishing practices of Māori and Polynesians in general. There are many indications that guts and head were considered delicacies. Fifthly, the idea that fish would be cooked in an earth oven for as long as *kauru* surely cannot be correct. Enormous amounts of thermal energy were required for processing *kauru*, which involved more than a tonne of heated boulders, and a cooking time of 24 hours or more. The heat generated in these ovens is known to have melted greywacke, indicating that temperatures as high as 1190°C must have been reached (Fankhauser 1986: 41, 44, 48, 50). Finally, there appear to be contradictory statements about the drying and cooking. At one point it appears that pre-dried flesh was cooked when required, and at another that fish were dried after cooking. Certainly the preserving of fish by drying in the sun was noted by many early European explorers.

At the present time we do not know how to determine, from the bones alone, the season of the year when a fish was eaten; that is, distinguishing between fish eaten freshly caught and fish sun-dried and eaten months later. No doubt developments in archaeological science will solve this problem in the future. It is an important matter to resolve when reconstructing the annual economic cycle for a particular pre-European community, rather than simply inferring it from general ethnographic observations of 19th century Māori.

The behaviour of barracouta in the vicinity of Otago has been vividly recorded and described by David Graham in his *Treasury of New Zealand Fishes* (Graham 1956: 310 ff.). His comments derive from first hand observations over many years and describe fish stocks and fishing activities in this area which are the envy of recreational fishermen today. It is of interest that he records catching the occasional groper on a barracouta lure (ibid.: 311). Groper bones are so infrequently seen in archaeological sites that one wonders if this may have been the method of capture of the occasional one which is present, rather than deep water baited-line fishing. Graham also notes that seine nets in which barracouta were caught were severely damaged. This suggests that during their season of abundance inshore, it would have been sensible for pre-European Māori to have refrained from setting nets. He spoke to Māori at Opotiki in the eastern Bay of Plenty, and found that the barracouta were a great favourite among them there. Women cleaned the fish which were brought ashore, and hung them on racks to dry in the sun. He was told that a piece of *tawhai* wood (*Nothofagus fusca*) was used for the lure, because of its dark red colour.

There is a strong seasonal basis to the presence of barracouta in inshore areas, and Graham's description is summarised in the following chart:

January to March:	Large shoals of fish near Cape Saunders
April to June:	Fish in best condition. Roes well developed
July:	Fish disappear from the surface with nearly ripe roe about to spawn. Later in the month 100 mm long barracouta found in stomach of other fish
August to December:	Fish re-appear at the surface and have spawned. Very thin and hungry.

We can add to this chart Graham's observation that large migrations of immature fish (100–130 mm long) come into the Otago harbour in early summer and autumn. Barracouta of this small size are not known from any of the archaeological sites studied so far.

The barracouta is distributed throughout New Zealand waters, but is more abundant from Cook Strait southwards. It is a lean fish with medium to low fat content (Armitage *et al*. 1981: 31). The darkish flesh is sometimes heavily infected with worm parasites. Despite this, the flesh is considered good eating and is often smoked. The average size of adults varies from 60–90 cm, with some individuals reaching 120 cm. The fish are believed to have a maximum age rarely exceeding 10 years (Annala 1994: 31), although Ayling and Cox consider that otoliths from very large specimens may have been 30 years old (Ayling and Cox 1982: 287). Fish of 0 to 1 year in age have a fork length of 10–40 cm (Paul 1986: 12). Sexual maturity is reached at 2 to 3 years (50–60 cm fork length).

Barracouta bones occur in 96 sites in the Fishbone Database. There is wide variation in the proportion of barracouta in the total catches represented at these sites. This is illustrated in Figure 4.3. This variation is to be expected, given the strongly seasonal nature of their occurrence in coastal waters. Sites largely occupied during winter, for example, would not have abundant remains of

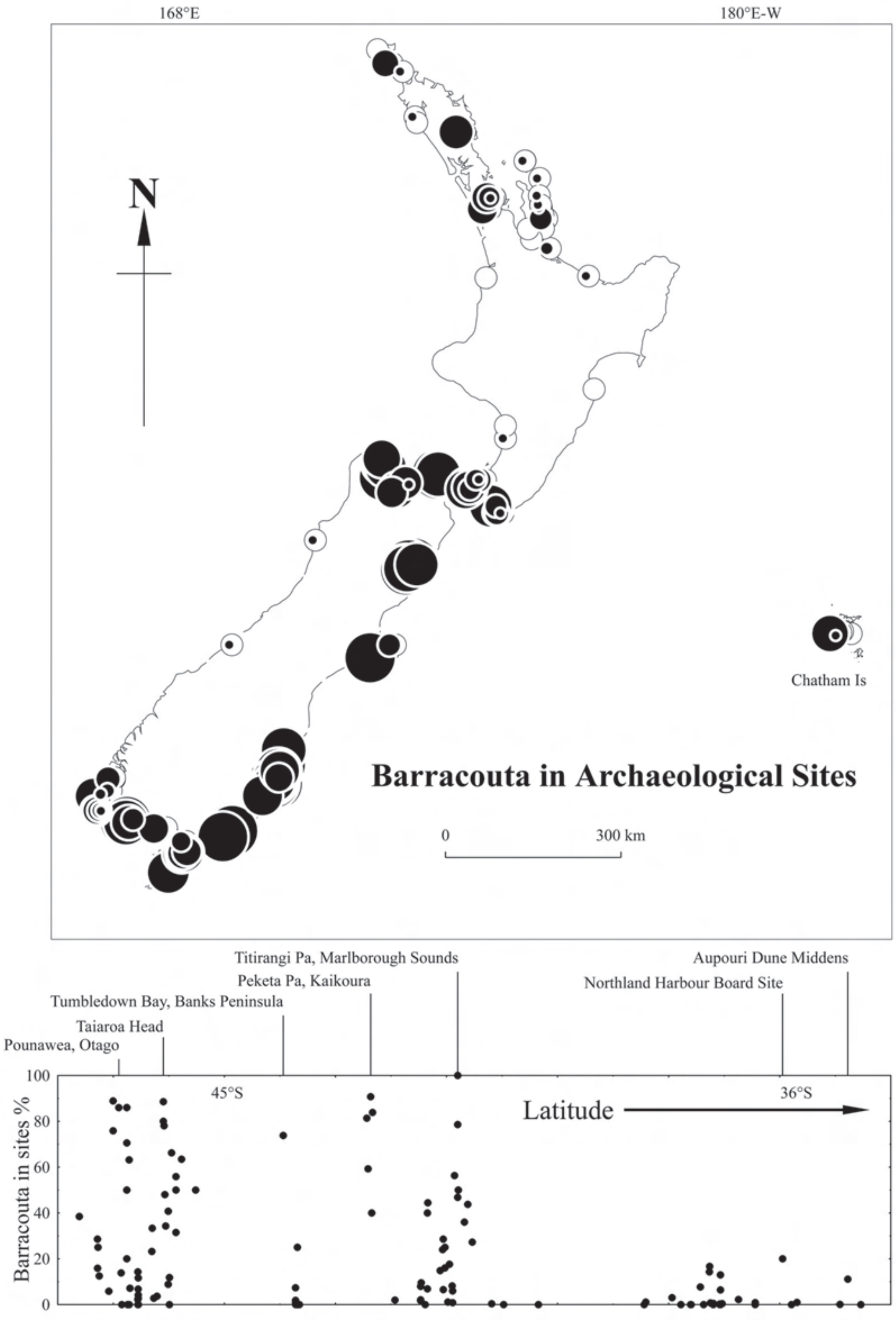


Figure 4.3: Upper: The size of the black circles indicates the relative abundance MNI of barracouta (log scale). White circles lack barracouta. Lower: Percent barracouta in sites by latitude. A few key sites are noted along the top.

freshly caught barracouta. Despite this seasonal variation, Figure 4.3 shows a marked difference between the South and North Islands. At no site in the North Island was barracouta represented by above 20% of the catch. Surprisingly few barracouta occur along the west coast of the South Island, and almost none in sites along either the east or west shores of the North Island south of Tauranga. North of Tauranga, quite a few sites show barracouta occurring in reasonable numbers. In the upper part of Figure 4.3 the size of a black circle represents the relative abundance in any one site. I chose a logarithmic scale for diameter size to give emphasis even to small numbers of barracouta; consequently, the apparent focus of barracouta fishing in the far north of New Zealand is not as strong as might appear from the map. However, it does show a significant batch of sites where barracouta are found, unlike the central areas of the North Island and West Coast of the South Island. Barracouta also feature in the fish catches in the Chatham Islands. In the lower part of Figure 4.3 the proportions of barracouta MNI in the sites are organised by decreasing latitude from left to right. In this and subsequent similar plots, all 126 sites are marked, but many on the x axis overlap. The positions of a few key sites are noted to provide landmarks along the top.

Barracouta bones from archaeological sites can be used to estimate the original live fork length and body weight in order to construct a size-frequency diagram for prehistoric catches and to estimate the relative amount of food from this source (Leach *et al*. 1996a). The archaeological site at Long

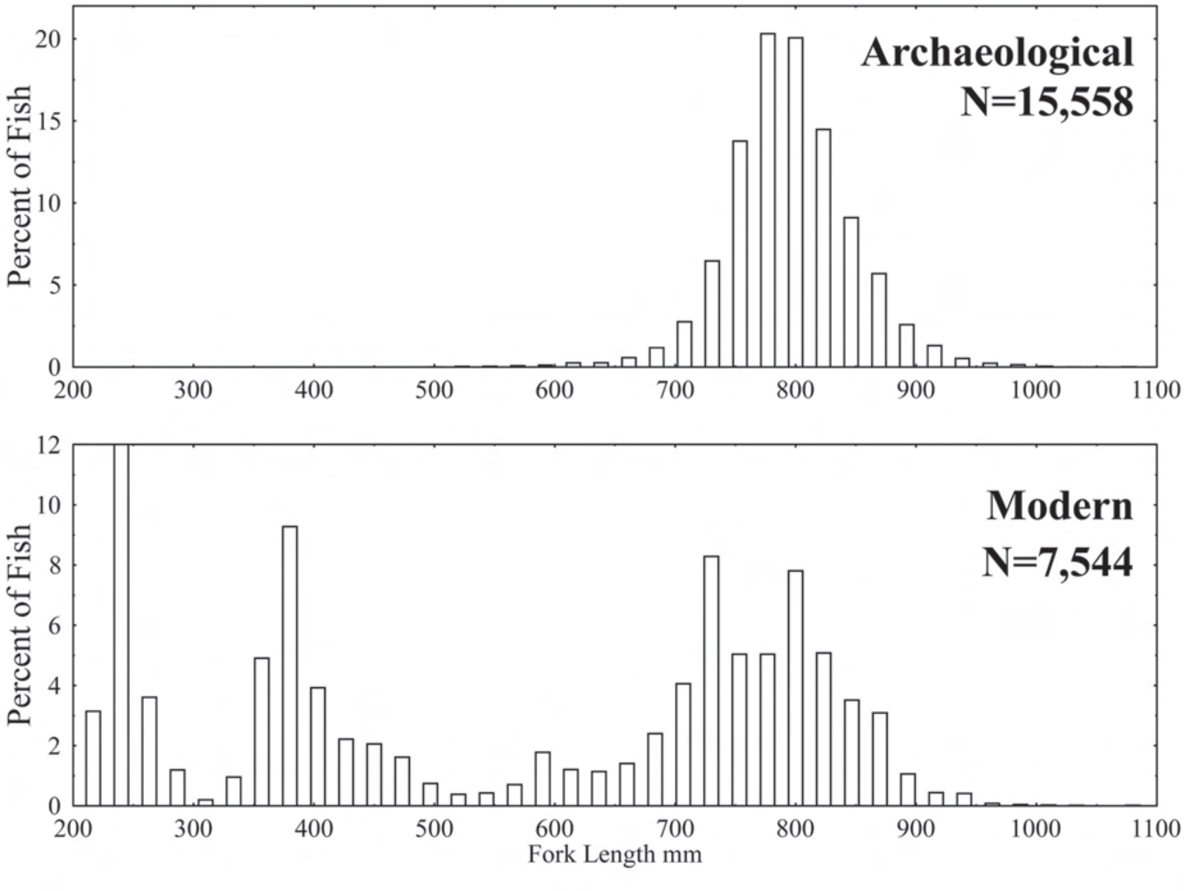


Figure 4.4: Upper: Size-frequency histogram of barracouta fork lengths from the site at Long Beach, Otago, based on 15,558 bone measurements (from Leach *et al*. 1996a: 19). Lower: A modern trawled catch of barracouta from southern New Zealand and the Chatham Islands area (after Hurst and Bagley 1987: 23 and Hurst *et al*. 1990: 29). Note the clearly different sizes of the age grades.

Beach in Otago provides a good example. The reconstructed catch (Fig. 4.4 upper) shows strong unimodal normal characteristics, with a mean fork length of 795 ± 0.4 mm. When this is compared with modern-day trawl data for Southern New Zealand and Chatham Islands (Fig. 4.4 lower), it is clear that the prehistoric people at Long Beach were taking individuals in the largest part of the size range.

Graham records his efforts catching surface barracouta at Otago during their seasonal abundance as being exhausting as the fish weighed between five and eight pounds [2.3 to 3.6 kg] (Graham 1956: 310 ff.). He states:

> The largest seen by me measured forty-four inches [1,118 mm] and weighed eight pound [3,629 g] when cleaned. It is stated that fish of ten pound [4,536 g] are caught but, although I examined hundreds, I did not see one this weight (ibid.: 315).

This is interesting information. Fisheries scientists have established the relationship between fork length and ungutted body weight of barracouta (Hurst *et al*. 1990: 35):

$$\text{weight g} = 0.009{*}\text{fork length}^{2.86}\ \text{cm}$$

Using this formula, we can estimate that a fish 44 inches long would have weighed 6498 g, well above Graham's figure. It suggests that he was measuring fish in their lean and hungry phase, when they reappear from October onwards into summer. We do not know when the Long Beach people were taking their barracouta, but it is likely to have been mainly during the great surface migration during the summer months when they feed inshore. This being so, the weight of meat per individual may have been on the lean side for the fishermen able to mass harvest these fish at this time. This is an example of the kind of information that can be derived from the detailed study of archaeological fishbone.

BLUE COD

The New Zealand blue cod, *Parapercis colias*, is not a true cod (family Gadidae), but belongs to the family Mugiloididae (Fig. 4.5). In New Zealand (as elsewhere) the name 'cod' has been given to various fish unrelated to true cod (see Leach *et al*. 2001b), although there are also two species of Gadidae. Other examples besides blue cod are the red cod *Pseudophycis bachus* (family Moridae) and the black cod or Maori chief *Paranotothenia angustata* (family Nototheniidae). This apparently conflicting taxonomy is merely a reflection of the diverse ways in which humans classify familiar objects with different objectives in mind.

When Captain Cook visited New Zealand his sailors referred to the fish as Cole fish (Cook 1967 (II): 807 n.) because of its similarity to a European species in the cod family. The English fish, colloquially referred to as coalfish or just coley, is more properly named saithe, and is the species *Pollachius virens* [*Gadus virens* Linnaeus 1758] (Wheeler 1969: 272, 274). This species is often confused with *Pollachius pollachius*, which is a small offshore non-commercial fish. In North America, *P. virens* is called pollack. The name coalfish possibly comes from the fact that its flesh is sometimes a rather dark colour. The New Zealand blue cod has clear white flesh, but has a dark green body coloration.

Blue cod is known variously as *rāwaru*, *pākirikiri*, or *pātukutuku* by the Māori (Williams 1971: 332). These names do not occur in the tropical Pacific, nor does the species. Williams (ibid.) records

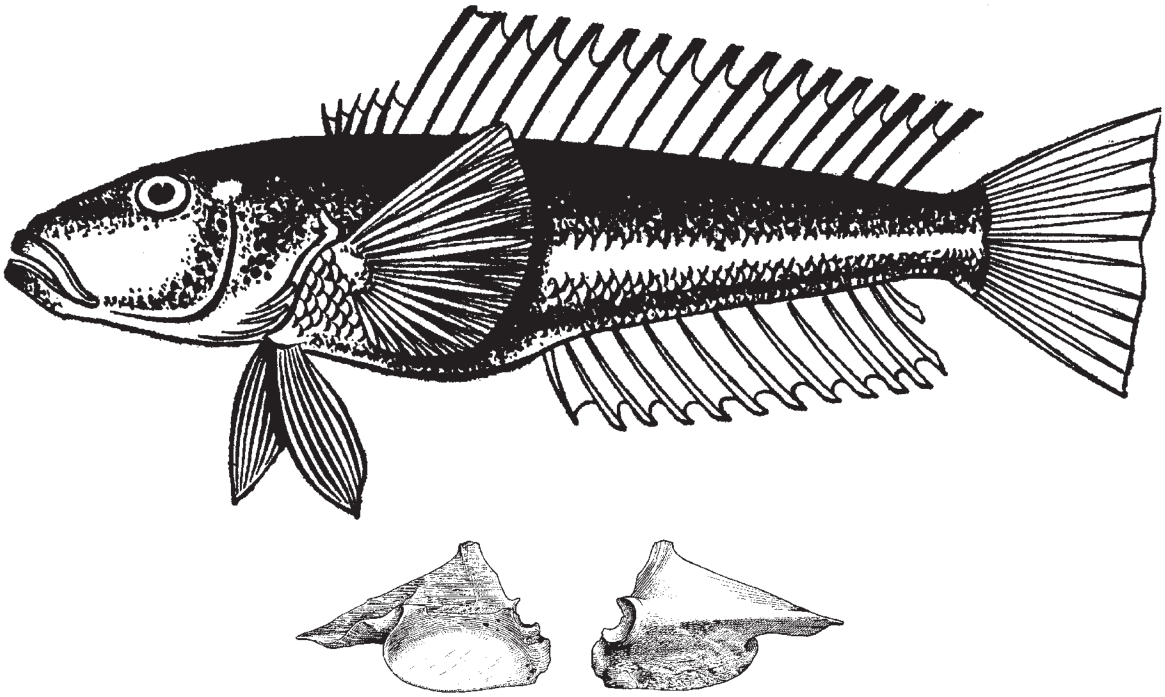


Figure 4.5: Blue cod, *Parapercis colias*, *rāwaru* (Māori) (after Doogue and Moreland 1966: 264, courtesy of Eric W. Heath). Below is the right articular bone, readily distinguishable from those of other species (from Leach 1997: 95).

that the name *pākirikiri* amongst the Ngapuhi also referred to both the spotty (*Notolabrus celidotus*) and a fish known further south amongst the Raukawa people as *tāngahangaha*. His entry for this name refers to spotty for the Raukawa people, and the banded wrasse (*Notolabrus fucicola*) for the Ngati Porou. This is somewhat confusing.

The blue cod is a plump fish producing good fillets, and a sizeable specimen is 50 cm in length. It occurs on all coasts of New Zealand, but is most abundant in the Marlborough Sounds, Foveaux Strait, Stewart Island, and the Chatham Islands, especially over rough rocky ground with weed. Graham notes that large numbers were formerly caught around Great Barrier Island north of Auckland (Graham 1956: 288), but the fish are smaller in northern waters. He also notes that these fish are sensitive to turbidity, and that when sediments are stirred they disappear to clearer water elsewhere. He believes this accounts for some dramatic changes in annual abundance in the Otago Harbour. Seasonal changes in abundance are also important, the fish coming closer inshore into the harbour as water temperature rises in summer. As soon as water temperature starts to fall about May with the onset of autumn, they migrate into deeper water where the temperature is warmer. Graham confirmed the sensitivity of the species to temperature with aquarium observations which show them becoming languid and uninterested in food in cold weather (ibid.: 289). He also records the unusual phenomenon that they become very nervous and agitated at the onset of stormy weather, and many would leap out of an aquarium to their death during thunderstorms. The influence of water temperature on abundance over fishing grounds is not apparent in northern areas (Doak 1972: 102).

Blue cod have a large gaping mouth and readily take a hook baited with almost any kind of fresh fish or shellfish. In the Marlborough Sounds, gut contents frequently contain small whole specimens of shellfish species.

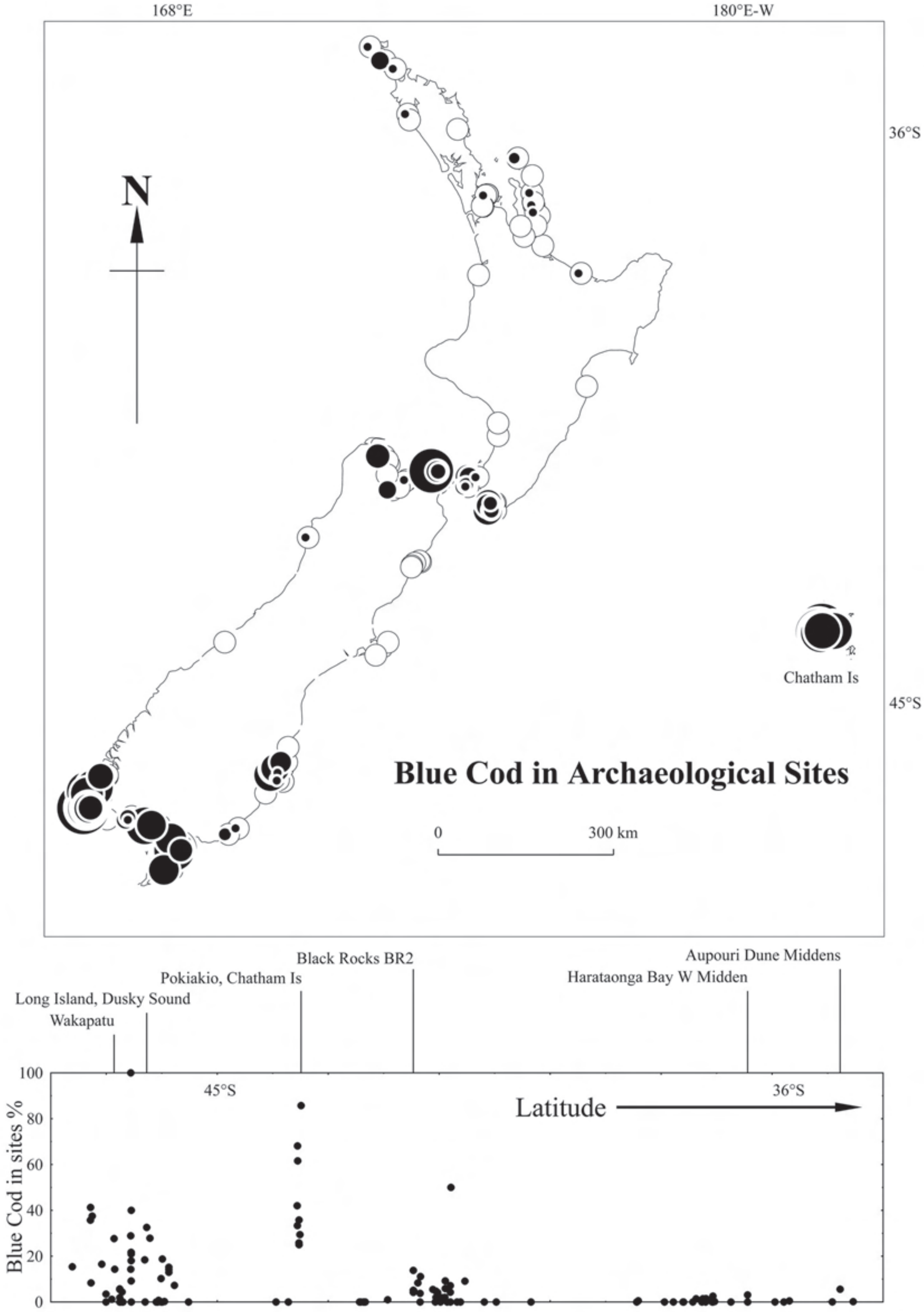


Figure 4.6: Upper: The size of the black circles indicates the relative abundance MNI of blue cod (log scale). White circles have no blue cod. Lower: Percent blue cod in sites by latitude. A few key sites are noted along the top.

Although blue cod live in waters down to about 80 m depth, they are abundant right up to the shoreline, and in many localities are strongly territorial all year round (Doak 1972: 102). This suggests that this species may be a suitable one to help document the impact, if any, of prehistoric fishermen on the inshore marine environment over archaeological time. This topic is explored in Chapter 7.

The frequency of blue cod in archaeological sites varies throughout New Zealand. In the Fishbone Database, blue cod are found in 78 sites, and comprise more than 10% of the total catch in 35. The species was important to the pre-European Māori in many parts of New Zealand (See Fig. 4.6).

This Figure illustrates the importance of the species in the Chatham Islands and in the Fiordland and Foveaux Straits area, with a second cluster of significant values around Cook Strait. They were only rarely caught further north.

For economically important species Government fisheries scientists usually have a well established relationship between fork length and body weight for very large samples of fish, and also for different sexes, at different seasons, and at different localities. However, in the case of blue cod, authoritative information is not yet available. Analysis of all data in the Ministry of Fisheries database for blue cod produces a working equation linking fork length in mm to ungutted weight in g as follows (Bradford 1996: pers. comm.):

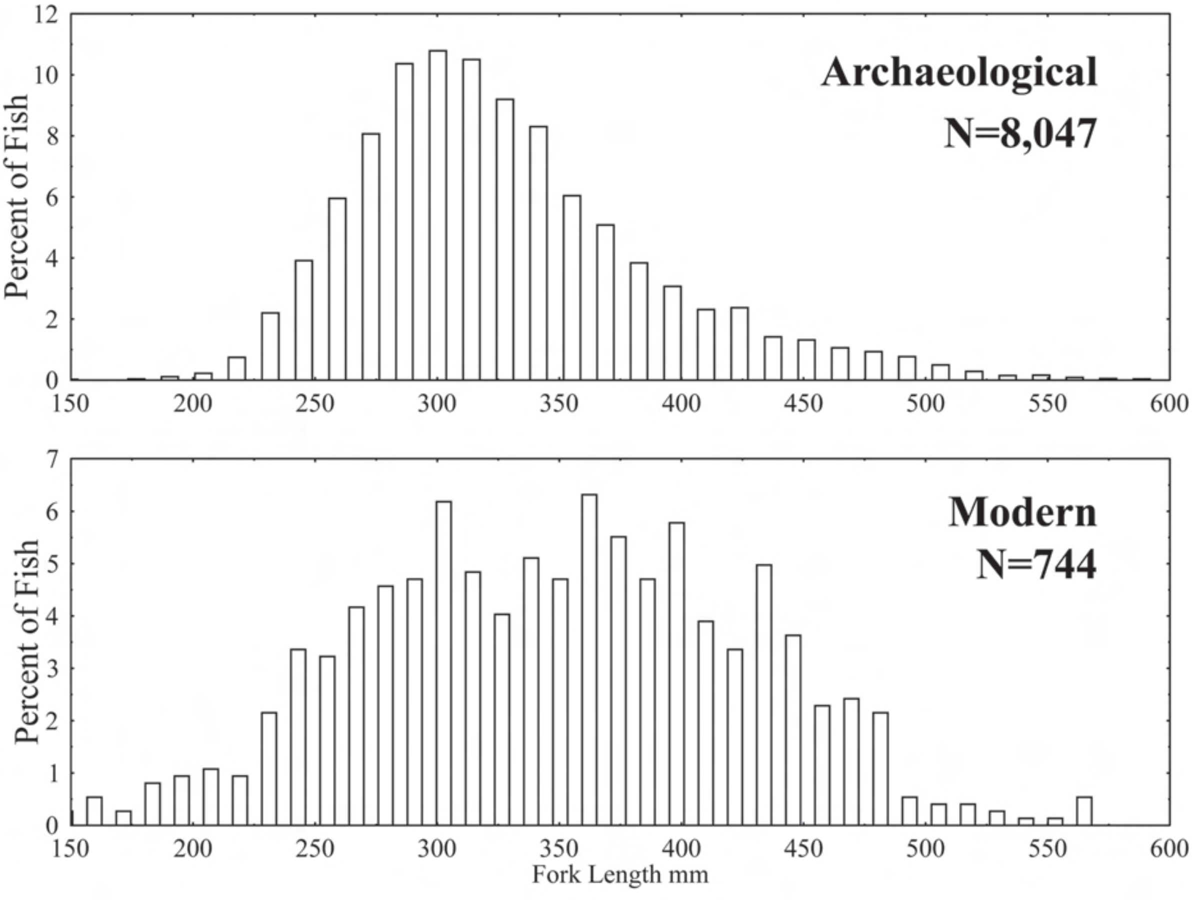


Figure 4.7: Upper: Size-frequency histogram of blue cod fork lengths from the Waihora Site in the Chatham Islands, based on 8,047 bone measurements. The largest specimen has a fork length of 616 mm. The mean is 327 ± 0.7 mm. Lower: modern trawled blue cod from Foveaux Strait south to the Snares area (after Hurst *et al*. 1990: 12, 17).

$$\text{weight g} = 0.0000119428 * \text{fork length}^{3.05} \text{ mm}$$

The relationship between archaeological bone measurements and live fish characteristics has been established for blue cod (Leach *et al*. 1997b), and enables the sizes of fish in prehistoric catches to be determined. The site at Waihora in the Chatham Islands (Sutton 1979a, 1980, 1989) provides a good example of this process. Of the 22,249 fish bones we were able to identify to species from this site, measurements were made on 8,047 bones from blue cod. After the live fork length and weight are estimated from the bone measurements, the data are pooled into a size-frequency histogram showing the character of the original catch (Fig. 4.7 upper). This can be compared with modern blue cod trawled from various locations in southern New Zealand from Foveaux Strait to the Snares area (Fig. 4.7 lower).

The mean weight of the fish represented by the bones from Waihora was estimated to be 569 ± 3.8 g (i.e., ± 0.67%). From this, the total weight of blue cod in the excavated part of the site can be estimated, using the MNI value for the species. Of the total MNI of 6,907 fish at this site, 2,547 were blue cod (36.9%). Thus, the total weight of blue cod can be calculated as:

Mean Body Weight	x	MNI		Total Body Weight	Usable Meat Weight
569 g	x	2547	=	1,449 ± 10 kg	1,015 kg

Smith (1985: 487–488, 2004: 8, 10) recommends using a figure of 70% for the amount of usable meat weight per total body weight for the common species of New Zealand fishes. At Waihora, this is estimated to be about 1.0 metric tonne of blue cod meat. The stated error of ± 10 kg for the total body weight is based on the standard error of the mean weight of fish, which is ± 0.67%.

SNAPPER

This fish, *Pagrus auratus* (Fig. 4.8), belongs to the Sparidae family. It is known as *tāmure* by the Māori. In the tropical Pacific, the most commonly occurring species in this family is *Monotaxis grandoculis*, which is widely known as *mū*. This name is traceable right back to the Malayo-Polynesian proto language (Biggs and Clark POLLEX 1996), and is therefore very widespread. Where a recorder was able to identify the precise fish of this name, *Monotaxis grandoculis* is invariably noted. Although the New Zealand snapper is not present in the tropical Pacific, it is surprising that the first immigrants to New Zealand did not name this fish *mū*. Despite the fact that they are clearly two different fish, they also have similarities, including strongly molarform teeth, somewhat human-like. Some years ago during a collecting expedition in the Solomon Islands I wished to obtain a specimen of *Monotaxis grandoculis*, but the people on the island where I was working did not recognise the name *mū*. When I described the fish as *te ika niho o te tangata* (the fish with teeth like a man) I was immediately understood and the fish was caught for the comparative collection. Of even greater surprise than the fact that the earliest Māori did not name the snapper after its Pacific counterpart, is that they gave the name *mū* to some other sea fish. Unfortunately, the identity of this second fish is not recorded (Williams 1971: 213; Biggs and Clark POLLEX 1996). The word *tāmure* as *tāmule* is traceable as far back as the Central East Polynesian proto-language, and derived cognates are present on Pukapuka (Northern Cook Islands) referring to *Lethrinus mahsena*, on Rapa referring to *Lethrinus fulvus*, and in the Tuamotus referring to *Lethrinus rivulatus*. It is hard to understand why the Māori gave the snapper the same name as a species in the tropical Lethrinidae family (emperors), but it highlights the importance of recognising that there is no single taxonomy of the natural world.

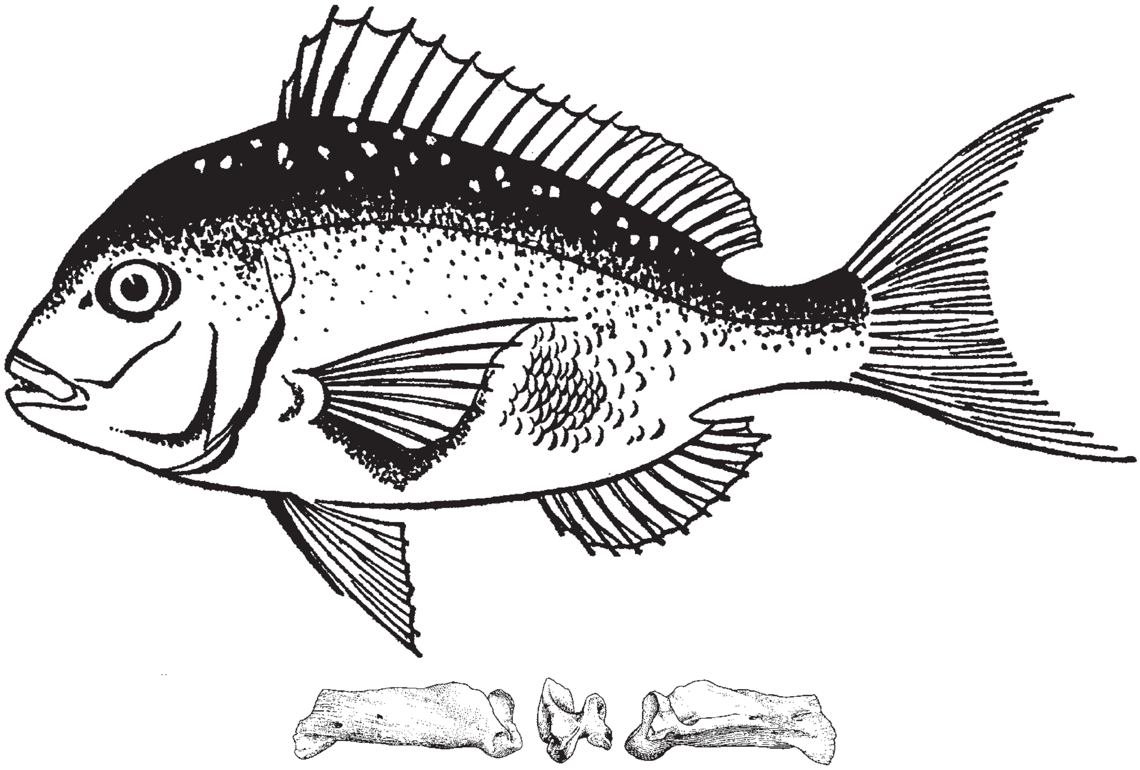


Figure 4.8: Snapper, *Pagrus auratus*, *tāmure* (Māori) (after Doogue and Moreland 1966: 239, courtesy of Eric W. Heath). Below is the right maxilla bone, highly distinctive of this New Zealand species (from Leach 1997: 101).

This fish is more common in northern waters than further south, and is easily taken in the spring spawning season, when it is referred to as school snapper. There appear to be several spawning grounds. The average size varies regionally, and it is thought that there are reasonably isolated populations, possibly genetically distinctive. Graham observed that fish in Otago waters were much thinner than those further north (Graham 1956: 243). Specimens on the north-east coast of New Zealand average 30–50 cm, whereas fish on the west coast tend to be somewhat larger (Paul 1986: 96) and have a faster growth rate. The maximum size is about 100 cm. The fish reaches maturity at 3–4 years, and adults often reach 20–30 years. Some individuals are thought to live for as much as 60 years. It is important to note that these fish are not strongly migratory in their habits, so a heavily fished locality takes time to recover. This makes it a useful species with which to assess human impact on marine environments. This matter is further discussed in Chapters 7 and 9.

An interesting feature of snapper is the tendency of large fish to develop pronounced exostoses (bony growths), particularly on the supraoccipital crest (one of the head bones). These growths are known as ‘tilly bones’, and occur in several fish species. All individuals of the same species do not necessarily have tilly bones, but if these bones are present they will occur on the same anatomy in individuals of one species. The presence or absence and function of tilly bones are not clearly understood, but may relate to age or other factors. Tilly bones are robust and in some archaeological sites and natural deposits provide the only evidence that fish were once represented (Konnerth 1966: 8). In the case of mackerel (*Trachurus* spp.) up to three tilly bones can be present in the skull of an individual; one in the supraoccipital region, and one attached to each cleithrum (Leach *et al.* 1994a). Tilly bones are relatively common in archaeological sites containing snapper and mackerel, and can be used for calculation of MNI. These bones were evidently of interest to Maori, as a number of archaeological examples have been carved, and sometimes perforated for use as pendants. Furey (2002: 44–45 and Fig. 58) describes a single example from Houhora, noting that this is the only reported example from an early site, and illustrates other examples from the later site of Oruarangi (Furey 1996: 43 and Figs 51–54).

Snapper readily take a baited hook and can also be taken in either dragged or set nets. They are usually a bottom dwelling fish. Although they shoal during the spawning season, older individuals leave the shoal and become solitary in shallow coastal waters. The fish spawn in late spring or summer when the surface temperature reaches 18˚C. They gather at this time in large shoals, in November and December, rising and falling in depth with changes in water temperatures. This process extends to January and February in some areas (Annala 1994: 197). Knowledge of these movements enables mass capture to be undertaken. Adults move to inshore feeding grounds in late summer after the spawn, and move into deeper waters in the winter.

It has been found that water temperature is a very important factor in the recruitment process — strong year classes are produced in warm years, and weak year classes in colder years. This is illustrated in Figure 4.9, which shows the abundance of one-year-old snapper in the Hauraki Gulf plotted against the mean February to June water temperature. The plot on the left shows the estimated number of one-year old fish in the trawlable area of the Hauraki Gulf during the years 1982–1994, and that on the right shows the modelled relationship between temperature and recruitment, which is exponential in character.

This strong relationship has important implications for archaeological studies of snapper fishing. In cases where short-term seasonal camps are being investigated, we might expect to see some significant changes in size-frequency catch distributions between one site and another, or from one layer to another. However, for sites occupied for many seasons, such short-term fluctuations will be smoothed over, and observed differences in catch statistics can be expected to signal the existence of longer term trends, such as human impact on the local marine stock, or changes in

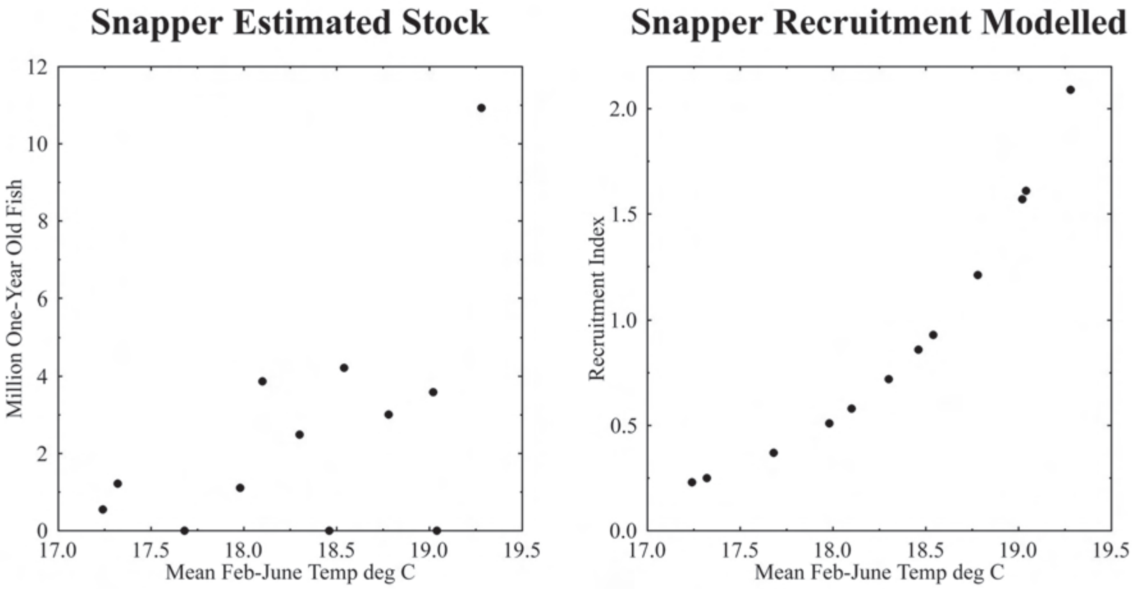


Figure 4.9: The relationship between water temperature and recruitment of one-year-old snapper in the Hauraki Gulf (after Annala 1994: 198).

climate. It is now well established that there have been significant climate changes in New Zealand during the last thousand years (further discussed in Chapter 7), and this is bound to have had an effect on the relative abundance of different fish species regionally at different periods of time.

Fisheries scientists at NIWA (National Institute of Water and Atmospheric Research) have undertaken many studies of the New Zealand snapper over a long period and a great deal is now known of the biology and habits of this species. This provides a rich background source of knowledge against which to evaluate archaeological finds. For example, the likely effect of modern human populations on fishing for snapper is now reasonably well understood. When we come to examine the possible impact of pre-European Māori on inshore snapper in Chapters 7 and 9, this is very useful information. One important concept used in these studies is the Maximum Constant Yield, MCY. This is defined as:

> MCY — Maximum Constant Yield
> The maximum constant catch that is estimated to be sustainable, with an acceptable level of risk, at all probable future levels of biomass (Annala 1994: 10).

In the case of a species like snapper, prone to major fluctuations in annual recruitment, there is a greater risk associated with a higher than average annual catch than for another species not prone to such fluctuations. It is a complex problem to work out what the MCY is for a particular species, but one important variable is the *Virgin Biomass*. In New Zealand, this is assumed to be the biomass at some time between the end of the prehistoric period and the beginning of significant European impact on the fishery. In other words, when trying to set limits to fish catches, it is currently assumed that the pre-European Māori had no significant impact on any commercial species. This has yet to be demonstrated in an acceptable manner, and is one of the focuses of archaeological research. Table 4.2 gives the currently accepted values for the Virgin Biomass, Current Biomass, and MCY, for the three main fisheries regions for snapper.

TABLE 4.2

Estimates of biomass and Maximum Constant Yield per annum of snapper for three areas of New Zealand. SNA1=Auckland East (Coromandel to North Cape), SN8=Auckland West/Central West (North Cape to Cook Strait), SNA7=Challenger (Cook Strait to Haast). Values are in tonnes. After Annala (1994: 199 ff.).

Area	**Virgin Biomass**	**Current Biomass**	**Biomass Lost**	**MCY**
SNA1	450,000	40,427	91%	3,470–6,130
SNA8	73,200	12,700	83%	1,175
SNA7	20,700	1,000	95%	448

These figures relate to the entire area of waters covered by the New Zealand 200 nautical mile EEZ (exclusive economic zone), and the fish are largely taken by trawling. This species is most common in waters of 10–60 m depth range, although they are found to 200 m depth. The area where snapper are located is therefore within a few miles of the shoreline in many places; and although pre-European Māori fishermen would have traversed most of the area covered by modern trawling for snapper, their catch rate beyond the immediate shoreline is bound to have been orders of magnitude lower than that of modern fishing activities for this species. In other words, the effective biomass available to pre-European fishermen would have been considerably less than the suggested virgin figures cited above. This is something which needs to be taken into account when assessing the likely impact of early fishermen on the fishery. Annala calculates the maximum catch which could be sustained by the stock (the Maximum Sustainable Yield, MSY) as being reached when the catch to biomass ratio is 9.2% (Annala 1994: 202). This is a useful rule of thumb to bear in mind.

Of further interest are the relative catch rates of commercial and non-commercial (recreational) fishing activities. Some estimates for different areas and different years between 1984 and 1991 are given in Table 4.3.

TABLE 4.3
Estimates of annual non-commercial snapper catches (from Annala (1994: 197).

Area	**Catch tonne**	**Percent of Commercial Catch**
Bay of Plenty	400	30
Hauraki Gulf	830	20
East Northland	370	17
West Coast North Is	250	13
Tasman/Golden Bay	15	8

This provides another useful yardstick against which to evaluate the relative size of the pre-European snapper catch. This will be considered further in Chapter 9.

Snapper remains have been found in 54 of the archaeological sites studied. As might be expected from the foregoing, they are especially abundant in North Island sites, falling off dramatically to the south. The influence of latitude, as well as local fluctuations in frequency, are evident in the lower part of Figure 4.10. Sites with significant fish remains but low proportions of snapper probably indicate habitation during the months of the year when snapper moved offshore into deeper waters and were much harder to catch.

The map (Fig 4.10 upper) shows that some snapper occur as far south as Pounawea and Papatowai in the Catlins area of Southland. These sites are relatively early in the archaeological sequence, and the somewhat warmer climatic conditions which prevailed in New Zealand at that time may be the explanation for these very southerly catches in the prehistoric period. This remains to be verified. It is a little surprising that very few snapper appear on the map along the west coast of the South Island. Although not abundant there today, snapper do straggle down this coast. We could again be observing the influence of changing climatic conditions, since the sites excavated in the Fiordland area are very late in the prehistoric sequence, possibly all dating to the period of the Little Ice Age[3]. Archaeological sites studied in the Chatham Islands contain no snapper. However, these sites are relatively late in the prehistoric sequence. It will be interesting to see if any snapper remains occur in early sites in these outlying islands.

Research has been carried out to estimate live catch characteristics from archaeological bones of snapper (Leach and Boocock 1995), and this enables the sizes of fish in prehistoric catches to be determined. The site at Houhora in Northland, excavated by Roe (1969) and Shawcross (1972), provides a suitable sample with which to evaluate a prehistoric catch. We were able to measure 8,847 snapper bones. After the live fork length and weight are estimated from the bone measurements, the data are pooled into a size-frequency histogram showing the character of the original catch. This catch is compared with modern commercial trawl data for snapper along Ninety Mile beach in Northland in Figure 4.11; the archaeological specimens are much larger than the modern catch, on average 133 mm longer.

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[3] This is discussed fully in Chapter 7.

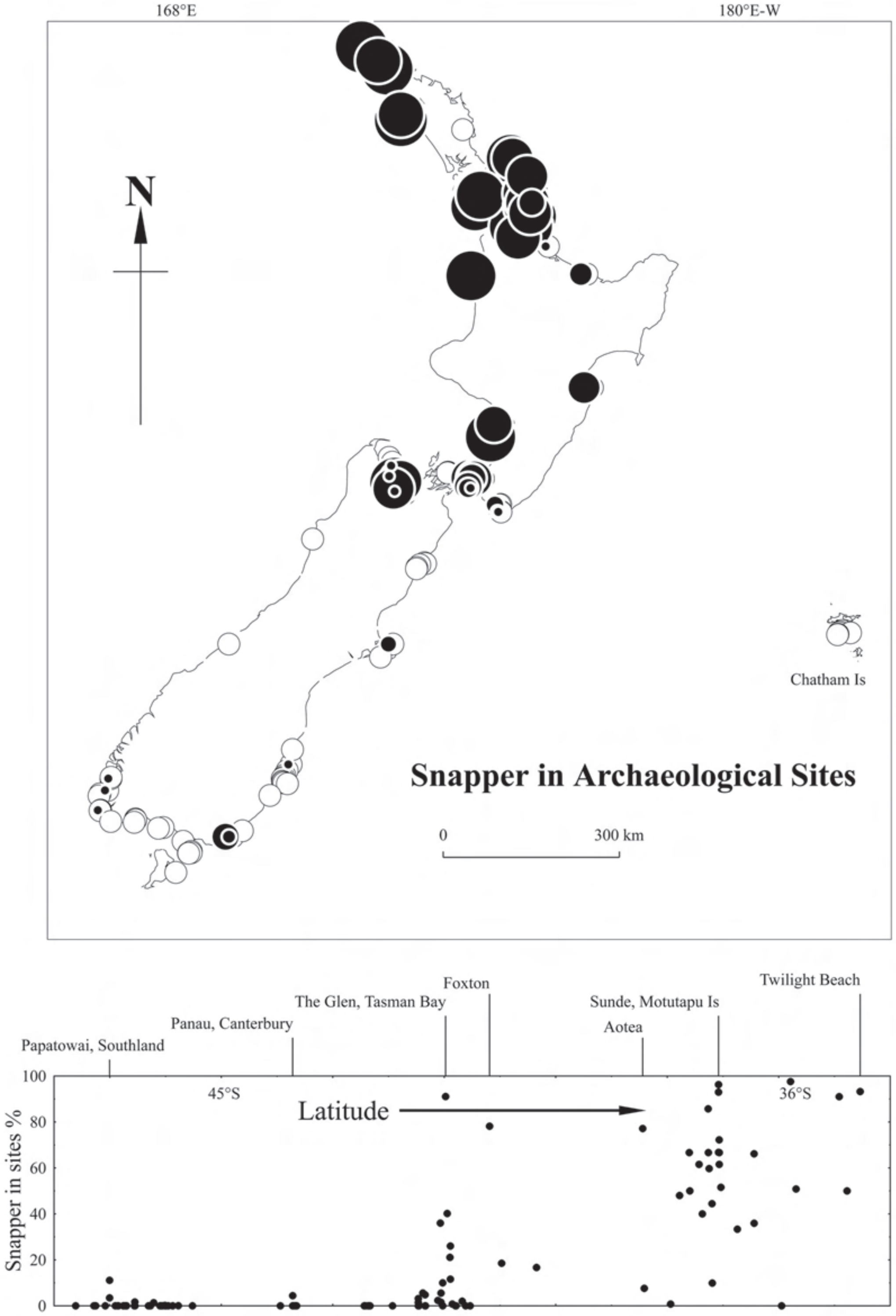

Figure 4.10: Upper: The size of the black circles indicates the relative abundance MNI of snapper (log scale). White circles have no snapper. Lower: Percent snapper in sites by latitude. A few key sites are noted along the top.

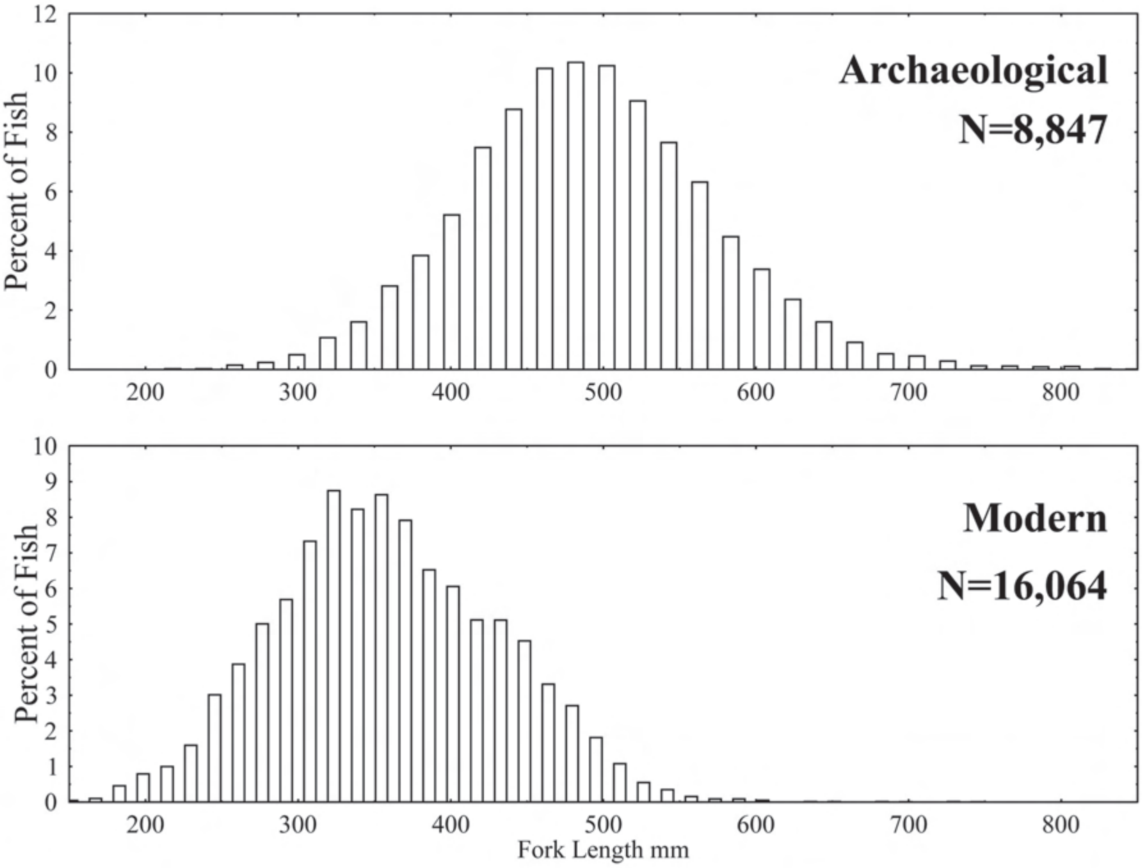

Figure 4.11: Upper: Size-frequency histogram of snapper fork lengths from the site of Houhora in Northland, based on 8,847 bone measurements. The largest specimen has a fork length of 1,010 mm. The mean is 491 ± 0.8 mm. Lower: Modern-day commercial trawls along Ninety Mile Beach (mean = 385 ± 0.6 mm).

The mean weight of the fish represented by these archaeological bones was estimated to be 2473 ± 13 g (i.e., ± 0.53%). From this, the total weight and usable meat weight of snapper in the excavated part of the site can be estimated. The snapper MNI at the site was 2,207 fish. Thus, the total weight of snapper can be calculated as:

Mean Body Weight	x	MNI		Total Body Weight	Usable Meat Weight
2473 g	x	2207	=	5,458 ± 29 kg	3,821 kg

The stated error of ± 29 kg for the total body weight is based on the standard error of the mean weight of fish, which is ± 0.53%. The usable meat weight is estimated using the figure of 70% of total body weight, as described above for blue cod.

The largest snapper at Houhora has an estimated fork length of 1,010 mm. This is an exceptionally large individual. Several other very large fish were around the 800 mm mark. If we use the formula suggested by Annala (1994: 198) of:

$$\text{weight g} = 0.04467 * \text{fork length}^{2.79}\ \text{cm}$$

this would provide an estimate of the body weight of this individual of 17,705 g. Our own metrical study, estimating live weight directly from bone measurement in our modern comparative collection of snapper, provides an estimate just on 1 kg higher than this at 18,762 g. The largest specimen in the comparative collection has a fork length of 940 mm, and weighed 17,200 g. Two points can be noted — Annala's equation does seem to underestimate for very large fishes, because the archaeological fish is 70 mm longer than our largest specimen, yet the estimated increase in body weight would only be 505 g. The second point is that whatever formulae are used, they represent extrapolation beyond the limits of our modern samples, and this is fraught with difficulties. We can, however, say that this fish was extremely large, and would have been a cause of great celebration when some early Māori fisherman brought it home in his canoe at Houhora.

SPOTTY, SCARLET WRASSE, AND BANDED WRASSE

A very popular book entitled *New Zealand Sea Anglers' Guide*, by Doogue and Moreland, first appeared in 1960. This useful reference work provides a short summary of the biology, habits, food qualities, and where and how to catch the most common fishes in New Zealand. The advice given on how to catch spotties is: "ask any small boy at the wharf" (Doogue and Moreland 1966: 257). This tongue-in-cheek comment conveys the simple message that the humble spotty is both ubiquitous and very easy to catch with even the most rudimentary fishing gear. This fish belongs to the Labridae family (also known as wrasses). Labrids are solitary foraging carnivorous animals with sharp conical teeth. They possess a highly developed pharyngeal mill for crushing up shell and other food-bearing matter. These specialised bones are characteristic of this family, and common in archaeological sites.

There are seven genera and 16 species of labrid in New Zealand waters (Paul 1986: 107), but most of these are found in northern offshore waters. There are only three common inshore species (Fig. 4.12): the spotty *(Notolabrus celidotus*), the scarlet wrasse *(Pseudolabrus miles*), and the banded wrasse *(Notolabrus fucicola*). Although these eat a wide variety of food, the spotty prefers bivalves, the scarlet wrasse hermit crabs, and the banded wrasse crabs, hermit crabs, and molluscs such as limpets, small pāua[4] and mussels (Doak 1972: 76, 82).

The Māori names for members of the Labridae family are somewhat confusing. Doogue and Moreland give *paketi* and *pakirikiri* for spotty, and *pau* and *puwaiwhakarua* for scarlet wrasse (Doogue and Moreland 1966: 257–258). Graham provides *paekirikiri* for spotty, and *puwaiwhakarua* for scarlet wrasse (Graham 1956: 270, 272); these are possibly southern dialect names. Ngata gives *pākirikiri*, *kopukopu* and *tāngānga* for spotty; and *tāngahangaha* for banded wrasse (Ngata 1993: 27, 446). Williams is a more authoritative source, particularly as names are often attributed to dialect. He records *pākirikiri* as being the name for spotty amongst Ngapuhi and that the same fish is known as *tāngahangaha* and *kopukopu* further south. He lists both *tāngahangaha* and *tāngānga* as the name for spotty amongst Ngati Raukawa, and the name for banded wrasse for Ngati Porou (Williams 1971: 254, 378). Biggs and Clark show that the Māori word *taangaha* (also *taangahangaha*) is the same word as *tagafa*, widespread throughout Western Polynesia, occurring in a number of cognate forms in different islands (Biggs and Clark POLLEX 1996). The name in the tropics refers to *Cheilinus undulatus* (a very large labrid, usually over 1 m in length with a bulbous head), or *Cheilinus fasciatus* (the scarlet-breasted Maori wrasse).

Observations by divers have shown that labrids are solitary, aggressive, home-ranging fishes that will defend a particular territory. They frequent rocky areas and are active during daylight hours.

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[4] Pāua, *Haliotis* spp. (family Haliotidae), are univalve molluscs closely related to European ormer and North American abalone. Pāua are prized by Maori as food and the shells are valued for their iridescent quality. In former times they were used in fish lures, as well as for ornaments and inlaid decoration on wood carvings.

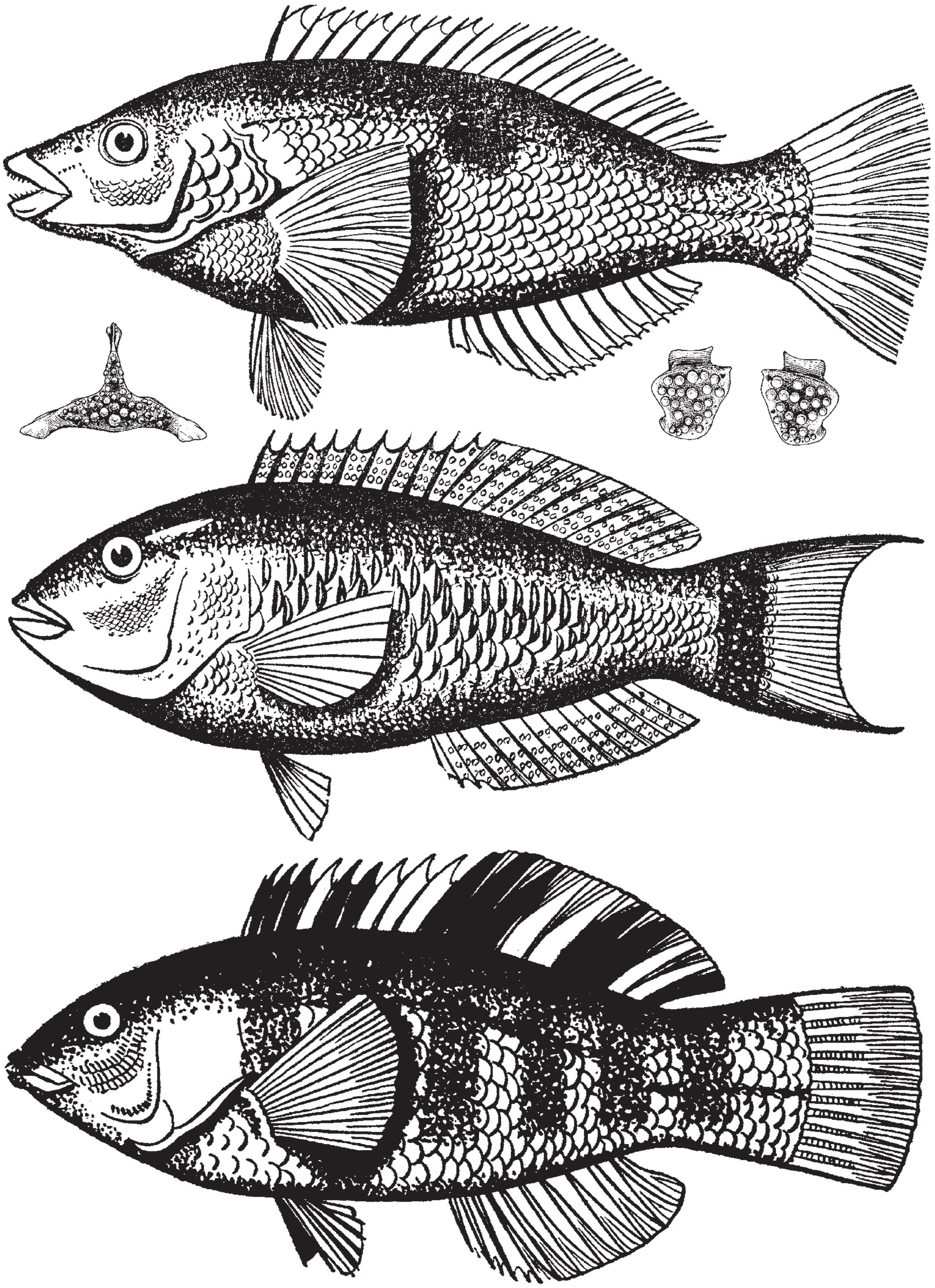

Figure 4.12: Three common species of New Zealand labrids. From top to bottom: spotty (*Notolabrus celidotus*), scarlet wrasse (*Pseudolabrus miles*), and banded wrasse (*Notolabrus fucicola*) (after Doogue and Moreland 1966: 257–259, courtesy of Eric W. Heath). Below the spotty on the left is its inferior pharyngeal bone, and to the right its paired superior pharyngeal bones (Leach 1997: 43).

At night they hide in crevices and do not feed. Spotties, the smallest of the three main species (mean fork length 183 mm), are found in greatest concentration in shallow water, tapering off at about 12 m. The scarlet wrasse, which is a medium-sized fish (mean fork length 290 mm), starts to appear at about the depth at which spotties tail off, occurring from about 9 m to 120 m. The banded wrasse (mean fork length 330 mm) lives amongst seaweed and at night rests in the upper 5 m depth range, covered in a protective mucous envelope. It is found down to a depth of about 36 m. It is interesting that these types of fish are almost never eaten by modern European New Zealanders, who consider them fit only for use as bait. However, they were a very popular food item in pre-European times.

Graham provides wonderful descriptions of each of these three fish with observations about their behaviour in an aquarium, their eating qualities, and general biology. The scarlet wrasse he describes as a rather docile fish, quite unlike the other two. Spotty are constantly on the move, darting this way and that, and will eat just about anything. Banded wrasse are extremely territorial and aggressive, and are capable of killing and eating pāua and even large crayfish. He was particularly fascinated by the fact that labrids went to sleep at night, lying flat on the bottom, but woke instantly if disturbed. He cites Aristotle[5] as being the first to make this observation of labrids (scarus is another name for labrids):

> Scarus alone their folded eyelids close
> In grateful intervals of soft repose,
> In some sequestered cell, removed from sight,
> They doze away the dangers of the night (Graham 1956: 273).

The biology and behaviour of the labrids can provide important clues about prehistoric human fishing behaviour. The fact that they are only really active during daytime suggests that pre-European Māori fishermen would only be able to catch them during daylight hours. The relative abundance of different species can also be a useful guide to the depth where fishermen were focusing their effort. The solitary and home-ranging behaviour of these fish makes this family a useful one with which to explore issues of overfishing and environmental impact of prehistoric human communities over archaeological time.

Although it is easy to identify live labrids to species from their colour and external shape, they are far more difficult to identify from their bones. The three common species, referred to above, have a distinctive spine formula (D. IX, 11; A. III, 10)[6], fairly reflecting the difficulty confronting

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[5] This English verse is obviously not attributable directly to Aristole. When I traced the source of this it appeared that Graham had copied Holder (1903: 275) without acknowledgement, who in turn had copied without acknowledgement Diaper's translation into verse of Oppian's didactic poem about fish c. A.D. 190 entitled the *Halieutica* (Diaper and Jones 1722 [Book 2]: 105). The original Greek of Oppian was translated by Thompson as "It is never caught at night, for it sleeps all night long" (Thompson 1947: 239, citing *Halieutica* ii: 662). Athenaeus, in his *Deipnosophistae*, probably written soon after Oppian's work, cites Seleucus of Tarsus in *The Art of Angling* (also called *Halieutica*) as saying: "is the only one of all the fishes that does not go to sleep: hence it cannot be caught at night" (Gulick 1929: 437). Gulick notes that Casaubon, in his 1595 edition of Athenaeus, added the negative to the Greek; it is obvious that without the negative the sentence did not make sense. No amount of searching uncovered any comment on the sleeping habits of Scarus by Aristotle himself.

[6] The spine formula refers to the number of spines on the back (dorsal) and lower body (anal) fins, counting from front to back in each case. The two sets of two kinds of spine can be seen in Figure 4.12. There is slight variation around the formula, sometimes as a result of injury to the fish. Even so, this formula clearly distinguishes these fish from other species and reflects their close relationship. The formula cited here D. IX, 11 means the dorsal fin has 9 sharp spines and 11 soft spines, and A. III, 10 means the anal fin has 3 sharp spines and 10 soft spines.

archaeologists. I believe that with a greatly improved modern comparative collection (multiple specimens from all 16 species) it may be possible to identify some species from some of the anatomy. However, it is unlikely that we will ever be able to identify species reliably from all five paired cranial bones which we routinely analyse from archaeological sites. The first step towards understanding ancient fishing behaviour is to establish the relative abundance of different types of fish. This is done, not on the basis of one part of the anatomy, but on the combined results from several parts of the bony skeleton (Leach 1997). Unfortunately, we have to accept that it is very difficult to separate bones into the different labrid species. Some recent attempts to do this rely on the different size-frequency distributions of the different species, and also on different allometric relationships between bone dimensions. The size-frequency distributions of samples of the three common species are shown in Figure 4.13, and some dispersion statistics in Table 4.4.

TABLE 4.4
Modern fork lengths for three common Labrid species

Species	**N**	**Range**	**Mean**	**SD**
Spotty	138	133–283	202.9	28.1
Scarlet Wrasse	122	184–375	290.3	39.9
Banded Wrasse	126	206–443	319.1	57.0

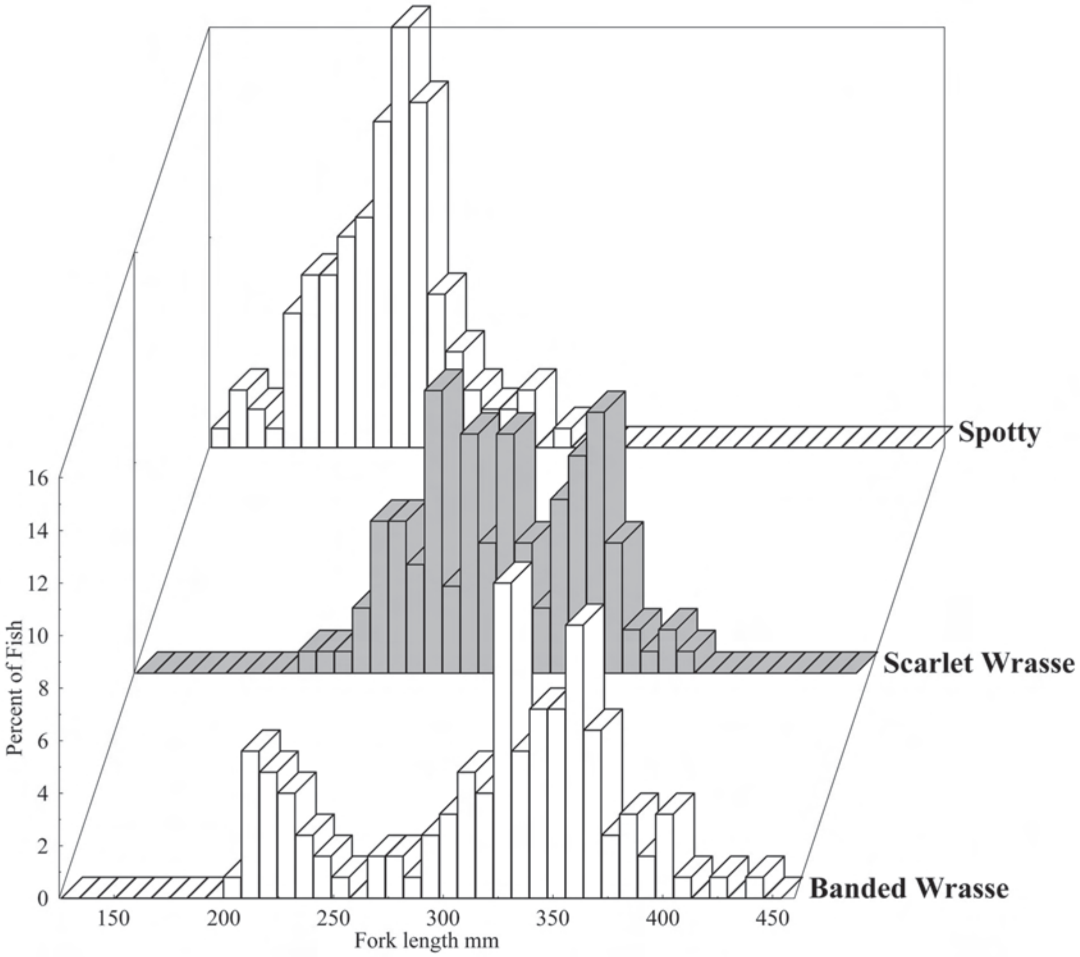

Figure 4.13: Size-frequency diagrams of modern specimens of three common species of labrids in New Zealand: spotty (N=138), scarlet wrasse (N=122) and banded wrasse (N=126) (after Leach and Davidson 2001b: 139).

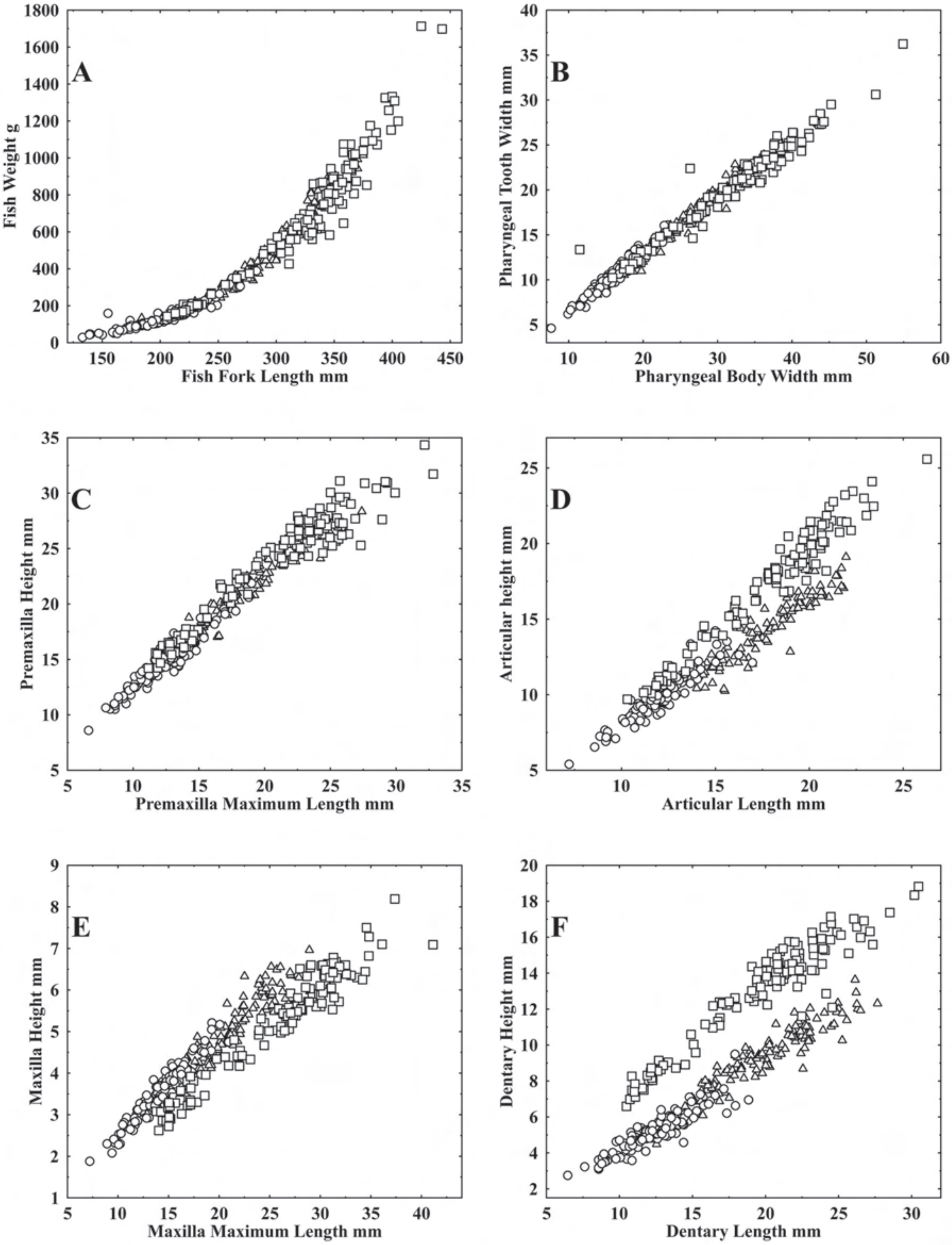

Figure 4.14: Scatter plots of various dimensions showing the extent of overlap between the three species of labrid. The open circles are the spotty at the small end of the size range, the triangles are the scarlet wrasse in the middle size range, and the squares represent the banded wrasse at the large end of the size range (after Leach and Davidson 2001b: 140).

Although there is overlap between the species, this is sufficiently small to raise the possibility of separating archaeological bones on the basis of size. Some bone dimensions of the same specimens are plotted out in Figure 4.14. This shows encouraging signs of separation of at least the banded wrasse from the other two species in the relative dimensions of the dentary. Dentary measurements have been subjected to multivariate analysis to see if reliable identification could be made using canonical equations (Leach and Davidson 2001a, 2001b), and this has proven to be very successful for separating the banded wrasse, and moderately successful for separating spotty from scarlet wrasse (Fig. 4.15). Unfortunately, other bones of the three species do not vary sufficiently in size to enable them to be distinguished at all using this kind of approach.

The frequency of labrids in archaeological sites in New Zealand is rather variable. In the Fishbone Database, 62 sites contain labrids at more than 5% of the total catch. The highest figures are from sites in Cook Strait, Foveaux Strait, and the Chatham Islands (Fig. 4.16). This partly reflects variations in natural abundance, but as discussed in Chapter 3 and illustrated in Figure 3.8, it also reflects preferential fishing close inshore at times when sea conditions made it very difficult to use canoes for access to favoured deeper water fishing spots (Leach and Anderson 1979a).

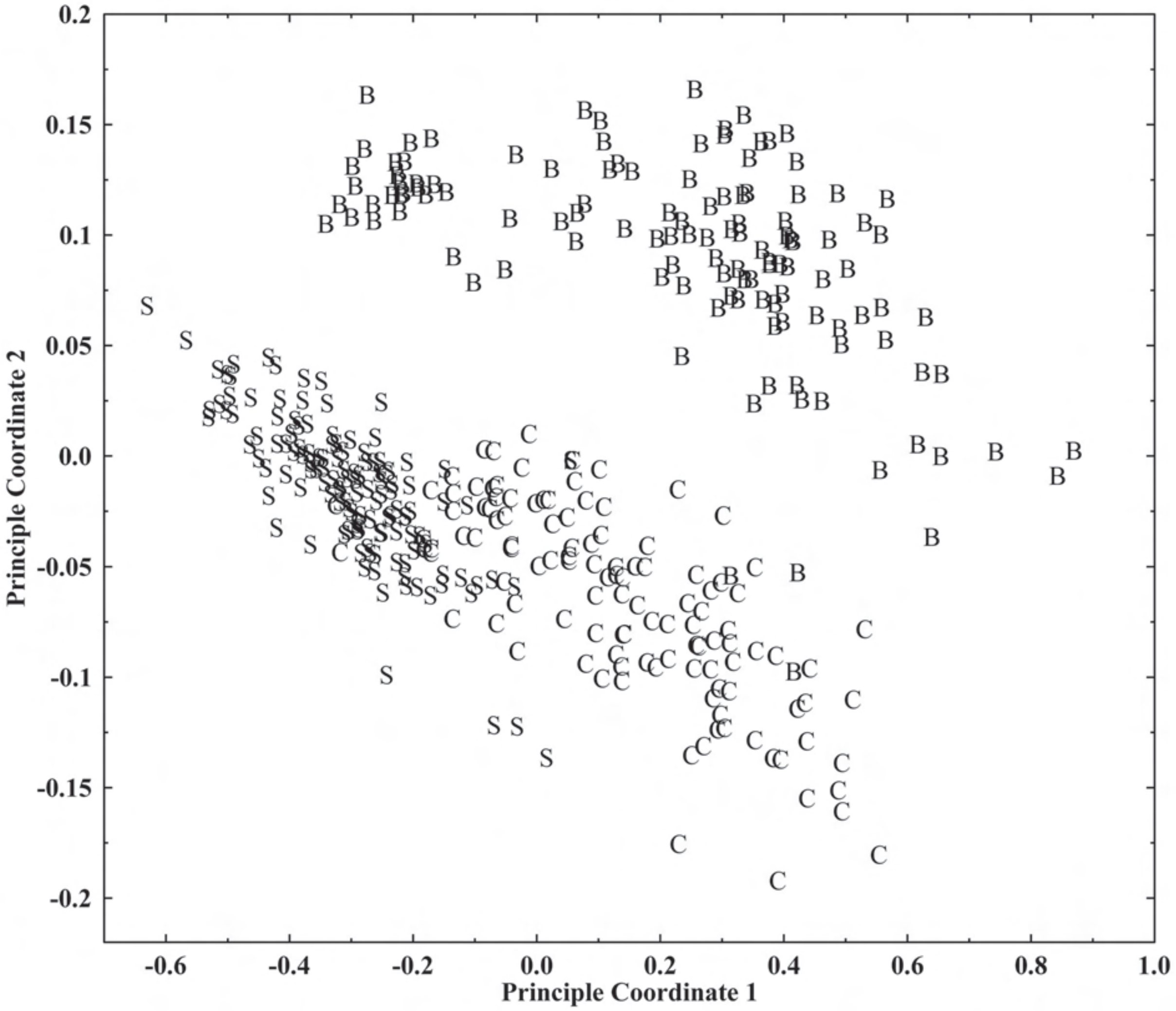

Figure 4.15: Principal coordinates analysis of dentary measurements of labrids permits separation of the three main species in New Zealand (S=Spotty, C=Scarlet wrasse, B=Banded wrasse) (after Leach and Davidson 2001b: 146).

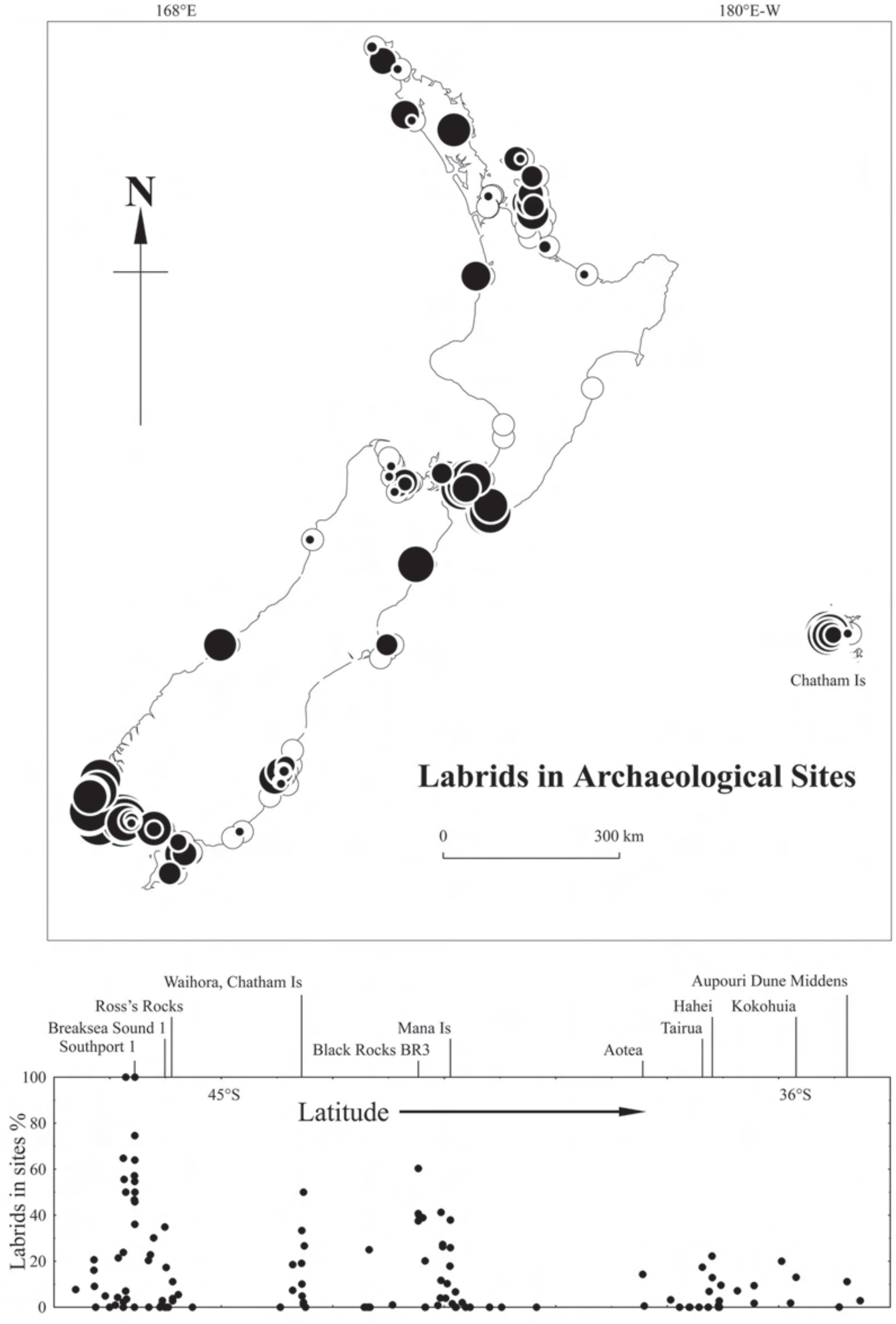

Figure 4.16: Upper: The size of the black circles indicates the relative abundance MNI of labrids (log scale). White circles have no labrids. Lower: Percent labrids in sites by latitude. A few key sites are noted along the top.

The osteometric problems associated with these closely related species become obvious when trying to estimate the size-frequency of pre-European catches from archaeological bones. This is illustrated in Figure 4.17 in which the bones of all species are pooled together. The upper part of Figure 4.17 shows the estimated fork lengths of a collection of archaeological labrid bones from the CHB site in the Chatham Islands. The lower part of the Figure shows the pooled values of the modern comparative collection in the Archaeozoology Laboratory at the Museum of New Zealand. This appears to be bimodal, but in fact is trimodal, with the middle peak less obvious.

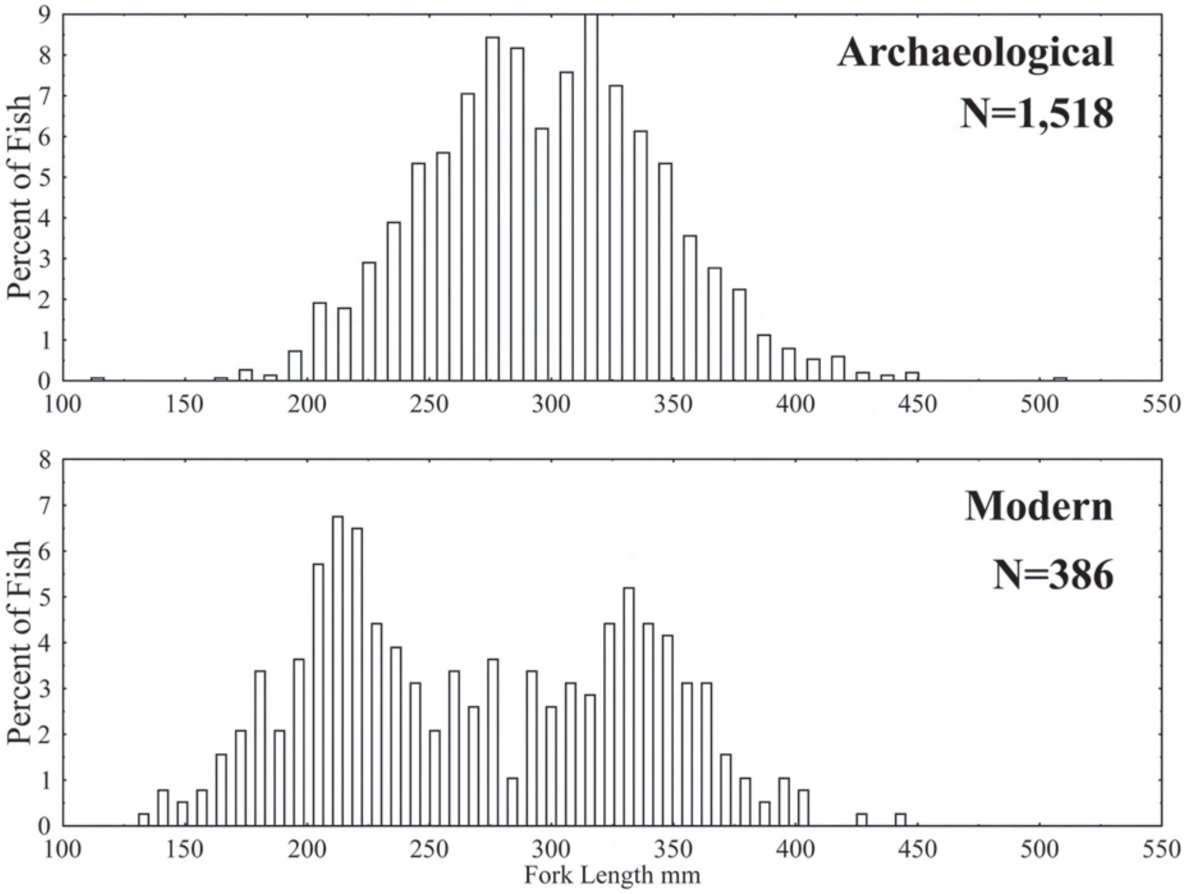

Figure 4.17: Upper: Size-frequency histogram of labrid fork lengths from the site of CHB in the Chatham Islands, based on 1,518 bone measurements. The mean fork length is 297 ± 1.2 mm. Lower: Modern comparative collection of labrids (pooled species).

This trimodal character of the length frequency distribution is a blessing in disguise. It makes it possible to examine the reconstructed size-frequency diagram of the undifferentiated pre-European labrid fish catch, and to separate it into its constituent species on the basis of their individual size-frequency distributions. This is a technique used for decomposing age-grades of fish from age mixtures. It has been shown to be moderately successful for archaeological assemblages from the Chatham Islands (Leach *et al*. 1999a: 126). This will be considered again in Chapter 7 when changes in fish catches through time are considered in detail.

Estimating live weight from archaeological bones for use in economic reconstruction is not easy in the case of labrids. The failure to identify cranial bones accurately to species, with the exception of the dentary, creates this problem. A number of alternative methodologies have been investigated; none is very satisfactory, and they have at best an error of about ± 7% (Leach and Davidson 2001b: 143).

RED COD

The New Zealand fish commonly known as red cod (*Pseudophycis bachus*) is a member of the family Moridae (Fig. 4.18). It is not a true cod of the family Gadidae.

The Māori name for the red cod is *hoka*, a word which, in various forms (such as *hoka* Paumotan [Tuamotuan], *so'aso'a* Samoan, *hoahoa* Hawaiian), is widespread in Polynesia, referring to a variety of sharp-pointed objects or activities associated with them. For example, the word *okaoka* in Mangarevan means to poke about with sticks amongst coral looking for fish (Tregear 1891: 78). The New Zealand red cod has a single barbel below the lower jaw, which functions in a very similar manner to *okaoka* amongst the Mangarevans, as the following passage makes clear:

> The barbel or feeler below the chin of Red Cod has special uses, which I have often observed in the Red Cod kept in captivity in the large outside ponds which have muddy bottoms. Lying flat on the ground, face downwards as near as possible to the pond, I have seen a Red Cod sink to the bottom and begin moving along the floor, using his barbel to feel and poke the mud. Again and again I saw him swim backwards and open-mouthed, and then swallow some creature he had evidently touched with his feeler. This barbel is an extra sense and very sensitive, for it no sooner feels some crab or worm than the Red Cod slips into reverse gear in a flash and the animal is not only in his shovel-shaped mouth but well down his gullet (Graham 1956: 170).

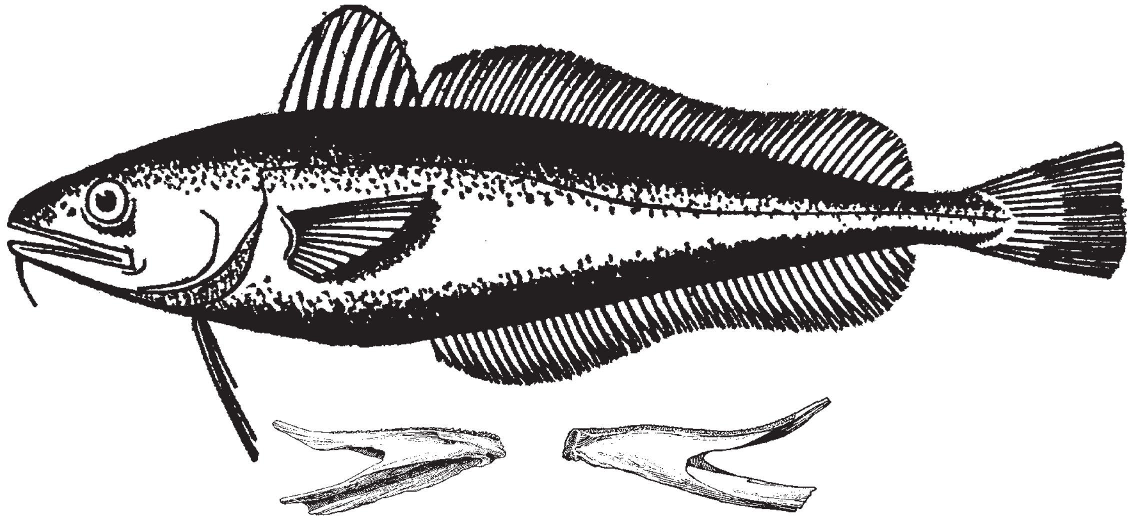

Figure 4.18: Red cod, *Pseudophycis bachus*, *hoka* (Māori) (after Doogue and Moreland 1966: 208, courtesy of Eric W. Heath). Below is the distinctive right dentary bone of this species (Leach 1997: 61).

Perhaps this is why this New Zealand fish was named *hoka*, on account of the barbel, poking about looking for food. Certainly, when the first Polynesians came to New Zealand, this fish would have been entirely new to them, as it is not found outside temperate waters. It is interesting that the Māori also named the ling *hoka* and *hokarari* (Williams 1971: 56). In one important respect a ling has a superficial resemblance to a red cod — it has slender pelvic fins set well forward beneath the lower jaw, where they are easily mistaken for barbels (Ayling and Cox 1982: 152).

Red cod are voracious carnivores, feeding on a wide variety of marine organisms. They average 30 to 50 cm in length, but very large specimens are known to reach 1 m in length and weigh over 6 kg (Ayling and Cox 1982: 142). They reach 25 cm in the first year, and 40, 50 and 55 cm in subsequent years. They are sexually mature at the age of two to three years (Annala *et al*. 2000: 338). They are found throughout New Zealand, but more commonly around the South Island. Ayling and Cox (1982: 143) suggest that there may be two distinct populations, one in rocky areas down to about 50 m depth, and the other in deeper water on the continental shelf over sandy and muddy bottoms from 50 to 550 m depth. They also note that the same species is found in southern Australia.

Red cod are schooling fish, migrating seasonally but irregularly from deeper to shallower waters, possibly in connection with their breeding activities and changes in food supply. There is conflicting information about the pattern of these seasonal movements and their abundance in various waters around New Zealand. Paul (1986: 57) states that spawning occurs about August, probably in offshore waters. Schools appear in the Canterbury Bight and Banks Peninsula around November, and are not found in any number in these waters after about June. Commercial catch data indicate that they move into deeper water at this time. However, even though in former times red cod were known to be especially abundant in the Otago harbour in summer months, local fishermen relied upon their catch of the species outside the harbour in winter (Graham 1956: 168). Moreover, commercial landing figures for red cod at Akaroa and Timaru show greatest abundance in winter (Leach 1979a: 114), and for Wellington between May and July. These observations hint that low water temperature may be one of the triggers determining changes in local abundance. Recruitment is highly variable, resulting in large variations in catches from one year to another (Annala *et al*. 2000: 338). In an interesting study of the types of fat present in red cod, Carter and Malcolm (1926: 649) argued that in Otago waters at least, these fish gorge themselves on whale feed[7] during summer and autumn, retiring to deep cold water in winter and basically living on their fat reserves until the whale-feed season occurs again. Generally speaking, at least on the east coast, these fish are more easily caught in inshore waters during spring and summer, before moving into deeper water during winter. In years when surface sea water temperatures are lower than normal, we might expect a somewhat different pattern.

These fish have a poor reputation amongst many modern fishermen. Doogue and Moreland, with their usual flair for getting straight to the point, comment:

> It is doubtful if anyone would go out with the firm intention of seeking out these fish. As they do not have speed, stamina or particularly good eating qualities, they are easily caught — if you want them. … Food qualities: little fat, a flaky rather flavourless flesh. Unsuitable for frying (Doogue and Moreland 1966: 208).

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[7] Whale feed, also known as krill, consists of huge quantities of tiny planktonic crustaceans. It is referred to as the 'red tide' when it comes inshore and washes on to the Otago beaches.

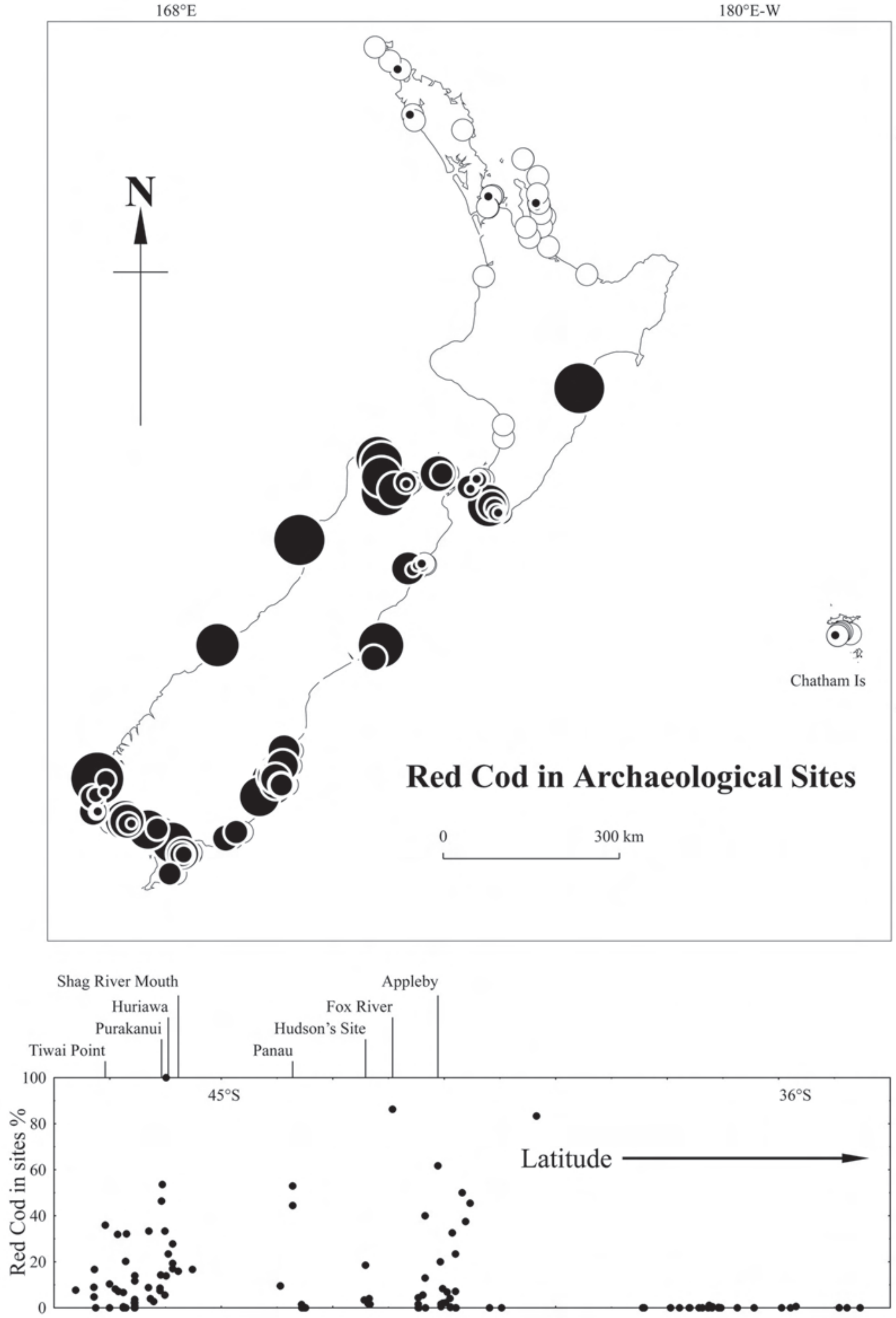

Figure 4.19: Upper: The size of the black circles indicates the relative abundance MNI of red cod (log scale). White circles have no red cod. Lower: Percent red cod in sites by latitude. A few key sites are noted along the top.

The comment about lack of fat contrasts with the observation of Carter and Malcolm, noted above. Recent research suggests that some recreational fishermen do indeed target this species, particularly in the southern North Island and South Island (Fisher and Bradford 1999: 24).

Graham (1956) makes some fascinating observations about red cod, although his suggestion that the name *hoka* is appropriate because in Māori it means "to eat anything" (Graham 1956: 167), one of the characteristics of this fish, is not correct. This meaning is not recorded in any known source on the Māori language (Harlow 2000: pers. comm.). Graham considered that the bad reputation that red cod has for poor eating qualities was not well founded, but then it is hard to find a species in his volume which he does not consider good eating. He has much to say about the eating qualities of red cod and suggests adding salt to the flesh some hours before cooking to firm it up. He also notes that although they can be caught in great abundance in some years, they can disappear completely from inshore waters for up to seven years at a time. His story that fishermen's wives refused to go into the harbour in rowing boats on account of the unnatural numbers of fish they had to pull through (Graham 1956: 168) stretches credulity, although very large quantities of red cod probably did come into the Otago harbour during this incident.

Red cod bones have been identified in 77 sites in the Fishbone Database. The sites where red cod are most abundant (measured as a percentage of MNI) have a strong southern bias. This is evident in Figure 4.19.

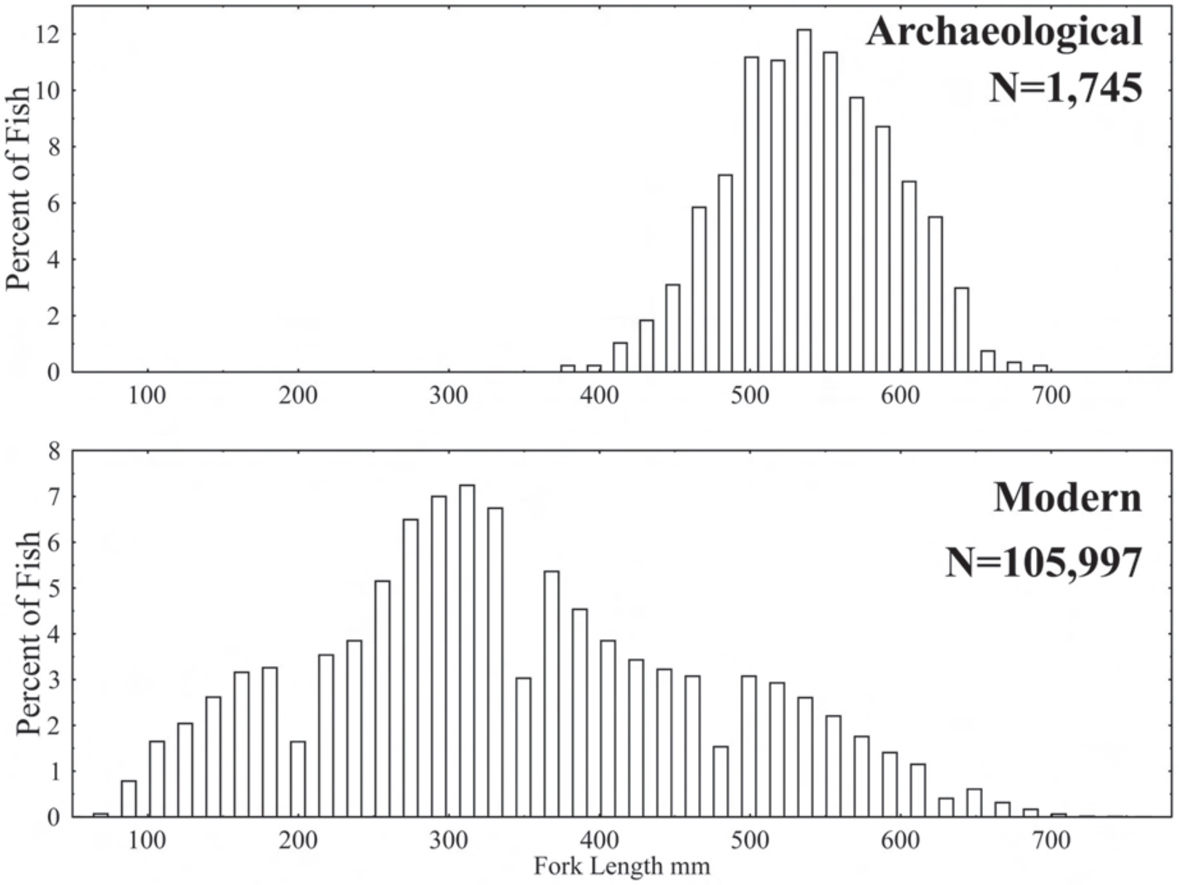

Figure 4.20: Upper: Size-frequency histogram of red cod fork lengths from the Tumbledown Bay site on Banks Peninsula, based on 1,745 bone measurements. The mean fork length is 540 ± 1.3 mm. Lower: Modern research trawl data (Paul 2005: pers. comm.).

An indication of the size of red cod in archaeological sites can be obtained from bone measurements from Tumbledown Bay on Banks Peninsula presented in Figure 4.20 (upper). This is compared with the fork lengths of all red cod from research trawl surveys from east and west South Island and Tasman and Golden Bays (lower). Pre-European Māori were catching large older fish.

A study has been carried out linking live fish size and weight from bone dimensions of red cod (Leach *et al*. 2001b). The relationship between total length and ungutted body weight was found to be:

$$\text{weight g} = 0.0000265 * \text{total length}^{2.84}\ \text{mm}$$

GREENBONE

The final fish type to be considered in this chapter is the greenbone (Fig. 4.21), also known as butterfish (*Odax pullus*). Of the two common names, greenbone is preferable because the name butterfish is also associated with the warehou family (Centrolophidae), and the name greenbone is not likely to be confused with any other fish. The reason for this name is the tendency for the bones to turn to a green colour fairly quickly after the fish dies. This is due to precipitation of an iodine

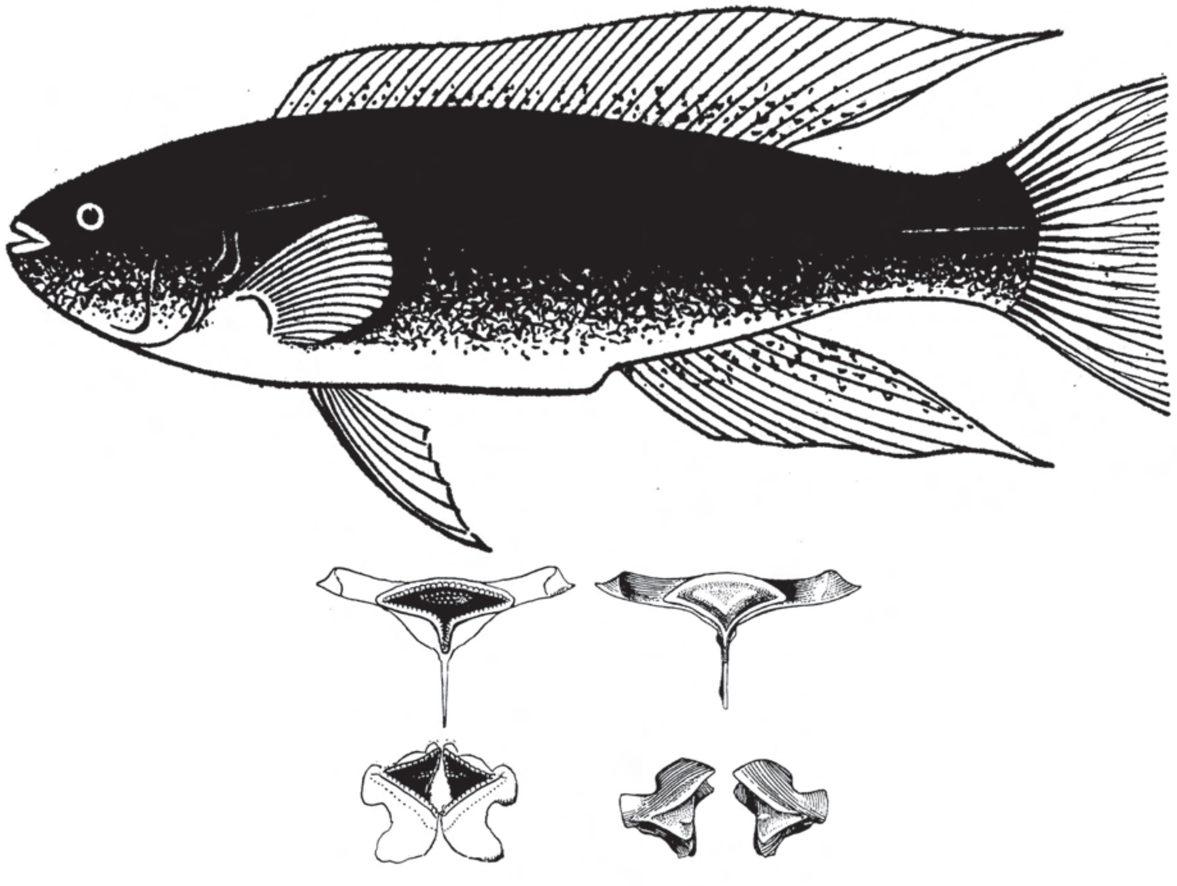

Figure 4.21: Greenbone, *Odax pullus*, *mararī* (Māori) (after Doogue and Moreland 1966: 256, courtesy Eric W. Heath). Below are its upper and lower pharyngeal bones (left: after Waite 1911: 228; right: after Leach 1997: 43). These bones are characteristic of this species.

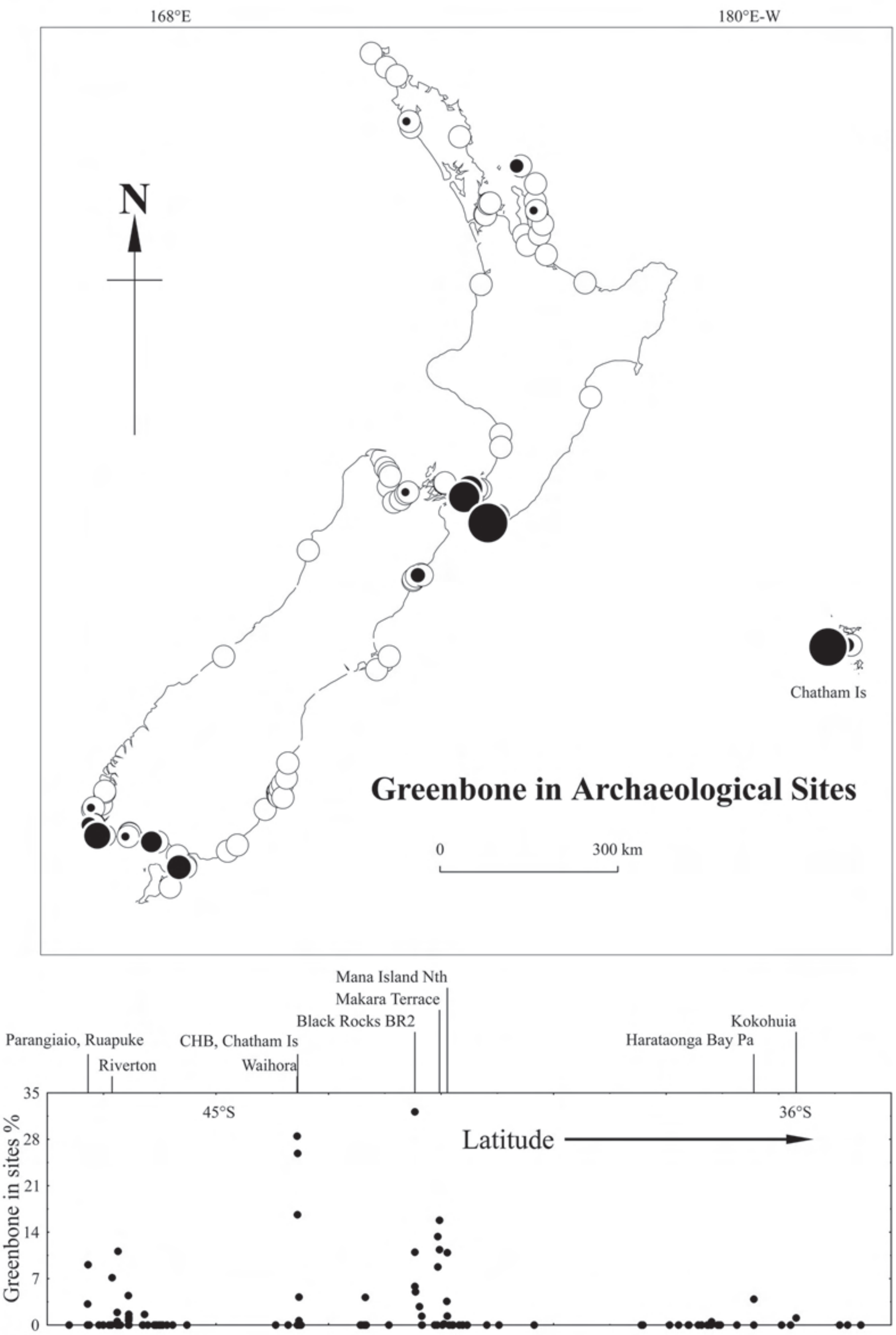

Figure 4.22: Upper: The size of the black circles indicates the relative abundance MNI of greenbone (log scale). White circles have no greenbone. Lower: Percent greenbone in sites by latitude. A few key sites are noted along the top.

salt. The flesh of this fish is very rich in iodine, something which makes it very useful for prevention of goitre. New Zealand soils are naturally low in iodine, and endemic goitre was noted in the 19th century. From 1924 onwards salt was iodised to alleviate this. Goitre would have been endemic amongst pre-European Māori unless they had some means to augment iodine in their diet. Consumption of greenbone would have helped.

The Māori name for this fish is *mararī*, or *rarī*. This name is common in many parts of the Pacific, often, but not always, applied to some form of labrid or wrasse. The word has many cognates and has been reconstructed to Proto-Polynesian **m(a,o)lali* by Hooper (Hooper 1994: 217)[8]. The word *maa-lali* and its cognates (Māori *mārari*) refers to things that are smooth, wet or slippery. This is an appropriate description for the greenbone fish, which has very tiny scales and no sharp spines and is very slippery when wet.

The greenbone is a vegetarian fish, feeding on seaweeds. They prefer a single species of kelp, *Ecklonia radiata*, but also eat *Macrocystis pyrifera* (giant kelp) and other species, including the reproductive branches of *Carpophyllum* plants. Their teeth are fused into a sharp beak-like jaw, similar to the tropical parrotfishes, and they bite pieces from the kelp leaving a neat oval hole in the frond. They have three sharp-edged pharyngeal bones in the throat (Fig. 4.21 lower), and these

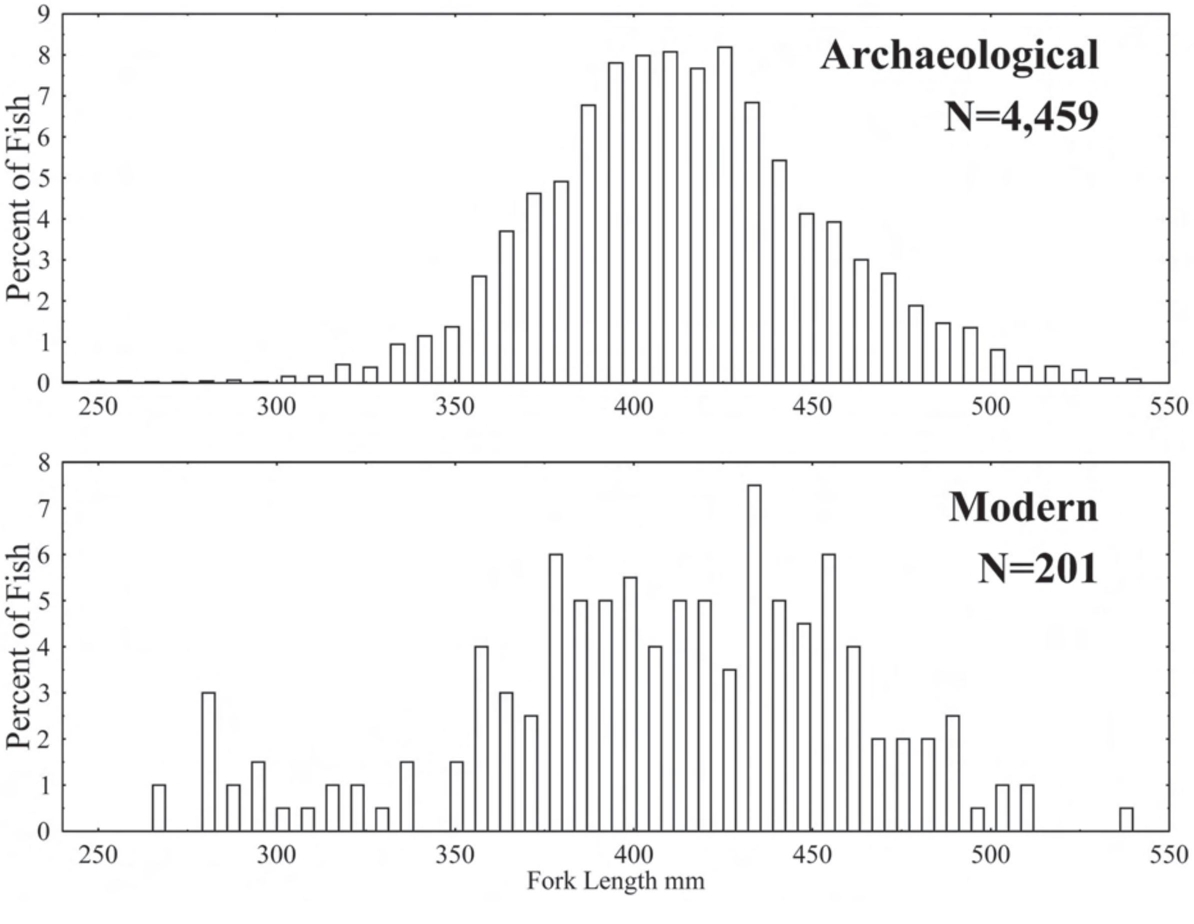

Figure 4.23: Upper: Size-frequency histogram of greenbone fork lengths from the Waihora site in the Chatham Islands, based on 4,459 bone measurements. The mean fork length is 414 ± 0.6 mm. Lower: Modern greenbone from netting experiment in Cook Strait (Paul 2000: pers. comm.).

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[8] Tregear lists the Māori word as *marare*, which is probably an error (Tregear 1891: 215)

cut the piece of kelp into smaller pieces before swallowing. Stomach contents also contain small crustaceans and shellfish. Greenbone are a beautiful deep blackish green or blue colour and thick in cross-section, providing good-sized fillets. They average 30–50 cm length, but can reach 70 cm or more. Thompson (1981: 213–215) provides some useful information about the species in the Leigh Marine Reserve north of Auckland. She notes that they are diurnal, something Graham also commented on (Graham 1956: 264), and that they are most abundant in waters less than 13 m deep. In the Reserve they reach densities of 14 fish per hectare, and are also present in deeper waters where *Ecklonia* forests are found, but at densities of about 2.5 fish per hectare.

In theory, the vegetarian habits of greenbone preclude the use of hooks, but I have heard that a tiny hook baited with a shrimp or even a fragment of kelp will occasionally capture them. However, this is a species which in pre-European times would have been taken almost exclusively by netting or spearing. Greenbone are found throughout New Zealand, around kelp-rich rocky shore habitats, but are not so common in the warmer waters of the far North. Graham describes them as having a range of colours, depending on environment and amount of light present. He also notes their habit of apparently sleeping in a vertical position in an aquarium, instantly returning to a swimming position when lights are turned on (Graham 1956: 264). These comments and those of Thompson are somewhat at variance with the use of gill nets by modern fishermen, whose nets are often set in the evening and collected in the morning after a tidal change. My own experience is that night netting is very productive, and when seen with a torch during night diving, these fish seem quite active.

Bones of greenbone have been identified in 35 sites in the Fishbone Database. There is a strong bias towards southern sites (Fig. 4.22); the species has been identified from only three sites north of Hawkes Bay (Kokohuia, Harataonga Bay, Hahei). Greenbone are abundant in sites in Cook Strait, Southland and Fiordland and Chatham Islands.

Biometrical studies of greenbone osteology are yet to be published, but a comparative collection of 306 individuals netted in the Cook Strait region has been assembled, rendered down and bones measured. A preliminary relationship between total length and ungutted body weight is:

$$\text{weight g} = 0.00011334 * \text{total length}^{2.646} \text{ mm}$$

Bones from the site of Waihora in the Chatham Islands have been studied in detail. The size-frequency diagram of the greenbone catch is given in Figure 4.23 (upper). It is compared with greenbone caught in a netting experiment in Cook Strait by NIWA staff (Fig. 4.23 lower).

CONCLUSIONS

In this chapter, only the six most abundant fish types in archaeological sites have been considered. Although these account for nearly 85% of the fish caught by pre-European people in New Zealand and nearby Chatham Islands in terms of numerical abundance, this is only one way of assessing importance. The food available from one large shark, for example, is worth a lot more than a netful of smaller fishes. Nevertheless, it should be clear from Table 4.1 that pre-European Māori did tend to focus attention on a small number of species, even though the composition of catches varied from one part of New Zealand to another.

CHAPTER 5: FISHING TECHNOLOGY AND MATERIAL CULTURE

INTRODUCTION

If a modern European was cast ashore on a small uninhabited island somewhere in a remote corner of the Pacific, the few items of material culture which he or she might have on their person would be soon worn out and discarded, placing the person in peril for existence unless they learned very quickly indeed some basic skills relating to the technology of survival[1]. The Polynesian immigrants who found their way to New Zealand during the pre-European era were in precisely the same position as this hypothetical European, but with one important difference — these people brought with them mental templates more closely aligned to the task of surviving with nothing except what was around them in the land and sea. That is, they possessed a knowledge or technology suited to living close to the land. Most Europeans would be hard pressed to make cordage for a fishing line, let alone a suitable fish hook to attach to it. Indeed, even a knowledge of basic knots is required for successful foraging for food. When we think about the first immigrants to New Zealand we should envisage them poorly equipped in terms of material culture, but very well equipped with basic skills and knowledge relating to fishing and other technology, which would ensure relatively easy adaptation to the challenges of this new land.

As we have seen in earlier chapters in this book, the Polynesian immigrants experienced considerable differences in the environment of New Zealand compared to the tropical Pacific, and as far as fishing is concerned, it was not just the types of fish that were new (not to mention the cold waters of temperate New Zealand), but all the natural materials used in fishing were new too. No pearl shell is found in New Zealand, so fish hooks could not be made from this. No coconuts grow in New Zealand, so coconut fibre could not be used to make fishing lines and nets. To the uninitiated, this restriction may be seem trivial — after all, there are many other fibres in New Zealand that could be used, especially swamp flax, *Phormium tenax*. On the contrary, the absence of coconut fibre would probably have been greeted with dismay. Coconut fibre possesses properties especially suited to long life in salt-water, and sennit made from it shrinks in the sea, making canoe fastenings even tighter than on dry land.

In considering the technology and material culture relating to fishing in pre-European New Zealand one must bear in mind adaptation to materials unfamiliar to tropical Pacific Islanders. There are several ways a chapter on this subject might be organised. The simplest approach would be to take each artefact category in turn and discuss form and function. Archaeological literature is replete with examples of this approach, which I think is a rather lifeless way of observing artefacts. Artefacts represent a marriage between technology and raw material, using the hand and knowledge of an artisan. In other words artefacts come into being as the result of a process, and they are inextricably linked with function. To discuss any archaeological artefact without consideration of process and function is to treat it as an isolated *objet d'art* with little cultural meaning. I therefore propose to adopt a somewhat novel approach in exploring the subject matter in this chapter — artefacts. From beginning by making artefacts for fishing, through going out to sea and catching fish, preparing them for eating, cooking them, preserving them, to finally dumping their bones, considerable knowledge was required to be effective. I shall try, wherever possible, to consider the technology associated with these various steps, rather than simply focus on artefact forms.

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[1] This is dramatically and realistically illustrated by Tom Hanks in the film 'Cast Away' when he demonstrates how impossible it is for the inexperienced to get food from a coconut without some elementary knowledge which even the youngest Polynesian would take for granted.

Since this chapter is concerned with 'technology and material culture', I should clarify the way these terms should be understood here. In modern parlance the term 'technology' frequently equivocates between two different senses, one referring to knowledge, and the other referring to physical objects. These two meanings are best kept separate. While the term 'material culture' might be unambiguous — it refers always to objects; that is, artefacts — it is sensible to use the term 'technology' to refer to the process by which such artefacts come into being. In the previous paragraph I stated: artefacts represent a marriage between technology and raw material, using the hand and knowledge of an artisan. The word 'technology' here is very close in meaning to the common use of the word 'knowledge'. It is that ingredient which people carry around inside the brain (knowledge), and which with suitable practical skill applied to wood, stone and shell turns into material culture (artefacts).

RAW MATERIALS AND ARTEFACTS THAT MAKE ARTEFACTS

A typical fishing expedition requires a considerable range of raw materials and artefacts made from them. Setting aside everyday items such as clothing, people required various tools for making fishing gear. These included a variety of stone tools, such as adzes for cutting and trimming wooden items, flakes for cutting and scraping wood, bone and shell items, drill tips, and the ubiquitous hammer stone for making these stone tools by chipping and pecking. Bone and shell items required finishing with small files. Finally, some stone tools required grinding and polishing. A wide range of stones such as argillite, basalt, greywacke, chert, obsidian, schist and sandstone were needed for these tools. There is strong evidence that pre-European Māori intensively explored New Zealand soon after first arrival and found all significant stone resources very quickly (Prickett 1975, 1979).

The raw materials that were used for fishing equipment were also quite diverse. For example, fish hooks were made from wood, many types of shell, stone, and several types of bone. Identifying the species of shell and bone on a finished artefact is not simple, and although many museum labels declare the species involved, most of these labels are really little better than guesswork. Unfortunately, little effort has been made in New Zealand to apply well-known scientific techniques for identifying raw materials to finished artefacts in museums. For example, New Zealand museums have abundant fish hooks partly made from wood. Yet to my knowledge no-one has carried out research identifying which species of trees were used for these hooks. Only a minute fragment is required for identification using thin-section microscopy or SEM (scanning electron microscopy). Debitage from bone hook manufacture shows that human bone was a favoured material, as well as bones of moa, sea mammals, dog, and also some types of ivory (dog and sea mammal teeth). Once again, well-known techniques of material analysis of bone and shell have yet to be applied to museum specimens of bone and shell hooks to identify what was being used for individual items. In this respect, an excellent example of what can be achieved is Wallace's pioneering research on wooden artefacts in New Zealand museums (Wallace 1985, 1989).

CORDAGE AND KNOTS AND MASS CAPTURING FISH — THE NET

A fish hook is of little use unless there is also a long line for attachment. People not experienced at fishing may not fully appreciate that cordage made from most natural fibres like flax stretches considerably, so that when a fish tugs at a hook on the end of a long line, it may be imperceptible to the person at the surface holding the line. Many fish, given a little time, will remove bait from a hook without being caught, especially if there is no resistance to the hook and line when the fish tries to swim away with the bait in its mouth. A fisherman feeling this small tug can sometimes seat the hook into the fish by jerking the line. A set-line, anchored in some way on the bottom, also provides resistance against the fish tugging so that it can be caught. However, a long line made from thick natural fibres such as flax is so heavy in the water that the fisherman cannot feel a fish chewing on the bait at the bottom, and it is therefore difficult to know when to jerk the line. There are two implications of this — one is that for most fishing activities line length is limited to fairly shallow waters in the case of Māori and tropical Pacific island fishermen. The second is that for deep water fishing, the form of the hook must be especially suited so that the fish catches itself rather than relying upon the fisherman tugging on the line to seat the hook. This is probably the reason why the jabbing hook, so familiar to European fishermen, is relatively rare amongst pre-European Māori and Polynesians, and the so-called 'rotating hook' is so prevalent. This latter hook form is more effective when completely swallowed by a fish. This subject will be further explored below.

As with the wood used in making hooks, there has been little research into Māori ropes and cordage, although there are many specimens in museums collected in the eighteenth and nineteenth centuries. Notable archaeological finds of cordage are from Lee Island in central Otago (Anderson *et al*. 1991), and Kohika in the Bay of Plenty (McAra 2004). As might be expected, these rare finds are only of fragments, but a great deal has been learned from them. At Kohika there are a number of short lengths of cordage. McAra describes a novel method of making cordage which she names 'two-ply spiral-wrapped twisted anti-clockwise (Z-twist)' (McAra 2004: 149–152). One-ply spiral-wrapped cordage and three-ply braided cordage are also represented at Kohika (ibid.: 149, 153). All specimens are made from untreated strips of flax, not prepared fibre. The Kohika site was occupied late in pre-European times, between AD 1650 and 1700 (Irwin 2004: 240).

It is useful to make a few comments about the technical terms used here. Setting aside for a moment the use of untreated strips of flax or other species, the common method of making cordage is to twist bunches of fibres on the upper leg or thigh with the palm of the hand. Bunches of fibre used for this purpose, when rolled and twisted in this way, are termed 'yarn' or 'strand', and sometimes referred to as the 'ready' (see Fig. 5.1). If two bunches are rolled at the same time, it will form two-ply cord, and if three bunches are used, then three-ply cord is produced. Typically, the person making two-ply cordage will hold the completed cord in the left hand, and while making sure to keep the two bunches of fibre separate on the thigh, use the palm of the right hand to twist the fibres in each strand. If the palm of the right hand is pushed forward on the thigh the fibres will twist in a clockwise direction when looking towards the end of the cord. When the left hand is released, the loose cord, already made, on the left will twist to take up the tension, twisting the two strands together into two-ply cord. It is then customary to bring the right palm backwards on the cord, to untwist it. If you look towards the end of this cord so made, the strands are twisted together anticlockwise, the opposite direction to the twisted fibre in the strands. Cord twisted in this manner is termed Z-twisted. (See Fig. 5.1). If the right palm is pulled backwards from the knee on the thigh, the fibres will twist anti-clockwise, and the strands will be twisted clockwise, termed an S-twist. Contrary to this, a left-handed person might hold the cord in the right hand and use the left palm for twisting. In this case, pushing forward will make an S-twist, and backwards will make the Z-twist. Buck provides an excellent description of cord-making, including plaiting and braiding, in Samoa (Buck 1930: 232 ff.). In my experience, it is more common in Pacific islands for people to push the palm forward. It is therefore possible that most S-twisted cordage has been made by left-handed people, although it would be interesting to confirm this by direct observation on remote islands in the Pacific, as people still make cordage in this way in many places. It is one of the activities in which old men engage while sitting chatting about fishing in the men's house.

Of some interest is the fact that twisted cordage generally loses about 30% of its tensile strength after being twisted in this manner. That is, compared with the sum of the tensile strengths of all the

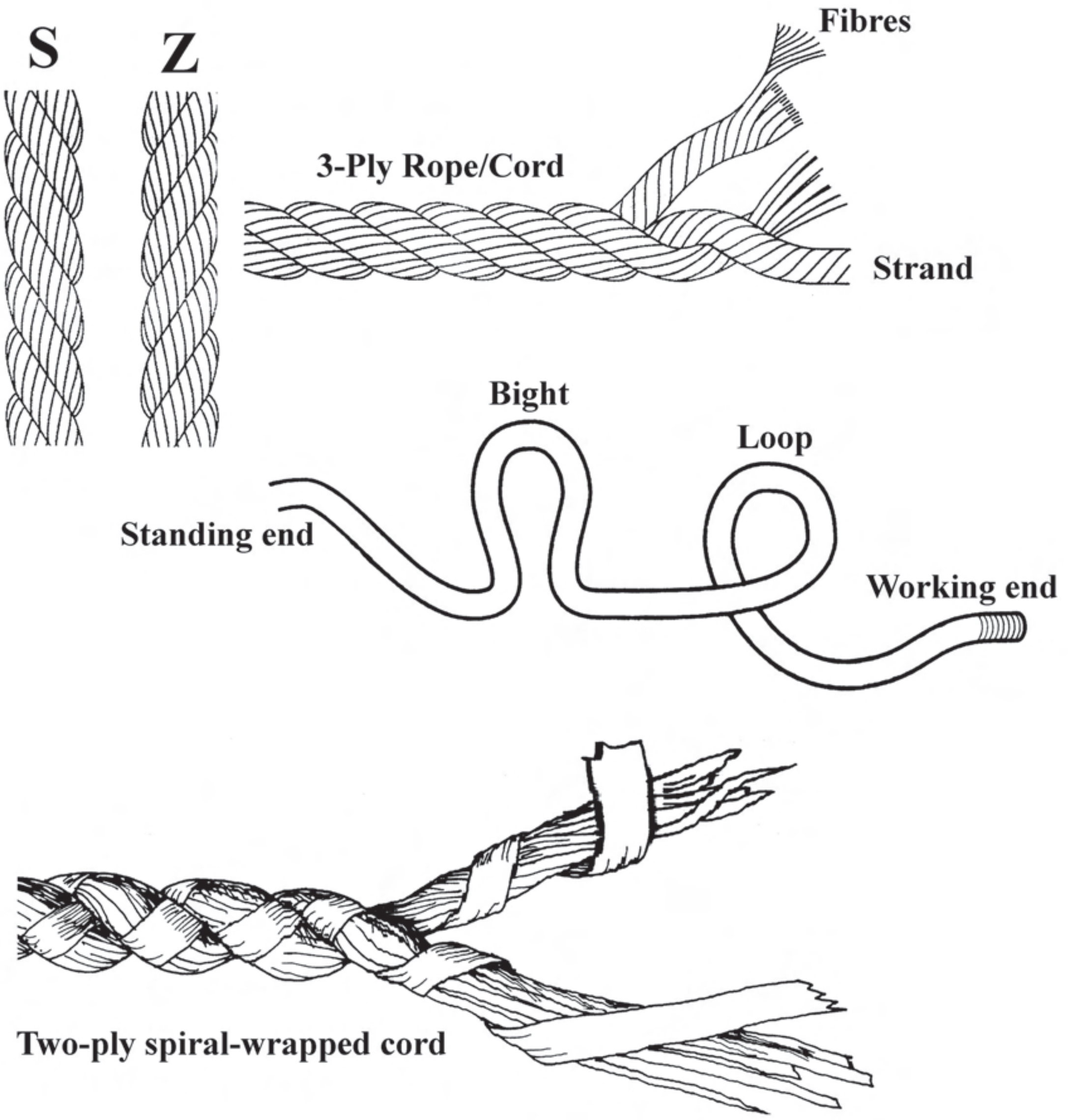

Figure 5.1: Some basic terminology relating to cordage (adapted from Budworth 1997). The two-ply spiral-wrapped cord is from McAra (2004: 152), courtesy of Geoffrey Irwin.

individual fibres, the final cord is weaker. There are two reasons for this — one is that each fibre when twisted becomes slightly weaker, and the second is that the forces along the length of the cordage are no longer axial along the length of the fibre, and this results in weakening. The addition of any knot into the cordage also reduces the strength of the line (Turner and van de Griend 1996: 185)[2]. Some natural fibre cordage also loses strength by as much as 70% when it is wet. I do not know of any experimental research on either of these issues for the types of cordage commonly made by pre-European Māori, or by Pacific Islanders for that matter.

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[2] This is well known amongst fly fishermen, who attach the fly using very fine line, which might have a breaking strain of only 1 kg before knotting.

Returning to archaeological finds, those from three Lee Island excavations provide a wonderful opportunity to examine something rarely found by archaeologists, and that is knots. A knot represents a single piece of pure technological knowledge. Very little is known about the discovery of individual useful knots and their spread from one human society to another[3]. At Lee Island, an impressive number of knots was recovered (Anderson *et al*. 1991). Forty examples of cords were found which had various knots in them, and an additional 16 pieces of twisted and plaited fibres without knots were recovered. Both S and Z-twist are represented at Lee Island. Twenty-eight examples of knotted cordage are made from *Phormium* sp. (flax), ten from *Cordyline* sp. (cabbage tree or tī), and at least one and possibly two from *Astelia* sp. (tree flax or bush lily). Twisted fibres of *Freycinetia* sp. (kiekie) were also present. Most of the flax specimens consisted of strips of unprocessed blades, only one case of scraped, beaten and softened fibre being found (Anderson *et al*. 1991: 45).

The collection of knotted fibres from Lee Island is a veritable gold mine of pre-European cord technology. They were carefully studied and illustrated by Anderson *et al*. (1991: 52–54), so that it is possible to understand the character of each knot in the collection. By my count there are 45 knots on the 40 pieces of cord, and many of these can be identified:

TABLE 5.1
Knots which can be identified at the Lee Island Sites

Identified Knot	**Examples**	**Unidentified Knot**	**Examples**
Overhand	17	'Lee Island Knot'†	5
Clove hitch	8	Other special knots	6
Reef knot	4		
Half hitch	3		
Cow hitch	2		
Totals	**34**		**11**

† See text

Radiocarbon dates from the Lee Island sites range from 281 to 399 years BP (CRA), which calibrate as from the sixteenth to early seventeenth century AD (Anderson 1991: 16–17). There is no reason to think that these knots have been influenced by European knowledge. The sites are away from the sea, on an island in Lake Te Anau, and although the cordage and the knots are not specifically related to fishing implements, they do form part of the knowledge system of pre-European Māori, and can be expected to have been employed in fishing and other activities. Most of these knots are quite familiar, but one in particular, which for convenience I will call the 'Lee Island knot', is represented five times and deserves some comment. There are six more knots not easily identified from literature. Unfortunately, with fragments of cordage containing knots it is not usually possible to identify which ends of the cords are 'standing ends' and which are 'working ends' (Budworth 1997: 16, see also Fig. 5.1). This means that it is not certain how the knot was intended to function when pulled tight, or indeed exactly how the knot would form when fully tightened. It is customary

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[3] The following incident illustrates the importance of knots. Some years ago I was asked to try and get the people of Taumako (a remote Solomon island), to make one final example of the great sailing canoe, tepuke, to celebrate the independence of the Solomon Islands. During a public meeting about this on the island the people expressed grave doubts whether this would still be possible. The main reason offered was that no-one any longer knew the correct knots to use for lashing the parts together. Twenty years later, in 1999, a tepuke was finally made by William Keizy on Taumako, and shipped to the Museum of New Zealand, where it formed a spectacular display. After much searching, William had learned the crucial lashing knot from an elderly relative on another island.

when tightening knots to choose two loose ends and pull them tight. There are two pieces of cord making up the Lee Island knot, with two ends each (ends 1&2, and 3&4). In pulling the knot tight, one of four possible pairs could be chosen (1&3, 1&4, 2&4, 2&3). When each of these pairs is

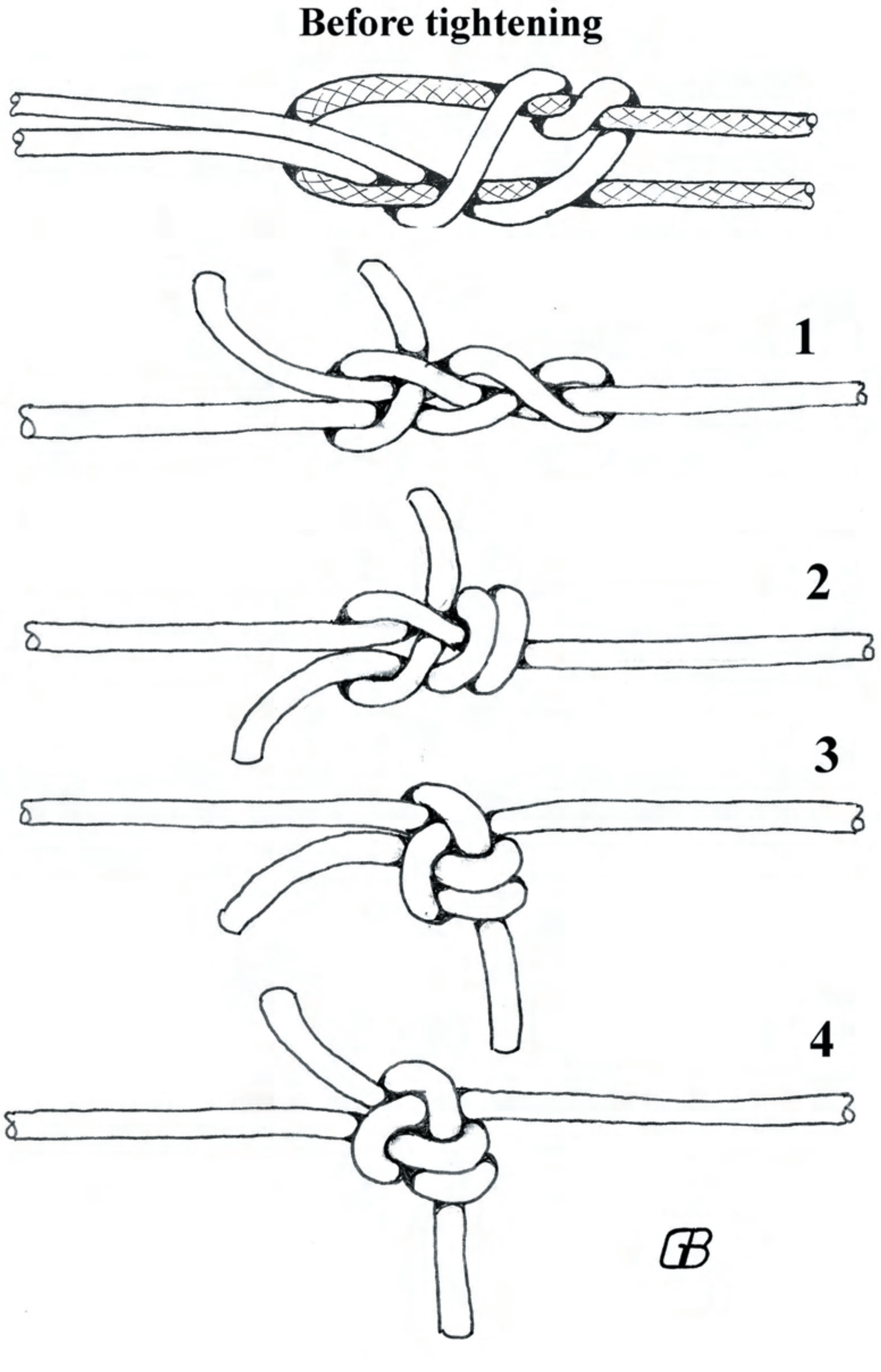

Figure 5.2: The so-called 'Lee Island Knot'—four possible forms (see text). Drawing by Geoffrey Budworth.

pulled apart, the knot will resolve itself into one of four possible forms[4]. Referring to Figure 5.2, Budworth comments that #1 and #2 are most practical and either of these two versions in small cordage could be a fishing or weaving knot; but that #3 and #4 are awkward and ugly and less likely to have been functional (Budworth 2005: pers. comm.).

The first Europeans who visited New Zealand came in sailing ships, which had ropes in great abundance, bristling with knots of many types. Māori coming on board would have taken notice of these and quickly adopted anything new to them into their own knot repertoire. Records of Māori knots from the historic era are therefore potentially filled with knots of European origin. This is what makes the finds at Lee Island so important. There are many examples of cords with knots in New Zealand museums collected from Māori people from the eighteenth century onwards. Many of these relate to fishing and they are a rich resource for future research.

The final archaeological example relating to cordage which merits discussion concerns fishing nets. Several specimens have been found in archaeological sites, notably Kohika (McAra 2004: 155–157) and Ruahihi (McFadgen and Sheppard 1984: 26–27, 30–31) in the Bay of Plenty, and Whakamoenga Cave on the shore of Lake Taupo in the central North Island (Leahy 1976: 58, Fig. 11). Several large pieces have also been found in a cave or caves on Banks Peninsula (McAra 2001).

The Kohika specimens consist of two small remnants, the larger of which has about 14 meshes made using the boustrophedon method[5]. This is suggested because the knots are alternately front and back on different rows (this is not necessarily correct, and is further discussed below). Judging from the published illustration (McAra 2004: 156), the meshes are about 44 mm[6]. This is clearly not suited for catching larger fishes by the gills, nor for eels, which would easily escape. It is a coarsely made net which could act as a barrier to encourage fish to swim away from it into another trap. It is made from unscraped strips of flax.

The Banks Peninsula specimens consist of three pieces of what is probably one net, found at Sandy Bay/Lavericks Bay, and donated to the museum over a period of years, and a fourth piece, 'the Bowman net'[7]. The latter, which is the largest piece, is 40 m in length; the other three pieces together total 70 m. No ends or section joins are present on any of the pieces. The untreated flax strips are very narrow, only 2–3 mm wide. The age is probably late pre-European or early historic. The mesh size is about 140 mm. The net was not made using the boustrophedon method. This may suggest that more than one person was involved in making longer nets, each working from left to right, so that several rows are made at the same time. When the boustrophedon method is followed only one row can be made at any one time and must be completed before a new row is commenced. Clearly if a very large net was being made it would speed things up a great deal if several people were knotting at the same time. It is likely that the large seine nets described by Banks and other

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[4] I am grateful to Geoffrey Budworth, co-founder of the International Guild of Knot Tyers, for much helpful advice on matters relating to knots.

[5] Boustrophedon is a term sometimes used when describing how nets are made when the rows of meshes alternate from left to right and then right to left, as with ploughing a field (see Best 1977: 15).

[6] The standard method for measuring net mesh size is to pull the diamond as far apart as possible and measure the inside distance between knots. The left to right measurement is identical to the vertical measurement, regardless of whether the upper and lower rows of the mesh elements are the same or different lengths.

[7] The catalogue information relating to these nets is now very confused and it was extremely difficult to relate the actual net pieces to their register numbers and accession history. Details are given by McAra (2001: 86, 99).

early visitors to New Zealand were made in the non-boustrophedon manner. McAra has studied these net pieces and has clearly identified that the knot being used is identical to that described by Buck (1926: 605 ff.)(McAra 2001: 88). This knot has several names: 'the weaver knot', 'the trawlers knot', 'the sheet bend' (a nautical term), and 'the netting knot'. For the sake of consistency, I shall retain the term 'weaver knot' here.

At Ruahihi, the fragment of carbonised netting with about 2,700 knots covered an area of 1.3 m^2 (see Fig. 5.3). This was a salvage excavation and it is not possible to be certain as to the precise position of the specimen stratigraphically, but it is either late pre-European or early historic (McFadgen and Sheppard 1984: 26–27, 30–31). The net itself is described as being made of unscraped split flax, with a mesh size of 40 mm (McFadgen-Richardson 1984: 53), which is similar to the piece from Kohika. Once again the 'weaver knot' was used. It is a beautifully made piece of netting with very uniformly spaced knots and joins of flax strip. The alternate facing knots suggest, but do not prove (see below), that the boustrophedon method was used.

Although a great deal of theoretical modelling has been attempted of net mesh selectivity and capture rates for different species and sizes (for example Helser *et al.* 1998; Kirkwood and Walker 1986), the reality is a great deal more complex. Practical catching experiments in netting New Zealand species are especially useful (Hickford and Schiel 1995, 1996). The mesh sizes of these three archaeological examples of fishing nets can be compared with observations by fishermen on typical modern nets in use in New Zealand (Clark 2005: pers. comm.). The first point which needs to be made is that nets can function in more than one way. A seine net is dragged through the water and is designed to surround fish and then beach them. It is not necessary for any fish to be entangled by the gills or spines, although some fish are caught in this way, and smaller fish will be able to swim through the mesh. A set net (or gill net) on the other hand certainly is designed to entangle the fish, and the mesh size is carefully chosen for the size of fish and the species. Snapper, for example, have strong dorsal spines which become entangled in almost any mesh size, and are

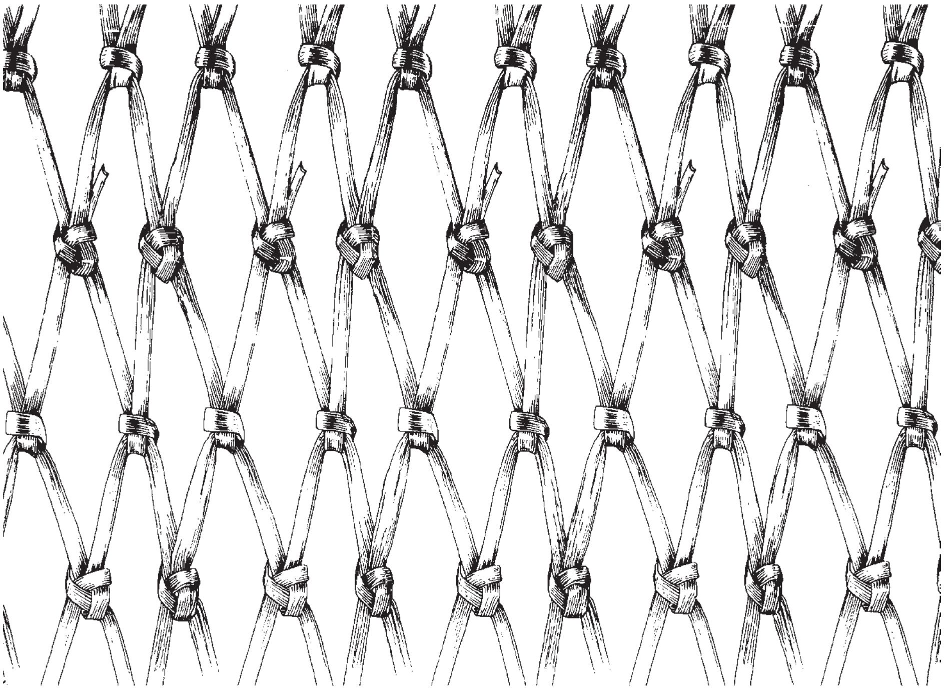

Figure 5.3: A drawing of the Ruahihi carbonised net, after McFadgen and Sheppard (1984: cover). Courtesy of Te Papa.

seldom caught by the gills. If there are plenty of snapper to be caught it would not be necessary to spend a lot of time making anything other than a net with very large mesh size. By contrast, greenbone and flounders have no sharp dorsal spines and must be caught by the gills. In this case the mesh size is critical to what sized fish are caught, if they are caught at all. A net with a mesh size of 140 mm is ideal for catching large flounder, but not small ones. Conversely, a net with a mesh size of 107 mm will catch smaller flounders but not the bigger individuals. Moki are a little like snapper and tend to be caught along their sides in a net rather than by the gill, so once again a quickly made large-meshed net is suitable. Similarly, barracouta can be caught in just about any mesh size, and thrash about entangling their numerous spines and sharp teeth. Blue cod are usually caught by the gills and mesh of 107–114 mm is very suitable.

The Canterbury net(s) would be effective in use either as a seine or gill net.

The Kohika and Ruahihi nets have a very small mesh (44 and 40 mm respectively) compared to these modern nets. They may have been used for freshwater fish. Both these sites are situated near rivers and are not directly on the coast. The three net pieces from Whakamoenga have even smaller mesh sizes. Two had a mesh size of 30 mm; a third fragile piece had a mesh size of only 15 mm (Leahy 1976: 58). All were made with untreated flax strips using the knot described by Buck. Leahy commented of the third piece that the mesh was about as small as it would be possible to make using untreated flax strips.

In the cases described here, the weaver knot used is clearly the same as that described in detail by Buck (1926: 605 ff.).

> The Maori netting-knot is the same as the usual European one except that in the latter the netting-cord is passed through the loop from below and the bight is made to the left. This is the opposite to the Maori method, but the results are the same (Buck 1926: 606).

Actually, the result is not quite the same at all. These two knots, immediately prior to their being tightened, are illustrated in Figure 5.4. This illustration does not adequately show the method of

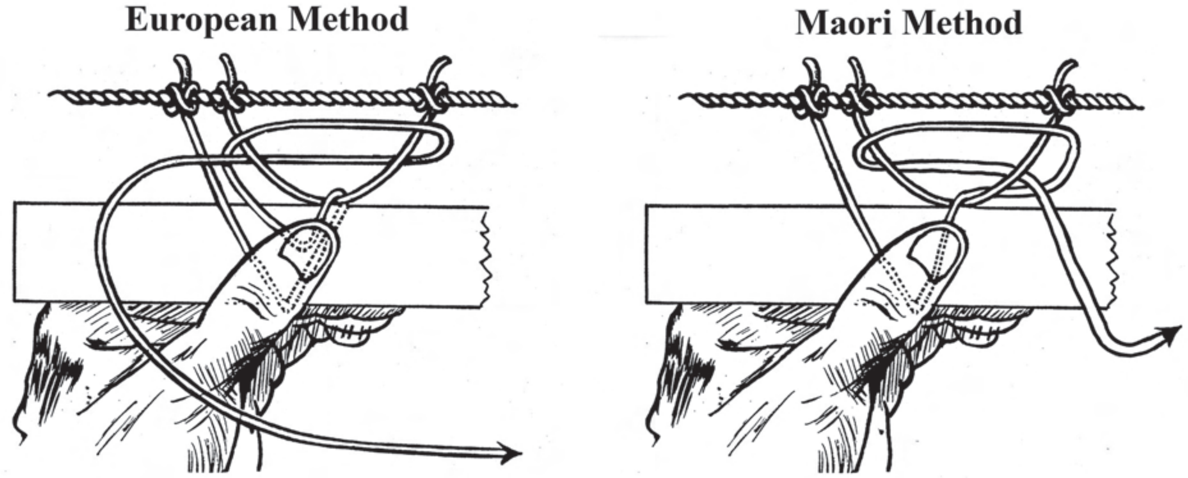

Figure 5.4: The netting knot just prior to tightening. Left: the European knot. Right: the Māori and Polynesian knot. Adapted from Collard (1948: 6).

actually tying the knot as described below. For example, the two different bights are not shown. A step by step fully illustrated explanation is provided by Ashley (1944: 64) and Buck (1926 :605). However, the difference in tying the knots may be summarised as follows. The European method requires the working end to pass under the loop and the bight to be thrown to the left; the right hand is used to pass the cord around the back of the loop and then over the bight, and then tightened by pulling the cord to the left with the right hand. Finally, when the knot is tight, the right hand is drawn to the right towards the next loop in line, twisting the knot just made. I was taught to make nets in this manner when a boy by an old fisherman and he used to laugh and call me cack-handed. I now realise that it is the knot that is cack-handed, when compared to the much simpler and more elegant method of tying the knot adopted by Māori and Polynesians.

The Māori method involves passing the working end over the loop, not under. The bight is thrown to the right, not to the left, the working end is then passed around the back of the loop and then over the bight (as with the European method), and then tightened by pulling the cord to the right, not to the left, with the right hand. Thus, the final movement tightens the knot correctly in the same

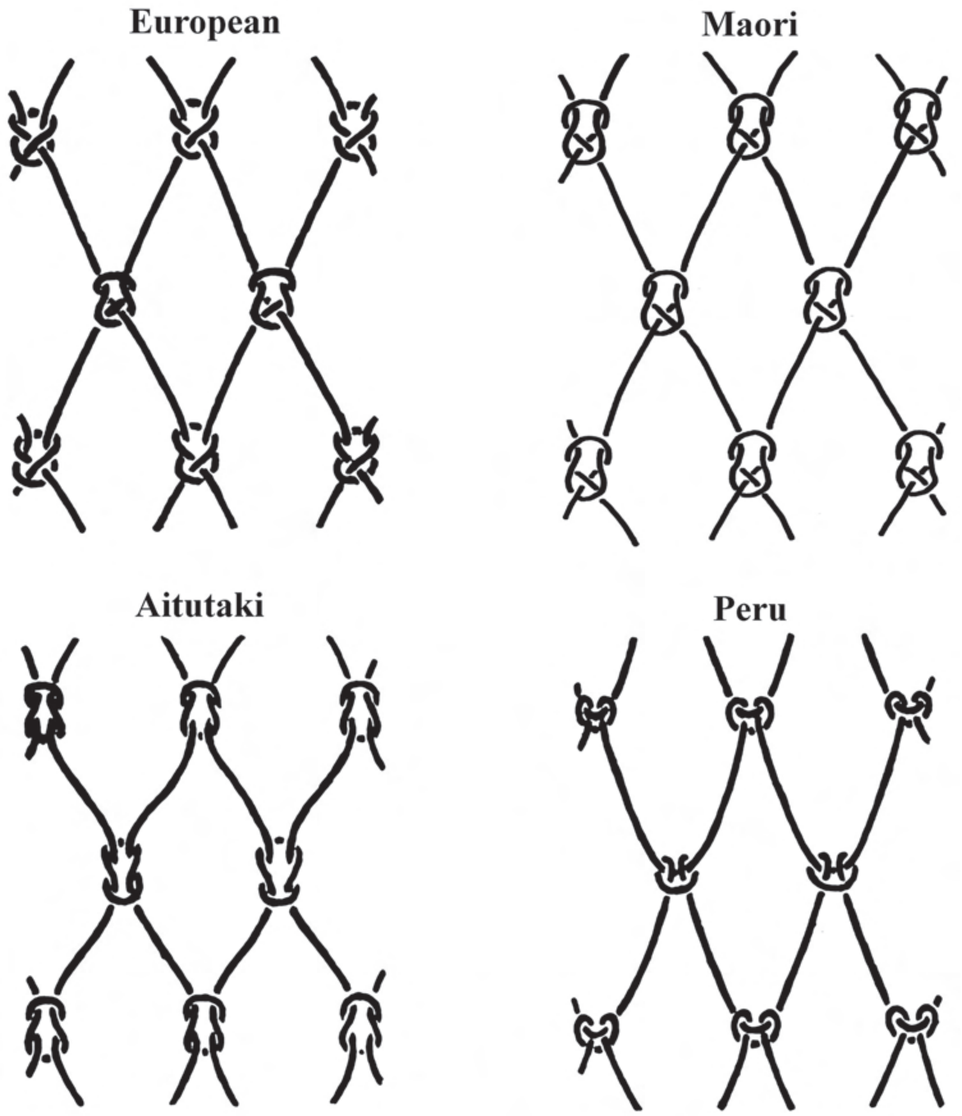

Figure 5.5: Several alternative netting knots. Adapted from Brandt (1970: 110)

direction as the next loop to be tied, rather than across the body with the right hand towards the left. This is a much easier and more natural way to tie this knot.

As many authors have remarked, this is a difficult knot to master, and can easily become a slip knot unless tied exactly right. Learning this knot requires paying careful attention to the method of tying and tightening, and one must get into a consistent rhythm. It is a complex piece of technological knowledge to pass from master to pupil (described by Firth 1939: 97 ff. and also Buck 1930: 470 ff.). This being so, it is a matter of some importance to discover where and when the Polynesian weaver knot came into being. The European weaver knot is known to have been used in both Finland and Schleswig, just south of the present German border with Denmark, at least 4,000–5,000 years ago (Brandt 1984: 208–209, 1970; Sirelius 1934). According to Brandt (1984: 208), the reef knot method of tying nets was more common amongst Asiatic fishermen until recently, and a kind of ‘failed reef knot’, or cow hitch named the ‘Peruvian knot’ has frequently turned up in netting recovered in excavations in Peru. Several of these alternative netting knots are shown in Figure 5.5. It does not seem likely that the European weaver knot and the Polynesian weaver knot share the same ancestry, so this could be a case of independent invention.

In a very useful review of different kinds of netting knots, MacLaren studied specimens of nets from many countries in the ethnological museums at Oxford and Cambridge and researched literature on net making (MacLaren 1955). These nets were collected during and after the great period of European exploration of the world, and therefore novel techniques will have spread along with these contacts. As a result, an individual net displaying a certain feature cannot be claimed with certainty to be indigenous to that location. However, it is a useful starting point. MacLaren records the knot here characterised as the ‘Polynesian weaver knot’ in at least 17 island groups in the Pacific. He found one instance of the ‘European weaver knot’ in this region, from New Guinea. Although rare in other parts of the world, he records examples of the ‘Polynesian weaver knot’ from Texas, Bering Strait (Kotzebue), Rhodesia, Northeast Asia (Koryak), Northeast Burma, Andaman Islands, India (Central), and finally Egypt (Fayum, 12 Dynasty, and Fayum modern). The ‘Polynesian weaver knot’ is absent from both South and North America (apart from the Texas example), Japan, and Europe. MacLaren also makes the interesting observation “Aitutaki, Cook Islands, alone in the Pacific has the reef knot, and is without the shuttle, in contrast to the general use of the shuttle and the mesh knot in that area” MacLaren (1955: 87), citing Buck (1944: 225) as his source for this information. However, as described above (Table 5.1), the reef knot was present at Lee Island in New Zealand. Buck describes nets being made by this method (illustrated in Fig. 5.5) and notes that people on Aitutaki are very proud of the fact that their method is different from that of other Cook Islanders (Buck 1944: 226), but does not claim that the reef knot is unknown elsewhere in the Pacific. The significance of this method of making nets is that it is not necessary to use a relatively short length of cord on a mesh needle, but a very large ball of cord can be used. Moreover, very fine meshed nets can also be made with a large ball of cord (Buck 1927: 280 ff.). The use of a ball of cord for net-making was recorded by Best (1977: 15–16), something which Buck commented on, suggesting that the Aitutaki method may possibly have been present at some stage in New Zealand and the Society Islands as well (Buck 1950: 214).

One further point on a practical aspect of making nets, which suggests we need to be very cautious about interpreting fragments found archaeologically, concerns cases when the knots are shown to have alternate faces. This occurs when the boustrophedon method is employed, when one net-maker works from left to right across the face of the net with the header rope strung between two trees. When the right hand end is reached, the net-maker goes to the other side of the net, and continues working towards his right. The effect of this is that, when viewing the completed net from one face, the knots will show alternate rows with a different appearance. Although this is true of a net made

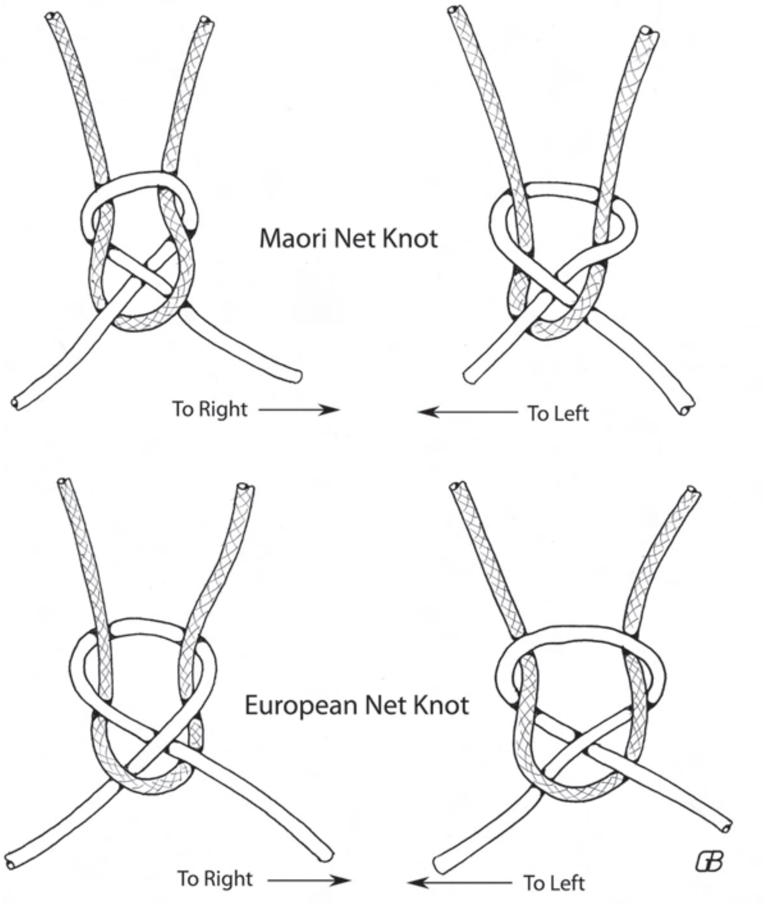

Figure 5.6: When making a net in a confined space, the net-maker may choose to work alternately from left to right and then from right to left. This results in a net that appears to have been made by the boustrophedon method, but it is not so (see Steven 1950: 20). Drawing by Geoffrey Budworth.

by the boustrophedon method, this appearance can be produced by another method. With small nets, and also when working in a confined space, when it is not convenient to string up the header rope between two trees, the net-maker may chose to work alternately from left to right and then right to left. This method is described by Steven (1950: 20), and the effect is shown in Figure 5.6 for both the Māori and European knot, working to the right and to the left. It should be evident that the Māori and European knots are not mirror images of each other (see also Turner and van de Griend 1996: 48).

Early ethnographic descriptions of nets in New Zealand amongst Māori communities describe a wide variety of devices: seine nets, small hand nets, set nets, hoop nets, basket-like traps with netting sides, etc. This makes it that much more difficult to identify accurately the rare small fragments found in archaeological sites, such as a net fragment with pumice float from the upper layers of Moa-bone Point Cave, Canterbury (Skinner 1923: 101 and fig. 9). Before leaving this discussion, mention should be made of the spectacular seine nets which the earliest European visitors to New Zealand observed. Banks described seines in his journal 4 December 1769 in the Bay of Islands thus:

> and after having a little laught at our seine, which was a common kings seine, shewd us one of theirs which was 5 fathom deep and its length we could only guess, as it was not stretchd out, but it could not from its bulk be less than 4 or 500 fathom. Fishing seems to be the

> cheif business of this part of the countrey; about all their towns are abundance of netts laid upon small heaps like hay cocks and thatchd over and almost every house you go into has netts in it making (Banks 1963 (I): 444).

In his general observations about Māori written 30 March 1770 in Admiralty Bay off D'Urville Island, immediately before *Endeavour* departed for Australia, Banks commented further about seines and nets in general:

> Netts for fishing they make in the same manners as ours, of an amazing size. A seine seems to be the joint work of a whole town and I suppose the joint property: of these I have seen as large as ever I saw in Europe. Besides this they have fish pots and baskets workd with twiggs, and another kind of net which they most generaly make use of that I have never seen in any countrey but this. They are circular about 7 or 8 feet in diameter and 2 or 3 deep; they are stretchd by two or three hoops and open at the top for near but not quite their whole extent; on the bottom is fastned the bait, a little basket containing the gutts &c. of fish and sea ears which are tied to different parts of the net. This is let down to the bottom where fish are and when enough are supposd to be gatherd together are drawn up with a very gentle motion by which means the fish are insensibly lifted from the bottom; in this manner I have seen them take vast numbers of fish and indeed it is a most general way of fishing all over the coast (Banks 1963 (II): 25–26).

What Banks is describing here is depicted in a pen and wash drawing by Sydney Parkinson (Fig. 5.7) of men[8] fishing from canoes in Queen Charlotte Sound (Cook 1968: Fig. 41 facing p. 209). This fishing group has been included in an engraving of a very different location — the picturesque hole in the rock at Mercury Bay, far to the north of where the fishing scene was actually observed (Fig. 5.8, Hawkesworth 1773: II: Plate 18, opp. p. 341). In my own personal experiments with replicas of these hoop nets in Queen Charlotte Sound, observing them with scuba gear, fish enter the traps but escape easily, despite careful pulling of the traps to the surface, or indeed pulling them up rapidly. My expectation of the behaviour of this fish species upon attempting to lift the pot was that it would immediately dive to the bottom rather than escape from the open entrance at the top, because this is a ground hugging species, which is seldom caught with hooks much above the bottom. However, this did not occur, and the fish rapidly exited at the top. Why these pots worked with blue cod in 1769, and do not work now is a good question, and appears to represent a change in fish behaviour. The difference can, perhaps, be attributed to the devastation of stocks of blue cod and other species in these waters since the arrival of Europeans, resulting in extreme wariness of modern fishermen and any artificial devices.

More information about seines comes from French visitors to the far north of the North Island. In 1769, during de Surville's visit to Doubtless Bay, Pottier de l'Horme described them as follows:

> The nets are very large, made like the ones we call seines. Instead of using lead, they fill with stones a kind of pocket fashioned to extend the whole length of the net. The material they use to make these nets is a very fine rush, which knots superbly. These nets are so big that it takes all the inhabitants of a village working together to pull one. So I assume that it is common property (Ollivier and Hingley 1982: 133–134).

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[8] Banks (1963 (I): 454) reported that the curious head-dresses depicted in this image were worn by women and "some men". Beaglehole, in an editorial footnote to this statement, shows that later writers believed them to be worn mainly, if not exclusively, by women. However, Parkinson has provided the wearers of the head-dresses with short beards, clearly showing that these people were men.

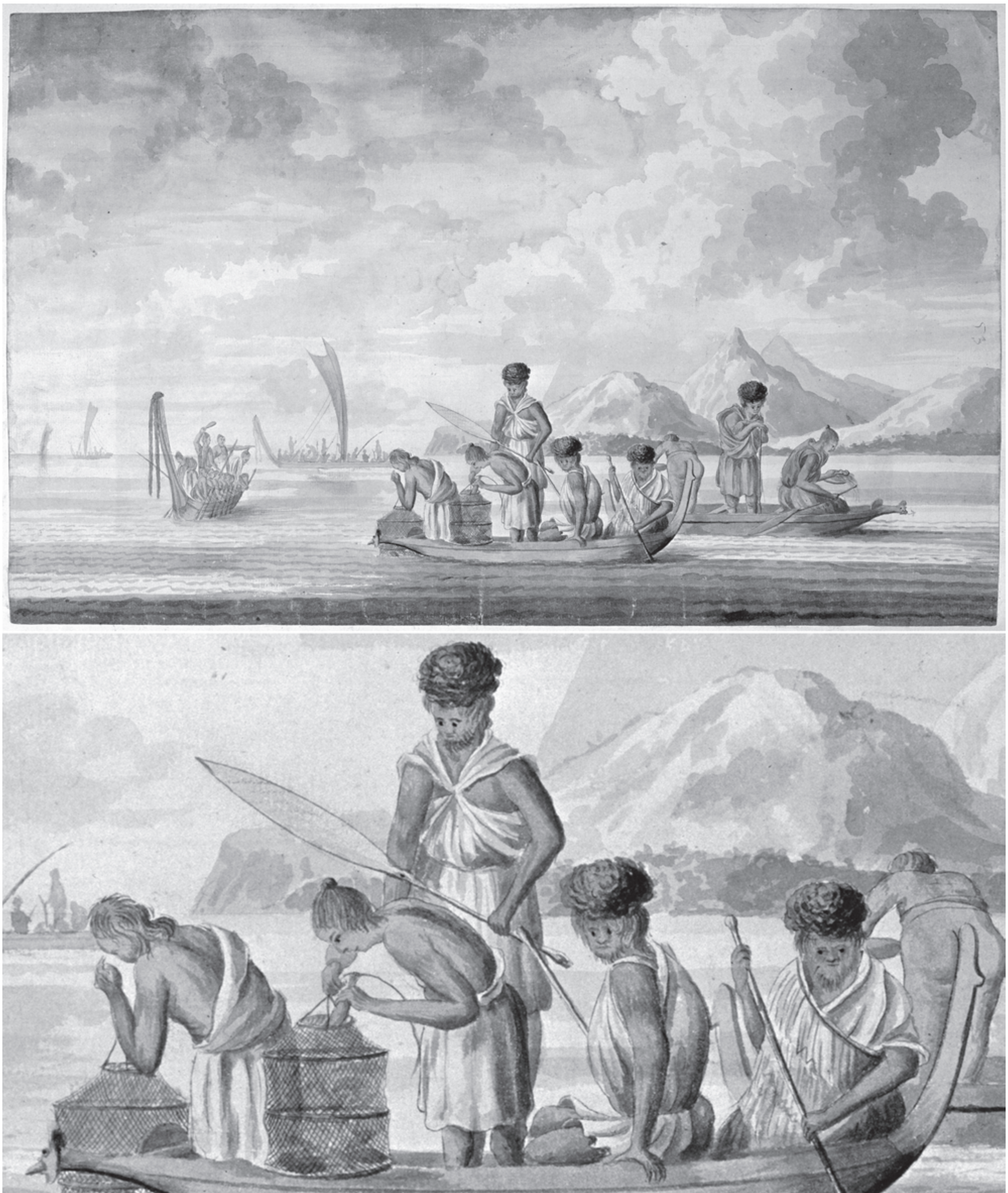

Figure 5.7: Māori people fishing in Queen Charlotte Sound using hoop nets. Painting by Sydney Parkinson (Cook 1968: Fig. 41 facing p. 209). Courtesy of British Library. See also Figure 5.8

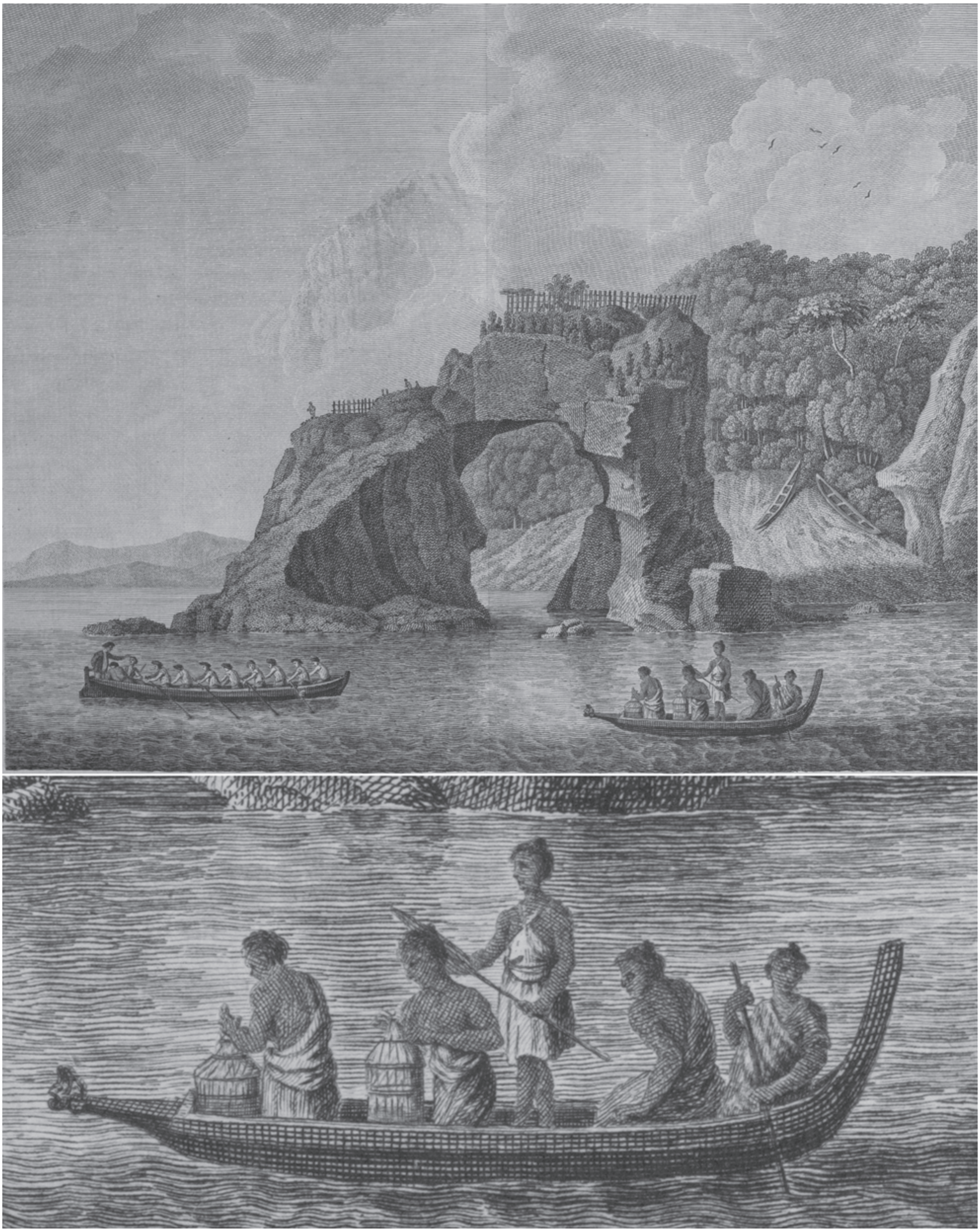

Figure 5.8: The fishing group depicted in Figure 5.7 now transposed into the very different location of Mercury Bay, Coromandel Peninsula (from Hawkesworth 1773. II: Plate 18, opp. p. 341). Courtesy of Te Papa, negative #E3538.

During Marion du Fresne’s visit in 1772, Lehoux observed large nets in Spirit’s Bay:

> a fairly large seine made of screw pine which had, instead of sinkers, little round pebbles in a casing of netting with very much smaller mesh than that of the seine... (Lehoux reported by de Montesson in Ollivier 1985: 227).

A few days later, Roux also made a useful observation about these nets:

> They are meshed like ours, being 80 to 100 fathoms long and 5 to 6 feet wide. At the bottom there is a pouch which contains stones to make it sink, having the same effect as the lead we attach to ours. At the top are attached at intervals little pieces of a round and very light wood, which replace the cork which we employ for this purpose (Ollivier 1985: 131, 133).

Unfortunately, these impressive nets would leave little trace in archaeological sites and would be difficult to distinguish from other types of net. However, a keen observation by Knapp on Rabbit Island, Waimea River estuary, Nelson, revealed lines of uniformly shaped slate stones in hollows in the sand dunes which may have been the remains of nets (Knapp 1940). Hamilton provides an illustration of such a net (Fig. 5.9) which shows several distinct sections, each with its own Māori name, the effect of which was to provide a belly in the net. This would be a very useful feature in a large seine to prevent fish escaping when it was full, as the fishes move towards the centre of the net while it is being pulled through the water (Hamilton 1908: 72, Fig. 77).

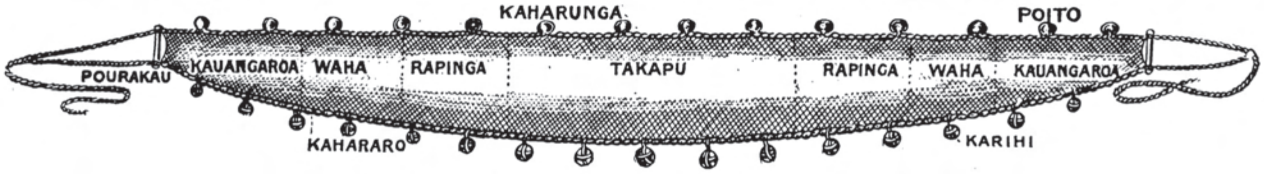

Figure 5.9: A Māori seine net, showing the named sections (from Hamilton 1908: 72, Fig. 77). Courtesy of Te Papa, negative #E5505.

Before leaving the subject of nets, it is worth noting that although many species of fish have excellent eyesight, they give more attention to information about obstacles in their environment from pressure sensors in their lateral line than from their eyes. This is well known by modern commercial fishermen when using trawl nets, the wings of which have wide mesh which fish could easily swim through. Rather than believing the evidence of their eyesight fish trust their lateral line which detects this part of the net as an impenetrable barrier, and they veer away from it. They are eventually funnelled into the far end of the trawl net which has a finer mesh and prevents escape. By contrast, cephalopods are very difficult to capture in this type of net, because they do believe their eyesight and simply swim through the wide mesh of the trawl net wings (Wells 1998: 164–165). This is worth bearing in mind when examining the mesh size of nets and trying to infer the size of fish which might have been caught by it. Best records the following of Māori in the early historic period:

> The mesh of a large net, such as seine, differed considerably in size, being much smaller at the middle part than at the ends of the fabric (Best 1977: 15).

Clearly, Māori were familiar with the phenomenon just described. I know of no comparable example in Polynesia, though this may well exist. It is hoped that the origin of this knowledge of fish behaviour will be found in due course by paying careful attention to any evidence of changes of mesh size in fragments of netting that are found in swamps or dry caves.

CATCHING AN INDIVIDUAL FISH — THE HOOK

Probably thousands of Māori fish hooks, collected historically or found in archaeological sites throughout New Zealand, are in museums. Unfortunately, only a relatively small number have been recovered during controlled excavations; most have been found by fossickers and curio hunters on the surface, or in some cases by wholesale digging for artefacts. Consequently, relatively little is known about stylistic and functional changes through time, although there have been some valiant attempts to order fish hook types into regional chronological sequences, usually with little scientific basis (Hjarno 1967; Simmons 1973). Many works of this kind suffer from the tendency to categorise entire archaeological sites as 'early' or 'late', 'Moa-hunter' or 'Classic Māori', etc., quite often on the basis of their artefacts, and then use the artefact forms in tabulations to illustrate change through time. This is circular reasoning. Moreover, the suggested reasons for these hypothetical changes through time are often pure speculation:

> In this analysis the major groups of fishhooks only have been taken together to illustrate the evolutionary trends (Simmons 1973: 43).

To use the term evolution in this context implies change, which in some manner involves moving to increasingly higher planes of organisation, complexity or entropy. One might apply the term 'evolution' if the observed changes resulted in greater efficiency during manufacture while maintaining the same degree of effectiveness functionally, or better still, actually improved function. In other words, evolution should involve change that in some way transcends from one level to another. In the case of pre-European Māori fish hooks, no such change has ever been identified, and we should forget about using the term evolution until this can be properly demonstrated.

Very few New Zealand archaeological sites have so far been excavated in which hooks have been found in reasonable abundance in several clearly defined stratigraphic horizons, so that significant changes in form through time can be convincingly demonstrated. At best one might say that if one took ten archaeological sites most reliably dating to the earliest period throughout the whole of New Zealand and combined all their fish hooks into one assemblage, this would look different from a combined assemblage of all the fish hooks collected from Māori by the earliest European visitors to New Zealand in the eighteenth and nineteenth centuries. There would be overlaps between these two hypothetical collections and there would be differences. Between these two extremes are bewildering complexity and changes. There are numerous factors that have the potential to explain change both through time and regionally. For instance, one factor is broad regional differences, such as the matrix of dominant fish species; another is local regional differences, where the coastal ecology might change from rocky shore to sandy beach; another relates to seasonal occupation of some sites compared to others; another is changing access to raw materials, such as decline in availability of moa bone[9]. In order to identify causes of observed changes, it is necessary to

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[9] This may be the reason for the observed change through time in the raw material used for hooks at the site of Cross Creek on the Coromandel Peninsula, where Sewell shows that early in the site's history moa and other bone was common, but shell dominates later. This is not accompanied by any significant change in the mix of fish species (Sewell 1988).

establish very local chronologies first as the basic building blocks of higher level interpretations. In my view, when it comes to fish hooks, we have only just begun to identify the first level of building blocks in New Zealand, and need to use more caution and constraint in how we interpret changes from one site to another.

A good example of building upwards from a local chronology is the research published by Leach and Hamel about the Long Beach site in southern New Zealand:

> In the Archaic layers there are characteristic silcrete blades, schist files, and the one-piece fish hook which later disappear, but there are also several composite fish hooks and good evidence that the barracouta point is being transformed already into the dominant Classic Maori dog-legged or lugged type. Within two or three centuries the assemblage displays some of the characteristic Classic Maori artefacts…. The composite fish hook points, while still made in the Late Archaic shapes, now show restrained but common use of serrations. In keeping with its date in the Classic Maori period, the "baroque" style is not yet evident in the fishing gear (Leach and Hamel 1981: 139).

Contrasting with this, in another region of New Zealand where a detailed regional chronology has been thoroughly researched (Palliser Bay) no significant changes in fish hook styles over time were observed, and unlike at the Cross Creek Site, both bone and shell hooks are equally common over a long period at both the Washpool and Black Rocks (Leach 1979b; Anderson 1979).

Another important factor relating to fish hook design is personal. This is not usually considered very important, but when we examine the few caches of fish hooks that can be considered to have belonged to an individual fisherman, there is a strong consistency of form across a small number of basic types. When we compare a pair of such assemblages the differences are striking. In other words, the difference is an insight into what one fisherman considers is right and proper for fishing, compared to another fisherman. It would be folly to put two such assemblages into their chronological sequence and suggest evolutionary or functional change. An excellent example of this are two caches which are very different, one from Pohara near Takaka in the north-west of the South Island, and the other from Serendipity cave, near Jacksons Bay, South Westland (Figs. 5.10 and 5.11).

I sometimes wonder if a modern fishermen, after reading an exposition about archaeological fish hooks, would conclude that the author has little or no practical experience of fishing. That is because archaeologists tend to dwell on features which a fisherman might consider trivial, such as how many denticulations (serrations or notches) a hook has. On the contrary, archaeologists have no monopoly on the emphasis given to minute details of style — modern fishermen are equally focused on trivia. A visit to any modern fish tackle shop will reveal this. Some years ago I went to a tackle shop in Anchorage, Alaska, to buy the small amount of gear to catch a local salmon. The shop was an enormous supermarket with a plethora of goods and every conceivable form of fish hook imaginable, each declaring its superior catching qualities compared with all others. I thought at the time that there were probably far more hooks in this shop than salmon in the nearby rivers. Although this might seem an amusing statement about the gullibility of recreational fishermen, it also made me think of the no less diverse range of prehistoric hooks from New Zealand and tropical Polynesia. The reality is that fishermen of all levels of sophistication, no matter how ancient or modern, are constantly engaged in experimental research with fishing tackle. Each fishermen has his own theory as to what works best, and while this ongoing research is not always very scientific, in my view it was alive and well throughout pre-European New Zealand. We should therefore think twice before attributing changes in form to changes in function, let alone use words like 'evolution'.

Figure 5.10: A selection of fish hooks from a cache at Pohara near Takaka (Courtesy of Manawhenua ki Mohua).

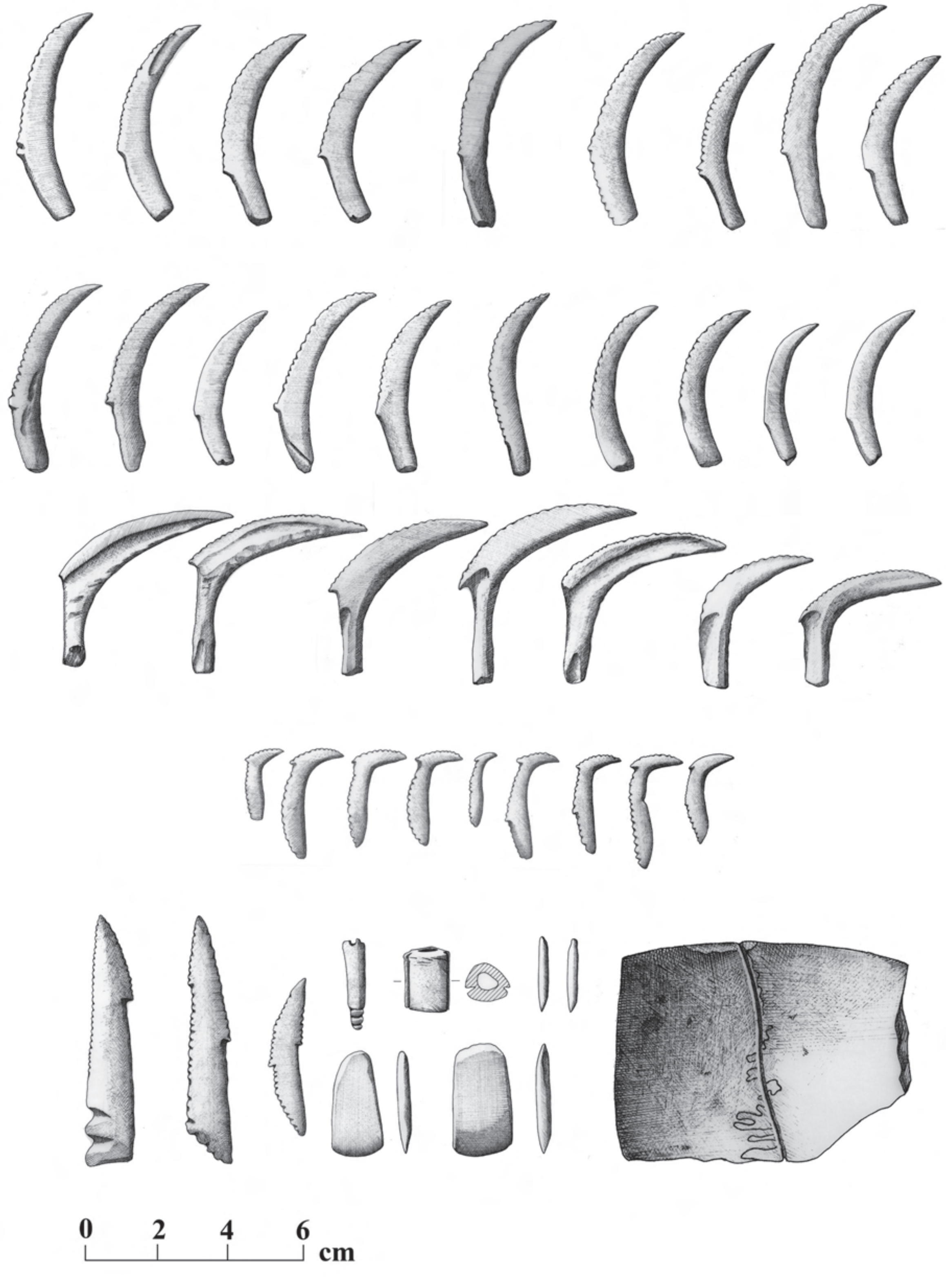

Figure 5.11: A selection of fish hook points and a few other items from a cache at Serendipity Cave, South Westland.

Having raised the concept of function, I must admit that this poses a considerable problem. When it comes to evaluating the effectiveness of design elements in hooks from archaeological sites in New Zealand (no less than in Polynesia and further afield in Oceania) we are on very shaky grounds. A European fisherman faced with a tray full of bone and shell fish hooks[10] would immediately notice several things which distinguish them from anything in his experience. These are:

1: the parts of the hook are very thick
2: the point is blunt
3: the gap between the point and the shank is very narrow

The fact that the parts of the hook are very thick is unavoidable, given the materials available to non-industrialised non-metal cultures, such as shell and bone, which are far less strong than steel. This would have been the main thing which, conversely, Māori would have noticed about the first European metal fish hooks they observed.

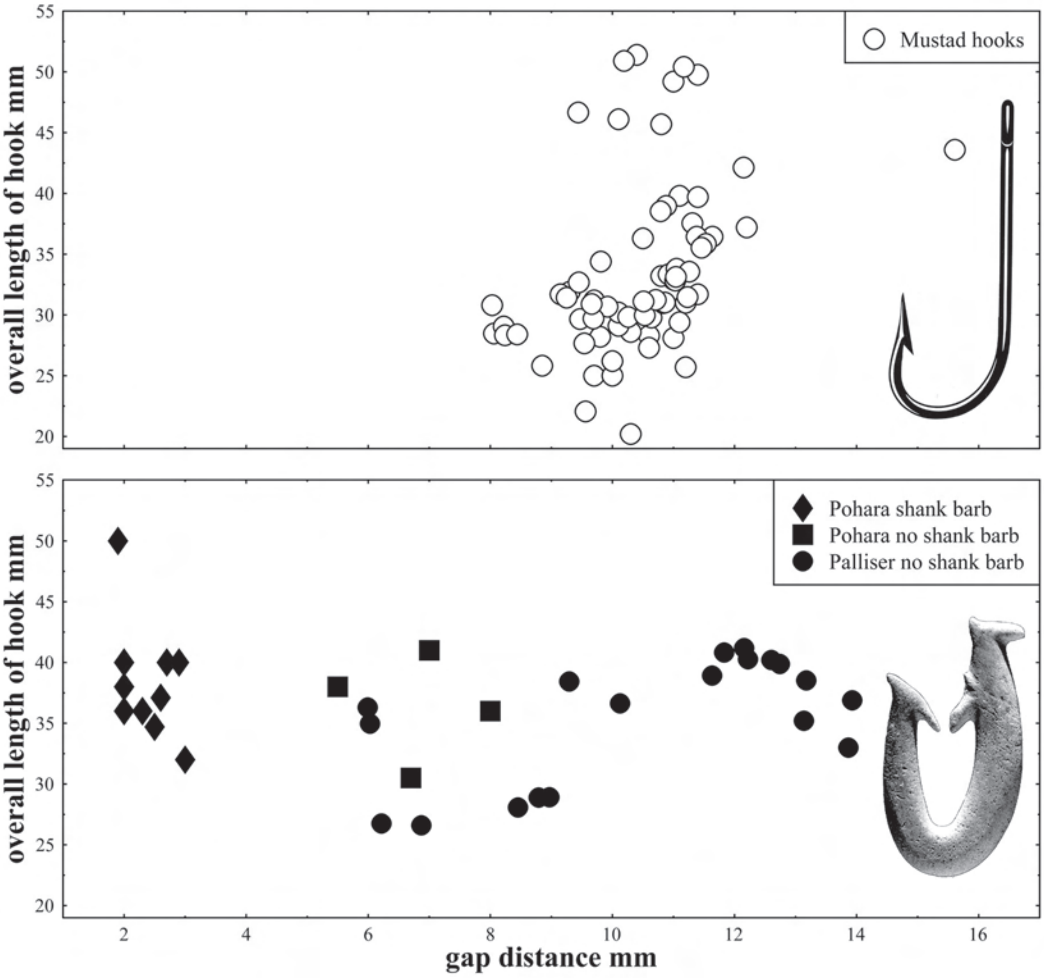

Figure 5.12: The gap between point and leg (x-axis) compared to overall hook size (y-axis) for samples of modern and ancient fish hooks. Upper: Six different types of Mustad hooks, the one illustrated is Mustad Norway #34968. Lower: Samples of Pre-European Māori fish hooks from Pohara and Palliser Bay. The gap in the illustrated hook from Pohara is 2 mm.

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[10] In this discussion I am only concerned with the most common type of fish hook; that is, the one-piece bait hook.

The fact that the point is relatively blunt is interesting. It is possible to make a very sharp point with bone or shell, although it would not be very strong. Pre-European Māori fish hooks were not as sharp as it would be possible to make them, and therein might be a clue about some functional or operational difference between European hooks and those found archaeologically.

Finally — the narrow gap. This certainly is a most striking feature to any modern fisherman. A typical example is illustrated in Figure 5.12 (See also Fig. 5.10). This hook is from the cache found at Pohara near Takaka. The gap is 2 mm. It can be seen that the shank has a projection, closing the gap between the incurved point and the leg of the hook. This projection is usually referred to as a 'barb', but that prejudges what the function of the projection was. It may simply have been a convenient way of narrowing the gap during manufacture, which was accomplished by drilling holes in a tab of bone and then punching out the centre. This cache of hooks from Pohara is very instructive. Four of the hooks do not have this projection on the shank; the gap in these hooks is three to four times the size of the gap in those with the projection. The hook gaps for this cache are plotted out in Figure 5.12 and compared with those on a sample of modern Mustad hooks[11].

Why did pre-European Māori make hooks with such a narrow entrance? The short answer is we do not know, although there is a theory, which might be termed *the rotating hook theory* (Leach 1973). According to this theory the fish does the catching, not the fisherman. In Figure 5.13, at A, the fish approaches the hook (bait not shown). Many fish are accustomed to eating extraneous matter, such as fragments of shell, with their food and a hook with no sharp projection could easily be swallowed without discomfort (shown at B). If the line is tugged at this point, the hook would come out of the fish's mouth, but if left alone the fish will swim away, carrying the line along its side (shown at C). The line will eventually become taught, and begin to pull the hook out of the fish's mouth. At first, the force on the hook is towards the front of the fish, but the instant the shank becomes clear of the

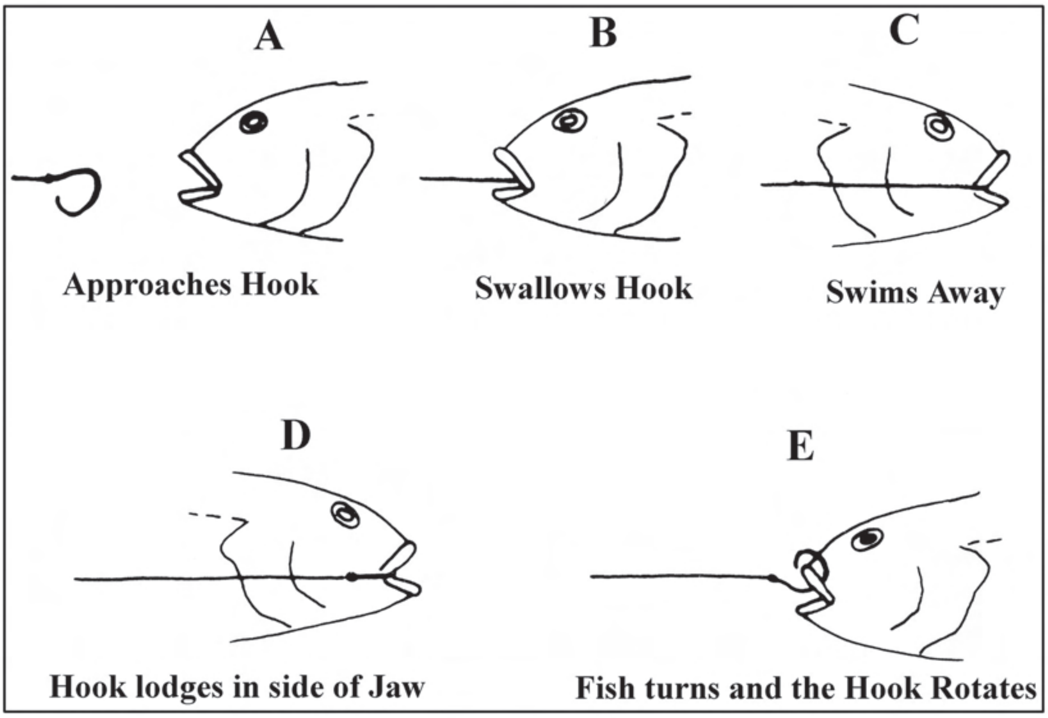

Figure 5.13: The rotating hook theory (after Leach 1973: 59).

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[11] These Mustad hooks are all size 1. Six different types of hook are included in the sample plotted.

mouth the direction of the force changes towards the rear of the fish, causing it to rotate rapidly. It will come to rest with the shank of the hook lying outside the jaw, and the point lying inside the jaw (shown at D). From this stage on the fish cannot escape. If the line is now tugged or the fish tries to change direction, the hook will rotate in the mouth, acting as a lever, and the point will penetrate behind the jawbone. In theory, to a certain extent, the narrower the gap between the shank and the point the better. In addition, the hook rotates more effectively if the shank is the same length as the leg on which the point occurs. The hook is therefore rounded, not elongated like typical metal hooks.

Is this theory correct? It has never been observed under water with real fish using replicas of rotating hooks, so it remains only an untested theory[12]. I have tried fishing with rotating hooks, using a series of replicas of a shell rotating hook (Fig 5.14), based on those found in excavations in Palliser Bay at the Washpool (Leach 1979b: 109) and Black Rocks (Anderson 1979: 57). These hooks do not have a shank barb but do have incurved points and with their short leg qualify as rotating hooks. Several types of fishing grounds have been tested, including those dense with blue cod (which has a big mouth) and banded wrasse, spotties and scarlet wrasse. Attempts were made to jab the hooks to seat them (contradicting the rotating hook theory), as well as leaving the line slack so the fish could swallow it whole uninterrupted. On all occasions bait was readily and consistently removed from the hooks within seconds. Despite numerous attempts to catch fish with these replicas, not one fish has been successfully hooked. It must be concluded that this theory about the functioning of the rotating hook remains a theory only, and requires far more research.

Some European metal hooks do have similar characteristics to the Māori and Polynesian rotating hook. One well known example is the *Mustad tuna circle #3997L hook*, which has an incurved point and short leg. These hooks are also known as either 'Circle hooks' or 'C' hooks, to distinguish them from the more familiar 'J' hook, which has a longer shank and a straighter upward facing point (Fig. 5.15).

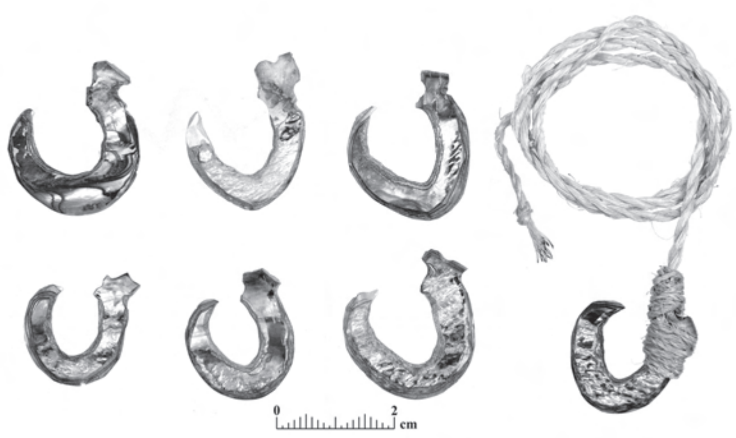

Figure 5.14: A sample of replica shell fish hooks based on examples from excavations at the Washpool and Black Rocks in Palliser Bay. They were made from pāua shell (*Haliotis iris*), and the two-ply cordage was made from New Zealand flax (*Phormium* sp.).

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[12] The description which I published (Leach 1973) was pure speculation, and not based on any observation or influence from published or unpublished inferences by anyone else. It was simply an 'educated guess'.

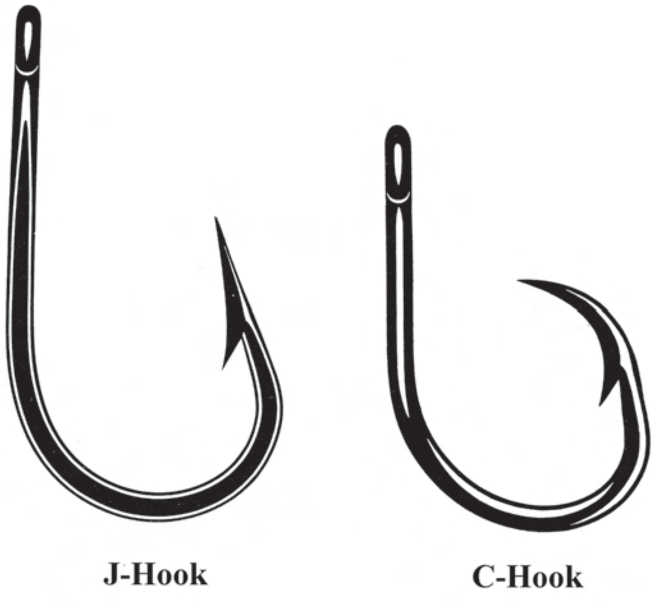

Figure 5.15: Modern European steel hooks. Left: the 'J' hook (example: Mustad—Southern and Tuna #7691); Right: The 'C' hook (example: Mustad Tuna Circle #3997L).

Experimental research on these hooks might shed some light on their different catching characteristics (as a proxy for the pre-European Māori forms). In one study (Orsi *et al*. 1993) in southeast Alaska, which was aimed at trying to reduce the mortality of undersized by-catch of salmon, it was found that C-hooks lodged in the periphery of the mouth more frequently than J-hooks, and wounds in this area had a lower mortality. In addition, C-hooks caught twice the number of fish as J-hooks. One especially interesting find relates to the size of the two types of hook and what fish they caught. In the case of J-hooks, small hooks caught more fish than large hooks[13]. However, in the case of C-hooks, the largest hooks caught more fish than smaller ones. Admittedly these experiments were carried out with hooks disguised in various lures, and were targeting a species not found in pre-European New Zealand, so they may not have any direct relevance, but it does serve to point the direction that research into these pre-European hooks might take.

A similar study, carried out in the Bay of Biscay off the coast of France, was inspired by South Pacific examples of traditional hooks with incurved points (Forster 1973). They chose size 6/0 hooks with the same patterns as those shown in Figure 5.15, and fished in 800 to 3,600 m depths with 1 m long snoods[14] at 10 m intervals, alternating between one form and the other. They caught 14 species of fish, and the C-hook caught far more fish than the J-hook (93 and 58 fish respectively). The discrepancy was most marked in the case of gadoid species (cods). They hypothesised the following explanation of the functioning of the incurved point:

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[13] Experimental research on hook size shows that while small hooks may often be ejected from the mouth; once a fish is hooked they are more likely to stay hooked than if a larger hook is used for a particular species (Shimizu *et al*. 1993).

[14] The term 'snood' is here used to refer to the short piece of cordage between the hook and the main line being used by a fisherman. However, it is sometimes used to refer to the often complex method of attaching this line to the actual hook itself.

> For the incurving hook to function there must be some slack in the line or snood, allowing the fish to move away with snood trailing. At the end of the slack the fishes head is pulled around and the hook (providing the point has engaged) makes a half turn usually in the corner of the mouth. Once one of these hooks is engaged it is very difficult for it to be shaken out (Forster 1973: 751).

This explanation is very similar to the *rotating hook theory*, cited above, but is obviously not based on any direct observation, in view of the depth at which these hooks were used. What is important in this research is the fact that the C-hook was so effective in long-lining, which is effectively passive fishing. The J-hook is more effective as a *jabbing hook*, which the fisherman seats into the fish's mouth when he feels it nibbling on the bait. The observations already made above about the use of cordage made of flax fibre, which is insensitive in communicating information from the fish to the fishermen, might suggest one of the reasons why the C-hook was so popular amongst Pre-European Māori. Further information about the passive nature of fishing with rotating hooks is provided by Nordhoff, who was encouraged by H.D. Skinner in 1928 to record observations about fishing in the Society Islands before old customs completely disappeared (Nordhoff 1930: 137). He had this to say:

> In one respect the use of all these in-curved or angular native hooks differs from that of ours. When the fisherman using a European hook "gets a bite," he strikes to set the point and barb in the fish's mouth. With the native hook, on the other hand, one must never strike; a steady gentle tension is kept on the line and the fish allowed to hook itself. The pull of the line, leading from the *inner* head of the shank and causing the hook to revolve, sets the point deeper and deeper in the fish's jaw (Nordhoff 1930: 156).

This observation related to the very large wooden hook used for deep water fishing of *palu*, the ruvettus or oilfish. It is not quite the same as fishing in relatively shallow water with small shell or bone C-shaped hooks. When fishing in deep water, as noted above, the heavy sennit lines make use of jabbing hooks impossible. Similar comments about fishing for ruvettus have been made by Powell (1964) for Rarotonga. He argues that the incurved-point hook was developed precisely because of the insensitivity of sennit lines in deep water. He suggests that ruvettus fishing was undertaken at depths of up to 500 fathoms (914 metres), and that even on a fine day there is a normal lone ocean swell so that the canoe rise and falls. In these conditions it is impossible to feel any fish biting. In addition, trying to seat a hook by jabbing is ineffectual because of the elasticity of the line, and the fact that it will form a curve down to the bottom. Attaching a large sinker might help, but it would have to be very heavy and therefore not easy to pull up. Polynesians developed several ways around this problem, such as using a 7 kg stone lightly attached to the bottom of the line which was released when the line reached the bottom or when a fish struck the hook.

> The hook depends on rolling through part of a circle when pressure is applied to the point and operates so that when the fish seizes the bait the hook is swallowed to the back end of the mouth while the fish moves off with a trailing line. If the line is struck at this time, the hook will be pulled out of the mouth easily. If, however, the fish is allowed to move off with the leader trails behind, the fish will at a certain moment pull against the tightened line, pulling the hook down into the corner of its mouth, or the top edge of the jaw is forced between the hook's shank and its point. If the line is kept steadily taught at this position the fish will change direction so that it swims at right angles to the line. In this position all the pressure bears on the hook's point and it rolls through a part circle coming out very often through the top of the head or the side of the jaw (Powell 1964: 288).

Although these comments are about ruvettus fishing, they are certainly useful observations, and may be partly appropriate to small circular shell hooks too. Unfortunately we do not know if these were direct observations, or from questioning old informants, since sennit lines of such length are unlikely to have been still used in 1964.

Although museums have very large quantities of stone sinkers from pre-European Māori archaeological sites, virtually nothing is known of their functional characteristics. The 7 kg example, cited above, provides a clue on the need for a heavy weight to take a line down any depth of water. It is probably not widely appreciated outside the circle of fishermen that stone is an appallingly bad sinker in sea water. The specific gravity of sea water (ρ=1.025) offers greater buoyancy than fresh water, and modern fishermen are used to their lead sinkers (ρ=11.34) plummeting to the bottom with nylon lines. Attach the same lead sinker to a 30 metre long line made of three-ply flax and it will be nowhere near as fast through the water. Replace the lead sinker with a stone sinker of the same size and it might never take the line down 30 metres because not only does the line have vastly greater friction, but it also has buoyancy. Increasing the weight of the stone sinker is necessary, but that is a mixed blessing because it also increases its surface area, providing further friction. Since the specific gravity of stone is less than one-quarter that of our familiar lead sinker, you will begin to appreciate the problem. The shape of the sinker will also have an important bearing on how fast it will reach the bottom and what it is like pulling it up again. No wonder some Polynesian fishermen are known to have invented a way of detaching their stone sinker once it got to the bottom. The sad fact is that most types of stone have low specific gravity of about ρ=2.7, which is the same as aluminium. If you imagine attaching a block of aluminium to your three-ply fishing line you have a fair reflection of what pre-European Māori faced. So, choosing which rock type to use is important. Granite, for example, has a specific gravity of ρ=2.69, whereas basalt has ρ=3.01. This small advantage must be offset against another problem with using stone for sinkers — it is not easy to attach a line to a stone. Most modern fishermen will be familiar with this problem, when they have thrown their last piece of lead into the sea, and are forced to try tying rocks on to a line. Pre-European Māori used another harder stone as a hammer to laboriously peck a groove around their stone sinkers to help keep cords attached to them. There is much that can be learned from the numerous stone sinkers which we have in museums — there will be excellent reasons for the choice of stone type, the shape of the stones, and their weights and specific gravities. Hamilton illustrates a fishing sinker made of stone with a horseshoe carefully tied on to the outside of it (Hamilton 1908: 54, Fig. 55). This would greatly increase its ability to sink (iron ρ=7.8–7.9).

Another aspect of the pre-European Māori rotating hook only appreciated by modern fishermen in relatively recent times is that it has more efficient penetrating power than most traditional forms of European metal hooks. This is illustrated in Figure 5.16, and is easily tested personally by putting the finger of one hand gently on the point of each of these hooks in turn, and holding the snood attached to the eye of the hook in the other hand. The hook will naturally resolve the two vectors of force by rotating, at which point you can observe the direction in which the point of the hook is facing. The two vectors are drawn in Figure 5.16 — one shows the direction of the line pulling the hook, and the other shows the direction of penetration of the hook. In the case of the pre-European Māori hooks, both the rotating and jabbing hooks show vectors which are equal and opposite, and therefore fully efficient in ensuring that all the force on the line is translated into a force penetrating the jaw of the fish. However, for the Mustad Norway hook, so typical of almost all European metal fish hooks until recently, the angle of the point is approximately 30° from the angle of the snood line and the penetration efficiency is reduced to about 87% (Cosine 30°).

While early European explorers into the Pacific region might have been astonished at the peculiar circular form of fish hooks being used by the indigenous peoples, the realisation that pre-European

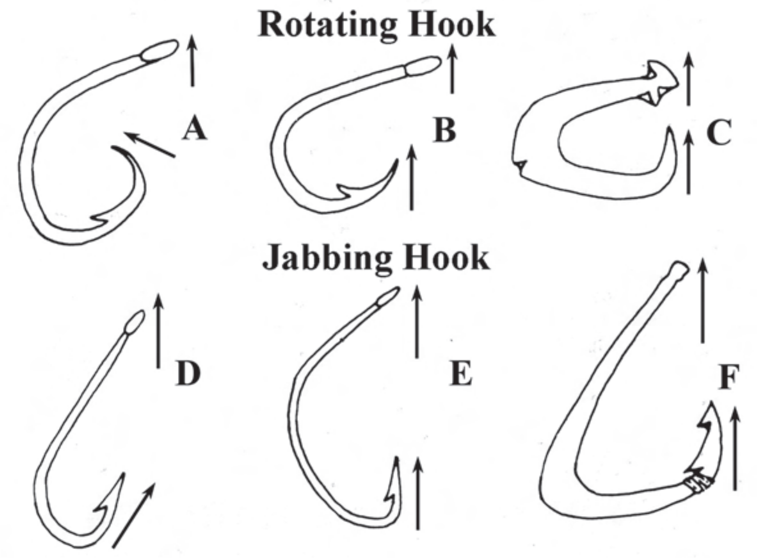

Figure 5.16: Penetration efficiency of various hook designs (after Leach 1973: 59). A: Mustad Tuna Circle #39960ST, B: Mustad Special Tuna #399L, C: Typical pre-European Māori rotating hook, D: Mustad Norway #34968, E: Mustad Wide Gap #37140, F: Typical pre-European Māori jabbing hook.

Māori and other Polynesian hook forms have superior ability to hook fish has led to dramatic changes in modern hook manufacture. Pottier de l'Horme recorded during de Surville's voyage to New Zealand in 1769:

> Their lines, or rather their hooks, are pieces of root shaped as in Plate Number 10[15]. To one end they attach a very sharp fish bone, the point of which bends inwards following the shape of the wood; I doubt whether they catch great quantities of fish with this implement (Ollivier and Hingley 1982: 134).

In 1777, Anderson expressed a similar view:

> They [Māori] live chiefly by fishing, which they do either with nets of different kinds or wooden fish hooks pointed with bone but so oddly made that a stranger is at a lose to know how they can answer such a purpose (Anderson 1967: 811).

Pottier de l'Horme and Anderson, have, on the contrary, eventually been proven wrong; for although the materials from which Māori hooks were made are inferior in many respects to tempered steel, the superior form of their hooks is now being finally appreciated. Sales figures of different types of Mustad hooks clearly show this. The traditional J-hooks (Norway and Kirby) declined from 90% of the market in 1987 to less than 10% in 1990. Conversely, sales of the Mustad Wide Gap hook and the EZ hook (Easy baiter circle hook) dramatically increased over the same period from about 10% to 90% (Løkkeborg *et al.* 1993: 43).

This functional superiority has been backed up with results from experimental research on the two forms of hook in the laboratory. The traditional J-hook gave a probability of catching cod of about 15%, compared to 36% for a hook with incurved point (Mustad Wide Gap hook). When the latter was used in commercial fishing trials, the catch rate increased by 17%. Similarly, the second form

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[15] This shows a wooden-shanked two-piece rotating hook.

of incurved pointed hook (EZ Easy Baiter Circle) also gave significantly greater catch rates in long line fishing at sea. This is attributed to the point being in the same direction as the line of pull (Løkkeborg *et al.* 1993: 43).

When considering the function of these hooks it must not be forgotten that (trivial stylistic features aside, no matter how important these may be for magico-religious observance) whether a particular hook form and size will or will not catch a fish and how frequently, does depend to some extent on the species of fish itself, its behaviour towards these hooks, the bait which is on them and its size (Løkkeborg 1991; Fernö *et al.* 1986; Fernö 1993). To my knowledge, systematic research on fish behaviour towards baited hooks has not been carried out for New Zealand species, with either modern hooks or copies of pre-European Māori ones. This requires use of scuba gear and underwater video filming and the capacity to bait different kinds of hooks quickly and lower them to the bottom. In this way research can also be carried out on the effectiveness of different kinds of bait (see for example Johnstone and Hawkins 1981). An example of the different behaviour of two species towards baited hooks is shown in Figure 5.17.

In this illustration:

B=Bite	The fish takes in the baited hook and closes its mouth
P=Pulling	The fish swims slowly with stretched snood with the baited hook in its mouth
C=Chewing	The fish chews on the baited hook
J=Jerk	The fish moves its head rapidly sideways with the bait and hook in its mouth
Js=Jerk series	The fish performs several very fast jerks in succession from side to side with the baited hook in its mouth
R=Rush	The fish accelerates rapidly with the baited hook in its mouth
S=Hook out of mouth	The hook with or without bait is spat or pulled out of the mouth
H=Hooking	Not a behaviour pattern. The fish was considered hooked when the hook was retained in its mouth for 20 s while the fish was struggling (Huse and Fernö 1990: 290).

In the case of cod (*Gadus morhua*), 139 bites are recorded in the flow chart in Figure 5.17, and we can see what happened in each case, finally resulting in 15 hooked fish (10.8%). For haddock (*Melanogrammus aeglefinus*), there are 46 recorded bites and 23 fish were hooked (50%). This type of experiment has been carried out for different hook types (a total of 19,500 hooks). Of interest here is the fact that two different versions of hooks that possess the characteristics of the pre-European Māori rotating hook out-performed the standard jabbing hook (Huse and Fernö 1990: 294). These are the so-called ‘Rush’ hook, and the Mustad Wide Gap 5/0 hook. Both these hooks have points which are incurved towards the shank. The same result has been obtained with long-shanked hooks, one with the point curved inwards towards the shank and the other without, on dogfish catches (*Squalus acanthias*) off the Shetland Islands in 20–50 m depth. A sample of 2,400 hooks of each type were tested, catching a total of 1,067 fish. The incurved hook gave 18.6% greater catch (Hamre 1968).

There are many factors involved in assessing the effectiveness of different hook forms and baiting methods (Løkkeborg and Bjordal 1992), and there is disagreement about how best to interpret the complex data produced from experimental research (Kenchington 1993). Fish may have strongly diurnal feeding patterns and their behaviour towards baited hooks therefore varies through the daily cycle (Løkkeborg and Bjordal 1989). It also varies through the tidal range and seasonally. The

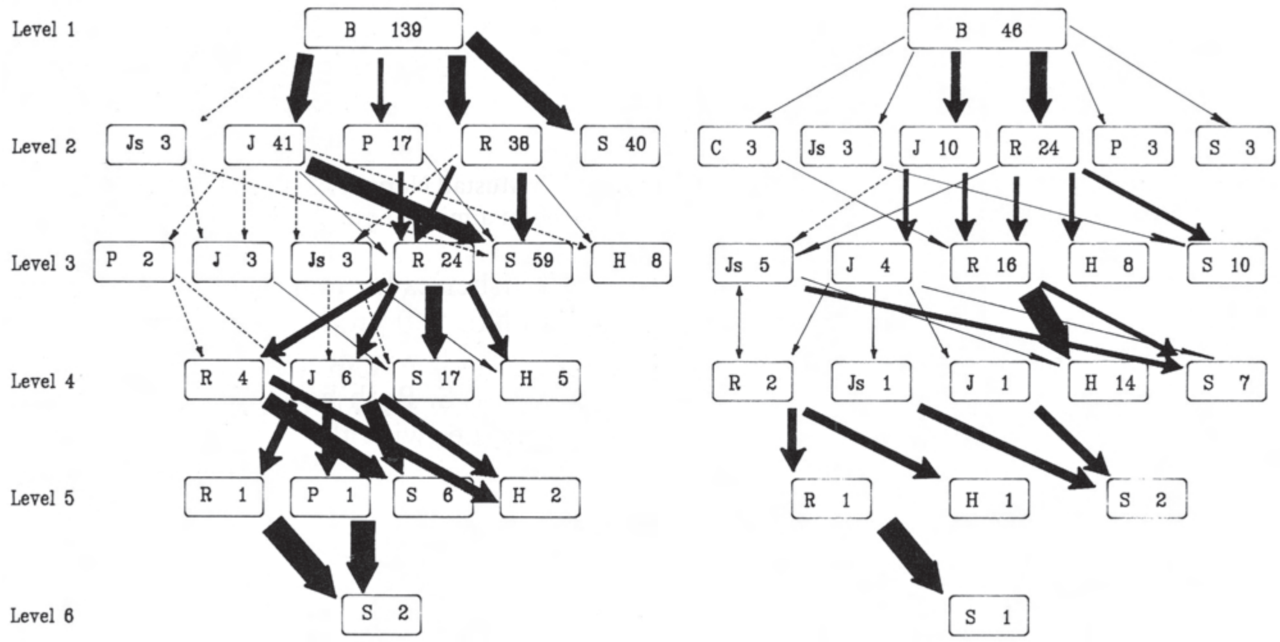

Figure 5.17: Behaviour flow chart of two different species taking a baited hook. Left: Cod (*Gadus morhua*), Right: haddock (*Melanogrammus aeglefinus*), after Huse and Fernö (1990: 292–291). Courtesy of Elsevier. See text.

presence of other species affects behaviour, and also different sized fish behave differently. Above all, prior experience with hooks has a dramatic effect on fish behaviour and this is one of the main problems in carrying out useful experimental research in New Zealand, where conditions are now so far removed from those of pre-European times. The inshore fishery has been massively depleted by commercial and recreational fishing in the last 150 years since Europeans arrived here[16]. Useful experiments with replicas of pre-European Māori fish hooks would only be meaningful if carried out in a fishing reserve, where fish had been left alone for several (fish) generations. Such fish suck the whole bait into the mouth, whereas fish which are hook-shy make incomplete bites, very often as a conditioned response to bad experiences in the past.

Fernö and Huse (1983) provide some very useful documentation on changes in fish behaviour towards hooks from their experimental research on cod in an aquarium[17]. They carried out two experiments, one lasting 10 days with 15 cod from offshore trawls, and the second lasting 17 days with 20 coastal cod. Five trials were made each day using a barbless Mustad Norway #6 hook. They used a similar recording protocol as Huse and Fernö (1990: 290), which is described above and ranged through several stages of the sequence from initial biting to being hooked or releasing the hook and bait. The fish were not fed during the period of these experiments. They found considerable variation in the behaviour of individual fish towards hooks. Two fish exhibited no behaviour at all towards hooks. Of the 27 fish which showed responses to the baited hook, 21 made at least five sequences, 11 fish made more than 20 sequences, and one fish made 413 sequences (slow learner?)! They found that most hookings took place in the first 3 days, and slowly decreased

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[16] The extent of pre-European Māori impact on the fishery will be discussed in Chapters 7 and 9.

[17] It has been pointed out that there are important differences between fish behaviour relating to baited hooks in the open sea and that in aquaria (Løkkeborg *et al*. 1993: 43). Research results can therefore only be applied to the open sea with due caution.

in frequency after that. Ten fish were never hooked, 11 fish were hooked twice, one fish was hooked three times, and two fish were hooked four times. Overall the hooking probability was 25% on the first strong response by the fish.

The most important finding of this research was that the intensity of behaviour responses to the hook and bait decreased over time, regardless of whether a fish was hooked or not. Physical stimulation from the hook was regarded as the most important factor in this decreased response. Even though the critical stimulus for this conditioned response was probably the hook itself, the fish did not seem to be able to distinguish between the hook and the bait. After this conditioning had set in, bait without hook was tested, and the fish showed the same reluctant and low intensity behaviour. In this respect, the form of the hook is of great importance, in particular how sharp it is and where any sharp projections are. Fernö and Huse make the following observation:

> In many Pacific types of hooks, the point is bent heavily inwards so that the hook almost forms a circle or a triangle…. This hook shape may decrease the probability that a fish comes into contact with the point of the hook and thus experiences aversive stimulation when biting which in turn could lead to a greater number of strong responses and higher percentage of hooked fish. Such an effect could combine with a higher hooking probability when fish rush on a bent hook as opposed to a straight hook (Fernö and Huse 1983: 27).

This decrease in response to baited hooks, although well known, is not well quantified for different species, but does appear to be highly variable. For example, Beukema (1970) has shown that one single hooking experience makes carp (*Cyprinus carpio*) more difficult to catch for at least a year. The main point is that experience with hooks makes fish less vulnerable to capture by this method. Another aspect of aversion behaviour of fish concerns the fishing line itself. It has been shown that by adopting monofilament line for long line fishing in place of multi-twine line, the catch rate for cod increases by 40 to 300% (Huse and Karlsen 1977, cited by Fernö and Huse 1983: 27). There are at least two possible causes for the aversion of fish to multi-twine line compared to monofilament — one is that the avoidance is because of prior association with baited hooks, and another is initial avoidance of novel prey attached to a more visible line. Whatever is the case, pre-European Māori baited line fishing was at a distinct disadvantage, because highly visible lines were being used.

Another aspect of fish behaviour that has a bearing on catch rates is the response to the use of wooden spreaders with multiple baited hooks. These devices are well documented amongst Māori fishermen during early historic times in New Zealand (see for example Best 1977: 25, Fig. 8), but would be difficult to document in the pre-European era unless intact specimens were found in swamps or dry caves. Many species of fish have been observed making rapid and intensive movements which stimulate feeding behaviour. A fish that has been hooked starts to fight vigorously, and this has been shown to stimulate other fish to attack neighbouring hooks (Johannessen *et al*. 1993: 49). Another aspect of these spreaders (and long lines too) is the length of the snood. A balance must be reached between the likelihood of the snood becoming tangled if too long, and the fact that catch rates fall if the snood length is decreased too far (Lee *et al*. 1990: 48). Many bone and shell hooks with snoods attached were collected by early European explorers to New Zealand and are now in museum collections. These offer useful research opportunities for the future.

The way in which a fish pulls against the snood has been studied in some detail (Lee *et al*. 1989), This research has indirectly shed some light on a possible reason for the incurved design of many pre-European Māori hooks. Lee *et al*. studied the behaviour of a species of fish (walleye pollock,

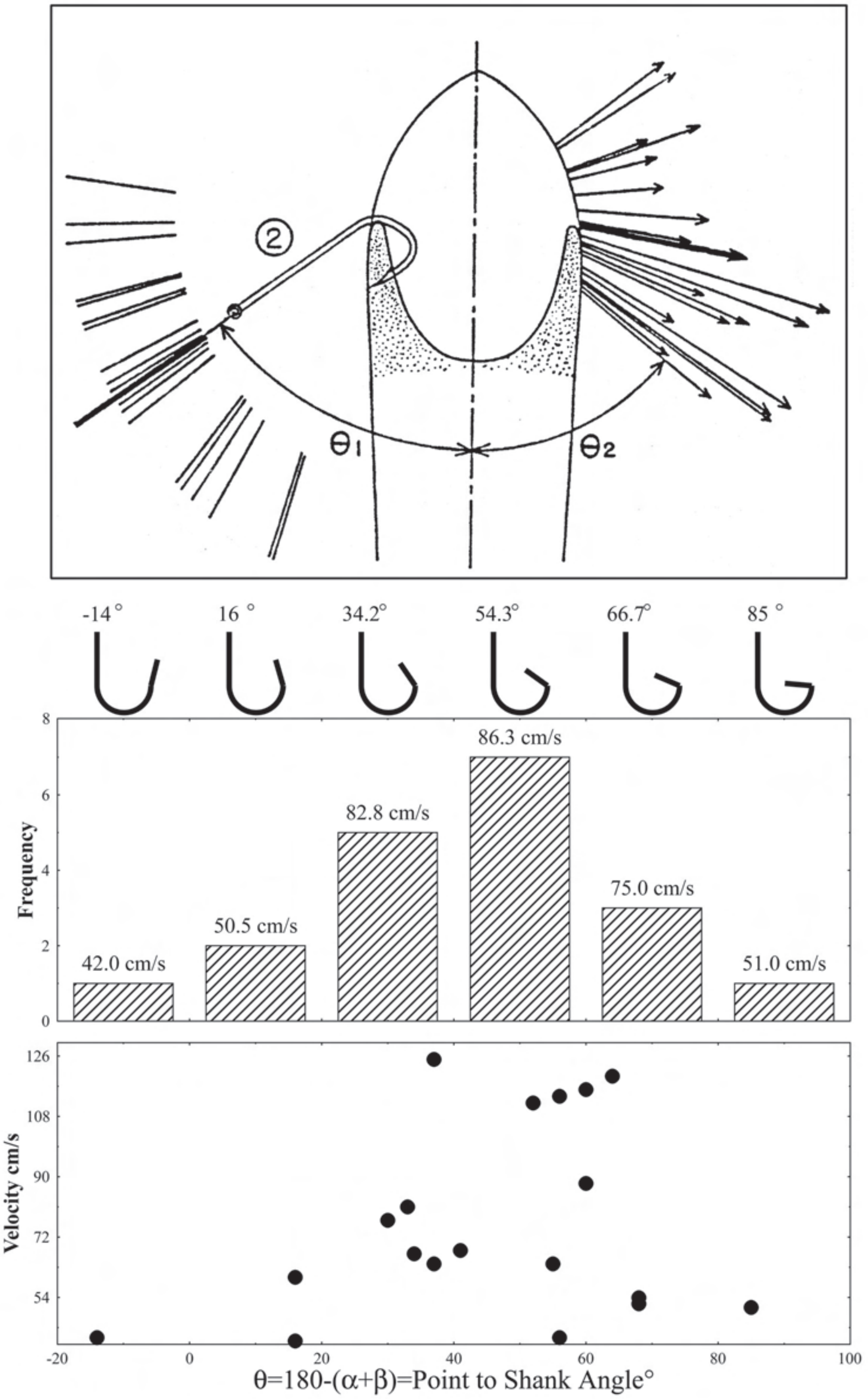

Figure 5.18: Upper: snood and head movement angles of fish during hooking (after Lee *et al*. 1989: 1556). Lower: analysis of angles and fish movement during hooking. See text for explanation. Courtesy of Chun-Woo Lee.

Theragra chalcogramma) in an aquarium, recording the movements of the fish during capture with a baited hook with a video taking 30 frames per second. The steps in the process closely followed those documented by Huse and Fernö (1990), described above. However, at the moment the fish was actually hooked, Lee *et al*. carefully recorded the angle of the snood, and the angle of the fish's head moving away from the hook. They also recorded the velocity of the head movement in cm/s, and the force on the hook in Newtons (kg.m/s^2) with a strain gauge attached between the mainline and the snood. The results of this study that are significant for the present discussion about ancient forms of hooks are summarised in Figure 5.18.

The upper part of this Figure shows a plan view of a fish with a hook (schematic only) caught in its mouth. The several lines on the left are recordings of the various angles between the snood and the longitudinal axis of the fish, when individual fish were being hooked. This angle is labelled α. The thick line is the mean angle of the snood, 55.4˚. On the right hand side several vectors are shown, which are recordings of the angle at which the head was moving at the moment of hooking. The length of each arrow indicates the velocity of this movement. This angle is labelled β. The thick line is the mean angle of this vector, 79.7˚. It should be obvious that the greatest possibility of the sharp point of the hook penetrating the flesh of the fish is when the point is facing exactly the opposite direction to the movement of the head away from the hook. This is where the shape of the hook becomes extremely important. In the example shown here, it will be observed that the point of the schematic hook is not in the opposite direction to the mean vector on the right hand side, and is therefore very inefficient. In this schematic hook, the line of the point is exactly the same as the shank, that is 0˚. For the point to be facing in the opposite direction to the vector on the right hand side, the angle between the shank and the point would have to be $180-(\alpha+\beta)$, which I will call θ.

So, the fish hook most likely to penetrate the jaw of this species of fish and hook it is one which has the optimum angle between the shank and the point that conforms to the predicted behaviour of this species. In the lower part of Figure 5.18, the recorded hookings, N=19[18], are presented as a scatterplot, with the angle θ on the x axis and the velocity of the fish's head on the y axis. The mean value of θ is 45.0˚; the mean velocity was 75.7 cm/s. The mean force was 4.3 Newtons. Above the scatterplot a bar graph is given, combining the results into groups in an effort to show the pattern more clearly. There is a central tendency in the band between 40-60˚. Above each bar the average velocity in each band is given as a number, and this also indicates something interesting — that there is a central tendency in this too, with the highest velocity occurring at the optimum angle. This reinforces the conclusion that the highest probability of a hook penetrating the fish's jaw is in this same band of angles. Above the bar graph are schematic drawings of what a fish hook would look like with these various angles between the shank and the point. In the band between 40 and 60˚, the mean observed successful hookings was at 54.3˚.

This research provides compelling mechanical evidence of why a hook with the point facing inwards is much more likely to catch a fish than the traditional Mustad Norway hook with its straight shank and straight upwards-facing point. Of course this research relates to a particular species and it is very likely that the behavioural details of strike angle, velocity and force will vary from one species to another. But this research gives us an insight into why pre-European Māori made their 'rotating hooks' the way they did — to improve the chance of a fish being hooked.

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[18] It may be thought that this is a small number of observations. However, obtaining these results was a formidable undertaking. Altogether, 974 observations were made of a fish approaching the baited hook. In 629 the fish tasted it, in 260 it took a bite, in 229 it spat it out, and in only 35 did it steal the bait or get hooked.

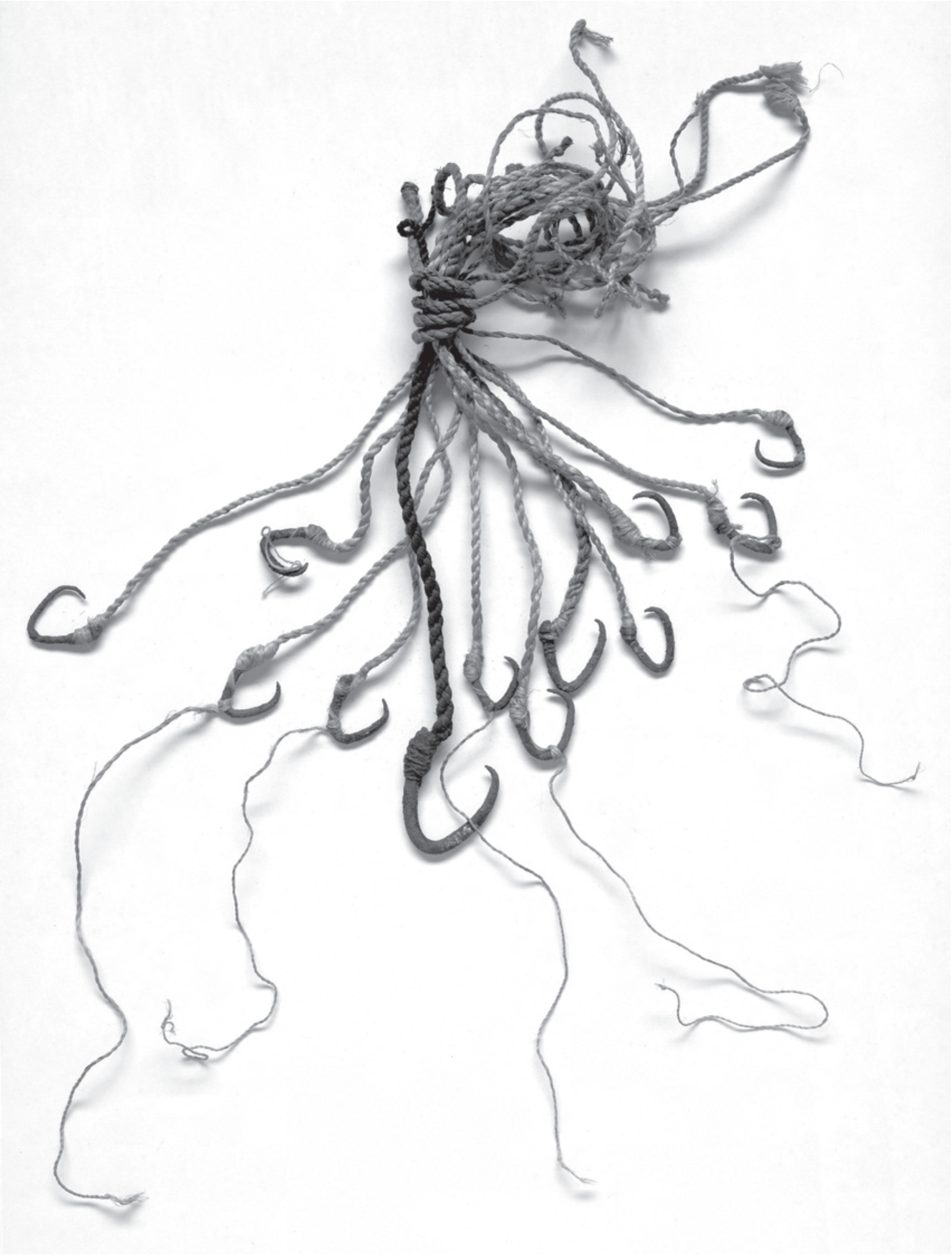

Figure 5.19: Nineteenth century Māori fish hooks made from iron following the ancient rotating hook form with incurved point (based on Hamilton 1908: 45. Courtesy of Te Papa, negative #E3598.

So much for the apparently peculiar shape of many of these hooks found in archaeological sites. It is only in the last 20 years or so that Europeans have finally discovered something which pre-European Māori knew a very long time ago. Where this technology arose and how it came to be in New Zealand is beyond the scope of this chapter. From the time of Captain Cook, when iron, copper and other metals began to find their way into New Zealand, Māori took no time to recognise the superior qualities of this new, malleable yet durable material, and quickly abandoned bone and shell in its favour for making fish hooks and other items of material culture. Yet they did not abandon their own fishing technology, superior to that of Europeans. They continued to fashion their fish hooks according to the shapes which had served so well for many centuries, but used metals in place of shell and bone (Fig 5.19). One aspect of this, unstudied to date, is what else Māori did to iron, in addition to bending pieces into the shapes they desired. A thin piece of untempered iron does not make a very suitable hook and easily bends with a decent sized fish struggling on the end of a fishing line. Māori in the early historic period also used pieces of copper to make fish hooks. These would be useless unless tempered in some way, such as work-hardened. Did Māori temper the newly made metal hooks after forming them into a hook shape? Pre-European Māori were thoroughly familiar with the use of fire for tempering nephrite, which greatly increases the hardness of tools made from this material (Beck 1981). It is but a small step to apply this existing technology to fish hooks made from iron after it was discovered how easily they bend when strain is applied. As well as being familiar with their own tempering technology, Māori were very quick to adopt new ideas from Europeans. Many early European visitors, not just blacksmiths, would have known of the principle of tempering iron. Museums in New Zealand and abroad have abundant examples of early historic Māori metal fish hooks, offering opportunities for future research to see if tempering was employed.

ATTRACTING FISH — THE USE OF BAIT AND LURE

So far, I have only considered the technology required for the most basic items of material culture for some hypothetical pre-European fishermen. They are now equipped with fishing lines, nets and hooks. There are many other smaller things also required, such as stone sinkers, net floats, etc., but these require less technical knowledge and merit less discussion. When it comes to using fishing equipment it is often necessary to attract fish in some way so that they may be caught. One very common item used in the tropical Pacific for attracting sharks is the *shark rattle*. It is made by stringing together a number of half coconut shells on to a rope made from vine or thick cordage. These are shaken in the water beside the canoe and are very effective in attracting sharks, which can then be captured by a number of methods. It is thought that noise in the water simulates struggling fish and it is this which attracts sharks. Sharks are cartilaginous fish but teeth and quantities of calcified vertebrae are regularly found in archaeological sites. The absence of bones makes it is difficult to estimate relative abundance of sharks in archaeological assemblages, but we do know that elasmobranchs (sharks, skates and rays) were caught by pre-European Māori. Whether or not they were attracted using some equivalent of the Pacific shark rattle made from New Zealand materials in the absence of coconuts is a matter for conjecture. This attracting method has not been recorded amongst Māori during the period of early European contact. This is somewhat surprising considering how widespread shark rattles are in the Pacific.

Other species that are attracted by sound and movement are various off-shore pelagic fishes, such as albacore and tuna, which straggle southwards into New Zealand waters. These require moving live bait or artificial lures. On the northern parts of the east coast of the North Island, larger pelagic fishes such as swordfish are reasonably common. Once again, trolled live bait or artificial lures are required for catching these species. Not one bone of any of these pelagic fishes has been found in archaeological sites in New Zealand. No doubt a few will be found in the future, but the message here is clear — offshore pelagic fishing was either very rare or non-existent in pre-European New Zealand. This is further discussed in Chapter 10. Despite this, lures do occur in archaeological sites, and it is a matter of debate exactly what they were used for. Many species of fish are attracted to the vibration of an object being towed through the water, and some are attracted to an object which is red coloured. Barracouta will strike at just about anything towed through the water, and I imagine that if one tied some red cloth to a big toe and dangled this over the side of a moving boat it might attract unwelcome interest too. This example points to the fact that there is only a low level of technology associated with lure fishing compared with baited hook and line. That does not mean that pre-European Māori did not appreciate the subtleties of lure forms, but it does call into question just how many lures were intended for fishing and how many might have served some other function, such as decoration or magico-religious observance. I find it hard to believe that anyone would spend 100 hours carving a lure from stone and then risk loosing it by trying to catch a

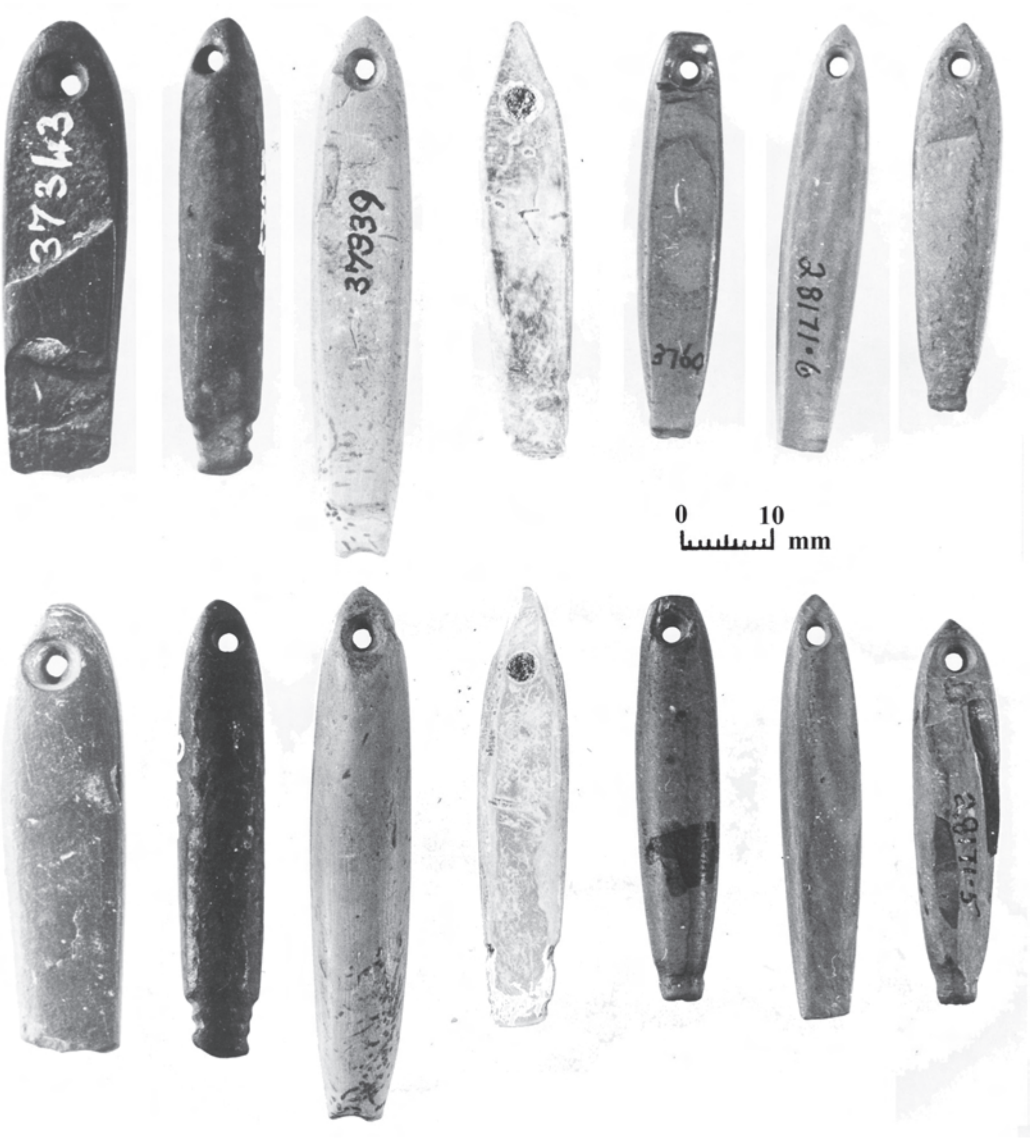

Figure 5.20: Centre: The lure shank (catalogue number AU1785) from Tairua on the Coromandel Peninsula, reputed to be made from tropical Pacific pearl shell. The other six lure shanks, of similar form, are surface finds, made from local materials, from the collections of the Auckland War Memorial Museum. Photo courtesy of Roger Green.

mackerel. Hamilton included these stone shanks in a discussion of fishing amulets. He described them as *manea* (sometimes *whatu*) or charm-stones, and reported that they were often used, without a point and after appropriate incantations, to attract fish or “draw the fish from the fountains of the sea” (1908: 21).

Quite a few early archaeological sites contain lures made from stone, and the form of these is very reminiscent of the pearl shell trolling lure, so widespread in eastern Polynesia and there used for catching tuna. These lures (Davidson 1984: 53, Fig 46) are made from a variety of stones including serpentine, slate, and argillite. Some are made from shell or bone. One especially interesting lure, found at the site of Tairua on the Coromandel peninsula (Fig 5.20), is reputed to be made of pearl shell, a species only found in tropical waters of the Pacific to the north of New Zealand (Green 1967). If confirmed by suitable scientific analysis[19], this would imply that this artefact came with some immigrant Pacific Islanders to New Zealand. The lures more commonly found in New Zealand archaeological sites had a bone or ivory point attached to them. These points are less often found in archaeological sites. Some of the stone lures, particularly, are shaped like small fish, and hence they are sometimes called minnow lures. At Wairau Bar, 80 stone lure shanks were recovered (Duff 1956: 207). There are no ethnographic or historical examples of lures from New Zealand with stone shanks, although a related form with a round-sectioned shank of bone, usually moa bone, survived into the early historic period (Hamilton 1908: 33–34).

Making lures from stone was a considerable undertaking, and it is clear from ethnographic research in Polynesia that these items of material culture acquired their own *mana* (prestige) and endowed the owner with respect (Nordhoff 1930: 192). It is possible that some of these lures in New Zealand were symbols of rank, but the sheer number of them suggests that they were actually used in fishing also. Apart from tuna, some New Zealand species which could have been caught with them are kingfish, trevallies, kahawai and carangids. At the moment there is no obvious correlation between the archaeological occurrences of these lures and any species of fishes.

One special lure, which in the historic period was said to be designed to catch a particular species (kahawai), is a wooden lure with pāua shell inlay. Numerous specimens of these characteristic lures are in museums around the world. The bone point on them is quite distinctive, and as far as I am aware, not one has been found in an reliable archaeological context. These lures are not known from the late eighteenth century Cook voyage collections. Beasley (1928: 16) claims that the earliest reference to them is by Labillardière, off North Cape in 1793. However, although Labillardière’s account mentions the use of feather lures, it does not describe the shape of the hooks to which they were attached (Labillardière 1800: 328). Crosby (1966: 148, 157) suggested that they originated in the Taranaki area on the west coast of the North Island and spread with the musket wars and tribal migrations of the early nineteenth century. Parts of a probable pāua shell plate were associated with other pieces of worked pāua shell in a context probably relating to Paremata pā, a nineteenth century Maori settlement in the southern North Island (Davidson 1978: 219, 221). It seems likely that many of these lures were manufactured in the nineteenth century as trade goods to meet the apparently inexhaustible demand by Europeans for artefacts from the South Seas.

Another lure, known archaeologically almost entirely from the bone point rather than the wooden shank, appears to have been made specifically to catch barracouta. Figure 5.11 illustrates a number of examples of points from Serendipity Cave, which also produced one wooden shank. These so-called barracouta points were made from a number of types of bone and a specially distinctive form

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[19] There are several ways that the supposed tropical origin of this lure could be confirmed. An obvious method would be to analyse the $^{16}O/^{18}O$ ratio to determine the water temperature in which the organism lived.

was made from the lower jaw of dogs. Large numbers of barracouta points have been recovered from southern South Island archaeological sites, where barracouta bones are also common. There is little doubt that this was the main purpose for these lures. Many wooden shanks are known from the nineteenth century with a metal nail in place of the bone point.

The most common form of lure for catching fish is some kind of edible bait attached to a hook. Clearly, we will never know what pre-European Māori used for baiting their fish hooks, but some clues can be found in the customs of early historic Māori. Buck, in his intensive study of the fishing activities of Māori along the East Coast north of Gisborne and also in the Bay of Plenty devoted an entire section of his report on the subject of bait for warehou. This deserves quoting in full:

> The best bait is the flesh of the crayfish (Buck 1926: 625).

Elsewhere he notes that some types of fish traps were also baited, and in this case the cephalothorax of crayfish was used with the carapace and legs removed. Most people today would consider that baiting hooks and traps with crayfish flesh is a prodigal waste of delicious food; however, fish adore this flesh as much as humans, and in earlier days before the inshore stocks had been devastated by the taking of vast quantities for export, this would have been an obvious choice for bait.

It was mentioned above that I have carried out experiments with replicas of one-piece shell fish hooks to see how they functioned. One of the problems encountered was how best to attach the bait to these hooks. A common method used with steel hooks is to attach the bait to the barbed point, or to the leg containing the point. Some groper fishermen attach a sizeable bait, most of which hangs down from the elbow of the hook so that the fish swallows the bulk of the bait before encountering the hook itself. The fact that I have been unable to catch any fish at all with these replica shell hooks (Fig 5.14) could be because I did not know how best to attach the bait, having experience only with steel hooks. Unfortunately, there is very little historic or ethnographic information for advice on this point. Nordhoff made an interesting observation about baiting the hook for a type of albacore caught in deep water:

> Very small fish are used whole; larger ones are *harara* (split), removing head, tail, and backbone. A whole small fish is placed on the hook by piercing, tail down, leaving the shank of the hook exposed and the point just breaking the skin of the head. Cut bait is sometimes similarly placed on the hook; sometimes tied on with thread. When tied on to the hook of native type, a fillet is placed on each side, and made fast just below the in-curved point, hiding the point, and allowing the tail ends of the two fillets to trail invitingly below. Then the baited hook, together with half-a-dozen small fish, or cut bits of larger fish, is made fast to a stone with the fisherman’s hitch, and the whole dropped overboard (Nordhoff 1930: 157).

When the line hits the bottom it is jerked to release the stone and the chum on it, which also acts to attract fish. The second description with the two fillets is slightly ambiguous, stating that the two fillets are placed on each side. This could refer to one side of each of the two legs of the hook, or both sides of one leg. In any event, these are very large hooks, and the advice is not likely to be relevant to small hooks.

It can be observed in Figure 5.10 that 7 of the 15 hooks illustrated have a small notch immediately below the elbow. These notches are referred to as ‘bait notches’ by archaeologists. There are specimens collected in the late eighteenth or nineteenth century that have a thin piece of cord tied on to this notch, in addition to a thicker snood attached to the upper shank. It is assumed that the purpose of this cord is to assist with attaching bait to the hook, although there are no direct records of this. It could, for example, be a chum line, as described by Nordhoff above. If we accept that it is for attaching bait, it will be further noticed that three of the specimens in Figure 5.10 are notched slightly differently from the others with a small projection on the leg containing the point (items #5, 12, 14). One of these even has denticulations running above the notch on the point leg (item #5). If these notches functioned to tie bait on, then the bait would have been on the point leg because the cordage loop around the notch would slip away unless it was being wrapped around that leg. Moreover, the denticulations on the point leg could have given further assistance by holding the bait in place while fish tried to nibble it off. Modern fishermen are only too aware of how bait slips away from where it was placed on the hook after small fish have pecked at it a few times. Shellfish bait, such as mussel, while excellent for attracting fish, comes off the hook very quickly unless wound around the point and/or leg with thin cord such as cotton. Even then, the bait quickly slips down to the elbow of the hook, exposing the point, which is very off-putting for the fish. Denticulations along the edges are an effective way of stopping the bait from slipping. Some modern steel hooks have additional shank barbs which serve this useful purpose (e.g., Mustad Beak #92641, #92646, Best Kirby #3164E).

All of this is actually surmise. It is possible that the bait was attached at some distance underneath the hook and this notch was designed to assist that. In this way, the fish would swallow the bait first, followed by a piece of shell attached to it, without any sharp projections. Only when completely swallowed might the hook function by rotating in the margin of the jaw, enabling the point to penetrate the flesh of the fish. This, or course, is merely one surmise built on top of another surmise; and it underlines the need for some definitive research to be carried out on this unsolved problem. There are many examples of fish hooks made from metal by Māori in the early historic era, and a considerable number carry a thin line in addition to the snood. Hamilton provides several illustrations of these (Hamilton 1908: Figs. 41, 43), and refers to them as bait strings, *pākaikai* or *tākerekere* in the Māori language. Some of these thin strings are attached to the elbow of these metal hooks and some are an extension to the snood. However, we should not leap to the conclusion that supposed bait strings on the much thicker shell and bone rotating hooks from the pre-European era functioned in precisely the same way as those found on metal hooks in the historic period.

TRANSPORTATION — THE CANOE

This volume is almost entirely concerned with fishing in the sea, but when it comes to water transportation, the ubiquitous canoe can serve several functions, on fresh waterways as well as on the open sea. However, there are limitations to how seaworthy a river canoe could be out at sea, especially in New Zealand waters which are quite different from the Pacific homeland of the earliest Māori immigrants. When it comes to fishing activities around the New Zealand coast, there are several quite different habitats requiring a different approach to transportation. For the present purpose, and at the risk of over-simplification, these habitats may be split up into the following:

Estuaries at the mouth of major rivers, and deep bays with shallow tidal water
Sandy beaches with low energy surf
Sandy beaches with high energy surf
Rocky coastline
Small rocky islets and pinnacles within 1–2 km of the beach
Open sea

The fish species available at these different types of habitat are obviously quite different, requiring different equipment, and also different transportation. On fine days without significant swell, fishing parties might venture out in a canoe more suited to rivers, using it to transport fishing gear including nets and pots to a well known fishing spot further along the coast somewhere, which would then be used as a base for fishing. This type of fishing expedition still takes place amongst tropical Polynesians today, and is for men only. They frequently use a cave or cliff shelter to rough it for a few days at a time. It is likely that many of the cave shelters around New Zealand with midden deposits are the result of this kind of activity.

Fishing from sandy beaches with seine nets requires no special transportation, and neither does fishing from rocky headlands. As soon as a group of men start to consider setting out to sea to fish pinnacles and small rocky islands within a few km of the shore, the local weather becomes the most important consideration. This determines what kind of canoe would be safe, and whether one can put to sea at all. In New Zealand, sea conditions can rapidly deteriorate, with calm seas turning into a maelstrom as a result. This was touched upon in Chapter 3 (see Fig. 3.7). Having a seaworthy craft was therefore important.

The types of fish found in all archaeological sites in New Zealand consistently show that fishing activities were almost entirely carried out within a short distance of the shore, so any canoes that were used would have been designed mainly to fulfil this purpose. There are exceptions to this which will be considered shortly. In my experience in small Pacific islands, where people still use canoes for fishing, there are several functional attributes that are necessary for fishing within a few km of the shore. One of these requirements relates to the need to empty the canoe of water, because they frequently get swamped. One might think that a bailer is all that is necessary, but a bailer is useless when a canoe is swamped. In anticipation of this happening, small canoes designed to go out to sea have a slanting floor at both ends. When the canoe is swamped, the men jump into the water and while treading water swing the canoe fore and aft, so that the water swills back and forth up this slanting floor, debouching over the end. When sufficient water has been emptied in this way for gunwales to appear, bailing can begin, even if for a time this must be done while the men are still overboard. Eventually, the men can get back into the canoe and complete the bailing. The point that I am making here is that if one finds a canoe with these sloping floors fore and aft, there is a good chance that it has been used for fishing out at sea.

Some canoes are known to have had special wooden covers lashed on to one or both ends. While this device may be useful for stopping wave slop from getting into the canoe, it has the unfortunate effect of prohibiting water from being removed from a swamped canoe in the manner just described.

Above all, to me the most curious thing about the canoes that are known from New Zealand is that almost none have an outrigger[20]. Outriggers provide a dugout canoe with far greater flexibility and stability than a dugout by itself. Best has this to say:

> It is evident that the outrigger gradually fell into desuetude in New Zealand. Cook and his companions saw it at two places only, and the early missionaries and settlers in these isles do not mention it at all. Polack, who resided in the Bay of Islands for some years in the "thirties" of last century, and also visited the east coast as far as Tolaga Bay, writes as follows: "Outriggers, invariably made use of by the South-Sea-Islanders, are unknown in

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[20] A contrary view to this is given by Anderson in 1777 who, in describing canoes, states "Some are fifty feet long and so broad as to be able to sail without an outrigger, but the smaller sort commonly have one and they often fasten two together by rafters which we then call a double canoe" (Anderson 1967: 811).

> New Zealand, and the canoes are never or rarely lashed together; nor are platforms raised over the gunwales, and sheds erected on them, as is the usage of the above nations" (Best 1976: 38, citing Polack 1840: 224).

There were only a few recorded sightings of outrigger canoes during Cook's voyages to New Zealand. During the first voyage, several were seen off Mahia Peninsula. Monkhouse on 12 October 1769 recorded "Here, were seen two Canoes with outlayers" (Monkhouse 1968: 575) and Parkinson added on 13 October 1769 "Several of the canoes had outriggers" (Parkinson 1972: 91). During the second voyage, Forster made the unlocalised observation 9 June 1773 "The single canoes have, especially when small & narrow, an outrigger fixed to the canoe by two transverse beams. They make very seldom use of a sail… " (Forster 1982: 301)

Buck believed that the general abandonment of the outrigger in New Zealand was due to the fact that much larger trees are available in New Zealand (Buck 1929: 205), and while this might be reasonable if one was only interested in very large canoes, it certainly does not apply to everyday canoes when only one, two, or perhaps up to six people were going to sea for fishing. A large canoe requires a team effort by a considerable number of people just to launch it. Fishing in waters even close inshore with any kind of swell is not always safe in a small canoe, and the outrigger offers great advantages of stability and safety.

Archaeological evidence of the use of outriggers on canoes in New Zealand is rare. What appears to be an outrigger float was found in Monck's Cave, Banks Peninsula, measuring 1816 mm long and 82.6 mm maximum width, with holes for attaching three booms (Skinner 1924: 155, Plate XXV). Unfortunately, its age is not known. A second float, found in a swamp near Te Horo, north of Wellington, is very similar in form to the Monck's Cave one, but much larger, 4,343 mm long and 29.9 mm maximum width (Adkin 1962: 271–272). These two floats share a somewhat unusual feature — the method of attachment to each boom on the canoe appears to have been the same. There are holes for two pegs to be driven into the float, and held in place by rope passed through a pair of converging holes, which meet in the middle. This V-form of perforation is situated between the two pegs. In the Te Horo example there are five sets of these holes, each of which would have had a separate boom to the canoe. Of special note was the high degree of wear in the V-perforation for the 2nd and 4th booms. It has been suggested that originally there were only three booms (2nd, 3rd and 4th positions), but that two additional ones were added later (1st and 5th) when it was found that the outrigger float was suffering excessive wear and tear (Adkin 1962: 276). Buck considered that the use of three booms with the Monck's Cave specimen was extraordinary, considering how small the canoe that it was attached to must have been. In my view, the obvious explanation is that the rougher waters around coastal New Zealand compared to Polynesia necessitated greater strength of attachment. The unusual method of attaching the float to the boom is illustrated in Figure 5.21.

A canoe found in the Taieri river area of Otago provides additional evidence of outriggers. In this case the canoe is closed in at the top (a typical feature of many Polynesian outriggers), but in general is so narrow that it could not have functioned without an outrigger (Best 1976: 44). A second example was also found in the vicinity of the Taieri river, at Henley. It seems likely that this one was used on the nearby Waipori and Waihola lakes in that vicinity. This canoe also has a narrow entrance. Once again the generally narrow cross-section of this canoe makes it unsuitable for use unless it possessed an outrigger. There are holes along the side which are thought to be for lashing booms (Best 1976: 41 ff.).

No doubt smaller canoes without outriggers certainly put to sea during good weather and were used for fishing. There are many examples of simple dugouts, generally thought of as river canoes,

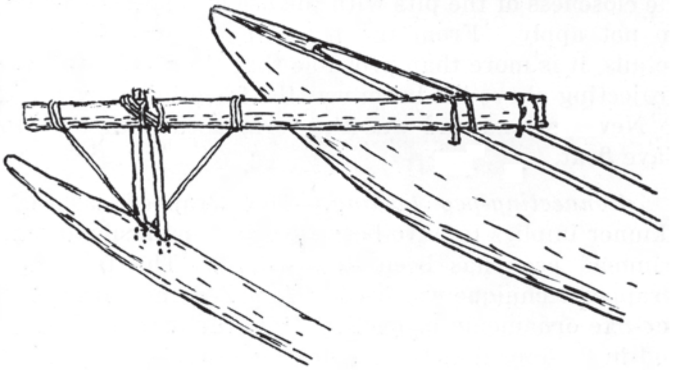

Figure 5.21: Buck's suggestion as to how the float found at Monck's Cave was attached to a boom (after Buck 1929: 212). A float from Te Horo (see text) would have been identical in this respect.

because that is where they are still found lying today after having been abandoned at least a century ago. A typical example is shown in Figure 5.22. This one was photographed in 1906 during the expedition organised by Major Brown (shown on the left of the photo) to examine cultural features

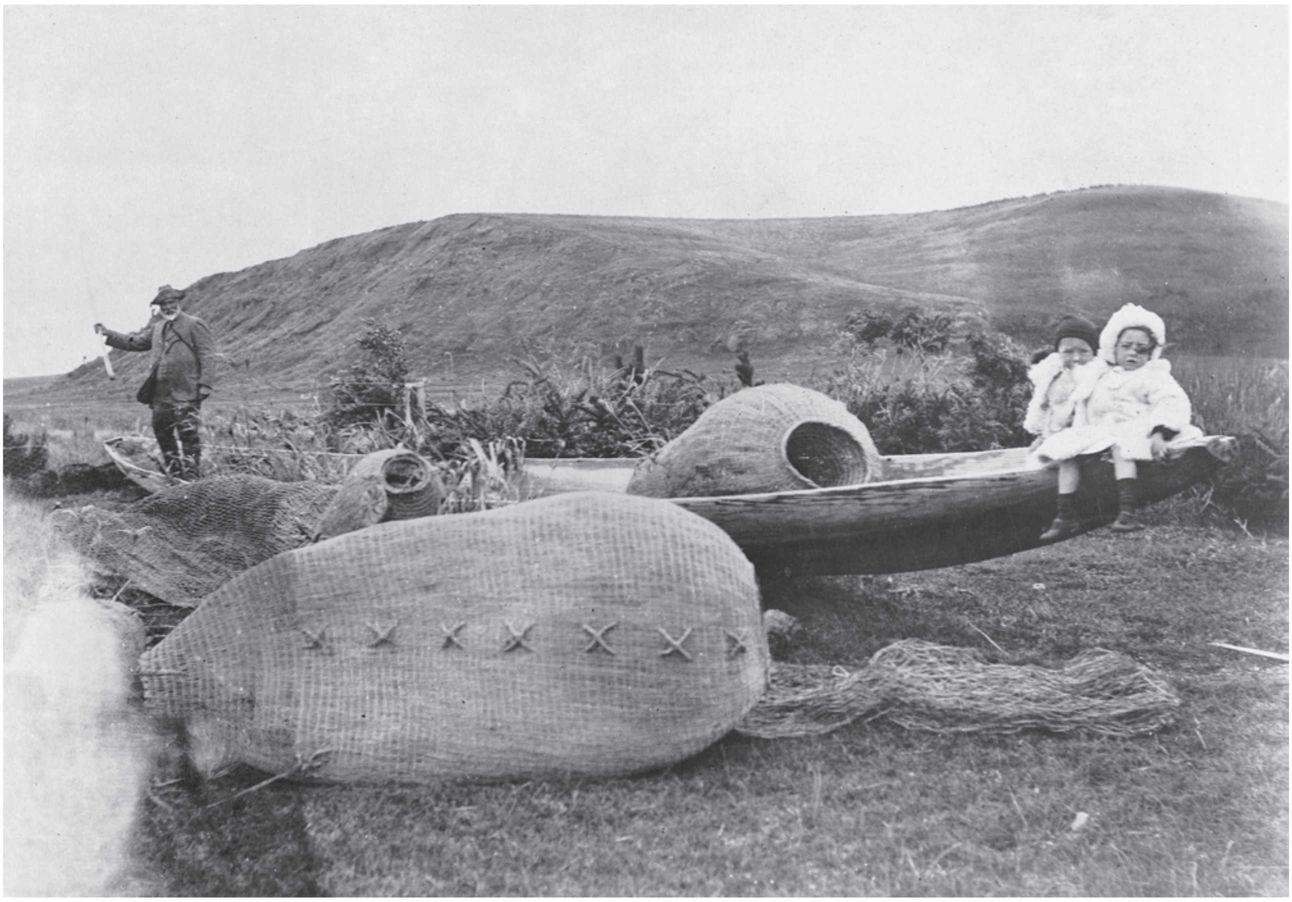

Figure 5.22: A dugout canoe at Kiriwai, Western Lake area, South Wairarapa. Major Brown is on the left, unknown children on the right. Note the hīnaki for eeling in the nearby lake and river channels.

in the lower Wairarapa area[21]. This canoe is about 7 metres long and could easily have taken six or seven men and fishing gear. Most canoes of this kind do not have holes along the sides, which is the best evidence of side strakes. Adding side strakes to a dugout makes it much more suitable for being at sea, serving to raise the gunwales and avoid being swamped. Examples of this have been found exposed in beach sands at Mason Bay, Stewart Island (Gillies and Skerrett 1998). In this case many of the pieces are elaborately carved, suggesting an important canoe, rather than an ordinary fishing canoe.

The type of New Zealand canoe that has attracted the greatest interest is the war canoe, a much larger vessel, capable of venturing considerable distances out to sea, but once again not a very suitable canoe to be in during any kind of rough weather. A typical example is shown in Figure 5.23. The upper part shows an illustration from the official report of Dumont D'Urville's visit to New Zealand 1826–1827 (Dumont D'Urville 1833: Tome 1, Plate 38, see also Wright 1950: facing page 65). The scene is at Astrolabe Bight, a small bay behind Adele Island in Tasman Bay. These early historic pictures were frequently copied by other artists who often took liberties with them, and one must be careful about examining details too closely in these copies. In the lower part is shown an engraving from an 1846 publication of Captain Cook's voyages to New Zealand (Anon. 1846: 149). In the latter, the man standing beyond the canoe could be mistaken for a European, but in the original he is more clearly a Māori wearing a rain cape. Similarly, the man at the front of the canoe in the original is pulling the boat and has bare buttocks, whereas the later engraving shows him pushing and more decently clad. Finally, the setting has changed completely in the engraving. These early pictures can be a veritable gold-mine of information if authentic. The details of houses, elevated platforms for food storage, clothing, equipment lying about, etc., are all important clues about Māori life during the earliest stages of European contact. Despite the liberties taken by the artist in the later engraving, it is a beautiful action drawing, possibly showing greater artistic skill than the original.

These canoes greatly impressed early European visitors. They were reputed to be up to 30 metres in length, and capable of carrying 40–100 men. They were highly decorated and fast in the water. Impressive though they may have been, they do not really qualify as fishing canoes, although no doubt they could be used for that purpose. Banks says:

> The common fishing canoes had nothing but the face of a man with a monstrous tongue and whose eyes were generaly inlayd with a kind of shell like mother of Pearl in the fore part of them, but the larger sort which seemd to be intended for war were realy magnificently adornd. … They sometimes joind two small canoes together and now and then made use of an outligger[22]… (Banks 1963 (II): 23).

These smaller boats, joined together, could well have been designed for fishing trips further out to sea. On February 15, 1770, Cook records four double canoes off Kaikoura with 57 men on board (Cook 1968: 252), and Banks notes that these canoes were further out to sea than they had ever seen canoes previously (Banks 1963 (I): 467). According to Salmond the distance was 15 to 19 miles

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[21] Hoani (also spelled Hone) Paraone Tunuiarangi, later known as Major Brown Tunuiarangi was a chief in Southern Wairarapa who took an active interest in preservation of archaeological sites during the late nineteenth and early twentieth centuries (Leach 1991: 84). The incident with the canoe is recorded by Smith as follows: "After photographing a large canoe and a number of large hinakis on the lake shore we partook of lunch and afterwards proceeded to Whatarangi under the guidance of Major Tunuiarangi" (Smith 1906, cited by Davidson 2003: Document Bank page 969)

[22] Beaglehole footnotes this word, and after some discussion suggests that this was probably a balancing platform on one side, rather than an outrigger. We will never be sure.

Figure 5.23: Two versions of the launching a large war canoe at Astrolabe Bight, Tasman Bay. Upper: the original illustration in Dumont D'Urville 1833: Tome 1, Plate 38, entitled *Village à L'Anse de L'Astrolabe (Nouvelle Zélande)*. Courtesy of Te Papa, negative #E3473. Lower: An engraving from Anon. 1846: 149.

(Salmond 1991: 262)[23]. These four double canoes with 57 men on board would have a crew of seven men per hull on average. This strongly suggests fishing canoe size.

The first double canoe seen by Cook and his party was in the Bay of Plenty off White Island 2 November 1769, and the next day it followed them under sail (Cook 1968: 189–190). Banks comments:

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[23] The end of the Kaikoura peninsula is 42°25′28″, 173°42′41″, and at noon on 14 February 1770 they were adjacent to Kaikoura (Banks ed. Beaglehole 1963: 466), at 42°34′06″, 173°56′54″, which is a distance of 25.1 land km.

> Just at night fall we were under a small Island from whence came off a large double canoe, or rather 2 canoes lash'd together at a distance of about a foot which was coverd with boards so as to make a kind of deck; (Banks 1963 (I): 423).

Unfortunately there is no mention of the length of this vessel or how many people were on board. Banks described Māori as being expert paddlers of their canoes, but considered their sailing skills to be less expert; he comments:

> But in sailing they are not so expert, we very seldom saw them make use of Sails and indeed never unless when they were to go right before the wind. They were made of mat and instead of a mast were hoisted upon two sticks which were fastned one to each side, so that they requird two ropes which answerd the purpose of sheets and were fastnd to the tops of these sticks; in this clumsey manner they saild with a good deal of swiftness and were steerd by two men who sat in the stern with each a paddle in his hand. I shall set down the dimensions of one that we measurd that was the largest size: it was in lengh 68½ feet, breadth 5, depth 3½; this was the only one that we measurd or indeed had an opportunity of measuring (Banks 1963 (II): 23–24).

Beaglehole adds an editorial comment that he considered this description somewhat unclear, but it seems perfectly clear to me, and an illustration of it appears in Salmond (1991: 189). This is a large canoe with a large number of people on board. The illustration does not, however, appear to be of a double canoe.

The earliest description of a double canoe in New Zealand was made during Abel Tasman's brief visit here:

> Their boats consisted of two long narrow prows side by side, over which a number of planks or other seats were placed in such a way that those above can look through the water underneath the vessel… (Salmon 1991: 79, quoting Muller and co. (eds) 1965: 19).

The drawing by Gilseman reproduced in Salmon (1991: 80) shows a flotilla of nine Māori craft in the background attacking the longboat. These are all clearly double canoes, showing two prows, and two rows of six paddlers in each. On the left there are nine more Māori craft. These are not nearly so clearly drawn as double canoes, but most may be. One canoe, however, bears a sail, and is quite plainly a single hulled canoe. Once again, they are drawn with six paddlers along one side. In the foreground, the detailed double canoe appears, showing five paddlers on the facing side, and four on the other. Two additional men could have steering oars; at least one of them certainly appears to be steering. Of interest is the fact that the man apparently steering is at the front of the canoe, facing the paddlers. This is contrary to Banks' description cited earlier.

The significant point to note here is the generally small size of these canoes. They are not typical war canoes and are much more like ordinary fishing canoes, designed to take six or seven men, and when two are lashed together twice that number. This would be a much easier vessel to launch and take to sea for fishing offshore and, more importantly, would be a more stable craft in choppy seas than a single dugout.

AFTER CATCHING THE FISH — WHAT NEXT?

At the end of a good day's fishing, there is still fish-related work to be done, a number of social niceties to be observed, and also some thought to be given to the possibility of hard times to come in the future, such as long term storage. In short, the actual fishing part is only half of the story. It is the enjoyable part to be sure, and the reason men still go to sea, rough it by camping overnight in cave shelters, and then return to the village expecting to be met as heroes returning with a huge catch.

However, fish may require scaling and cleaning and large fish might require butchering and dividing up in a certain way to be distributed according to rank or other social considerations. The catch itself may need to be divided and shared amongst different families. Then there is cooking and eating the fish, and afterward discarding bones. Finally, some fish may be split and dried in the sun, or smoked, and set aside preserved for later times of hardship or in some cases traded for other commodities if there is an abundance. All of these activities are aspects of human culture which vary from one society to another and should not be taken for granted; with keen attention to detail some of these things have an archaeological signature. This final section of this chapter then deals with these less tangible aspects of fishing technology.

Actually it is not always necessary or desirable to removes scales from fish. Fish can be baked whole, and the scales and skin lifted off whole and the flesh eaten. So it cannot be taken for granted that all catches were scaled. However, there is quite a lot of sound archaeological evidence of scaling fish amongst pre-European Māori communities. Probably the best evidence of this is when stacks of shells are found filled with scales, as was the case at the Station Bay Pā site, recorded by Davidson (Davidson excavation diary 23-12-1970). Similarly, I found abundant scales belonging to several species in the Washpool midden site in discrete lenses, suggesting scaling activities on the midden dump. Best records of early historic Māori that "a shell served as a fish-scaler" (Best 1924: 102), and this is verified by shells which show wear marks characteristic of scrapers from excavations of fish-rich middens. A good case is a salvage excavation at Raumati north of Wellington, where 130 tuatua shells were found with a distinctive concave wear pattern along the edge from some scraping activity. The site was a highly specialised midden with large quantities of shellfish from the open sandy beach and fish remains. The obvious interpretation is scaling. Since only right valves of this bivalve were retained for study, the number of scrapers at the site would have been considerably greater than those identified. The wear pattern is illustrated in the upper part of Figure 5.24. Some of the specimens show two concavities, one less shallow than the other. These could have been employed along the superior and inferior ridges of the fish, while the shallow concavities are more likely to have been used along the flatter sides[24].

As these scrapers are used more and more, the width of the scraping edge increases along with the deepest part. This is illustrated in the lower part of Figure 5.24, which effectively shows the life history of these scrapers from their first use to ones that have had considerable use. It would be useful to carry out some experimental research scaling fish with these shells to see how long it takes to accumulate the amount of wear observed on these specimens. It certainly looks like considerable wear and tear.

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[24] Terrell reported finds of pipi shells that had been used as scrapers (Terrell 1967: 63), but the illustrations of these show somewhat different wear patterns from those at Raumati. Although some may have been fish scalers, it is doubtful that all were so used.

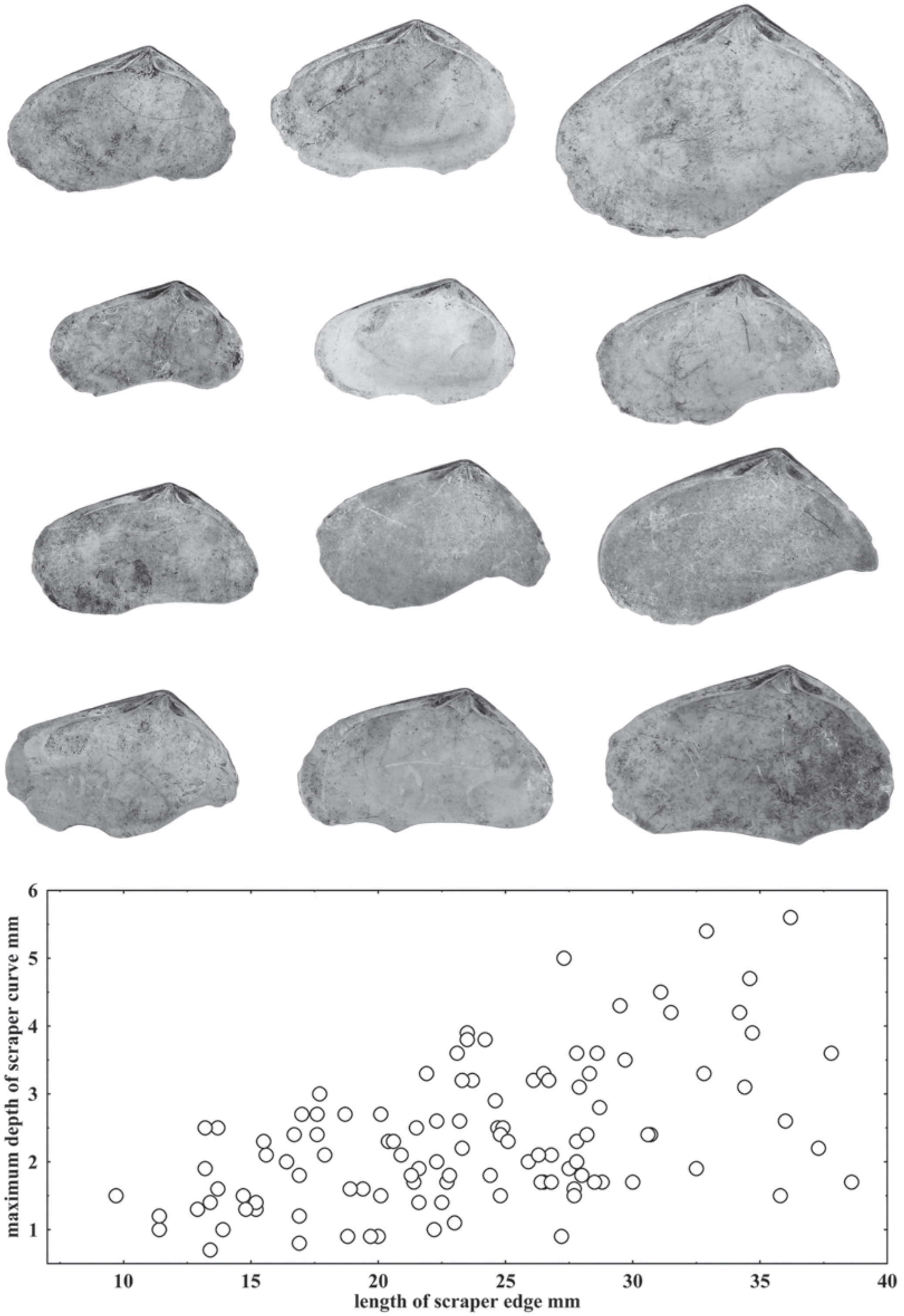

Figure 5.24: Upper: Some examples of tuatua shells from the Raumati site showing concave wear after heavy use as scrapers, presumed to be for fish scaling. Lower: A scatterplot showing progressive wear on tuatua scrapers from the Raumati site (Leach *et al*. 2000a: 27–28).

The assemblage of fish from the salvage excavation at Raumati was quite small (MNI=86). However, 14 families of fish are represented, although only 2 species were common, kahawai and red cod in about equal numbers (Leach *et al*. 2000a: 21). kahawai are not often found in high abundance in archaeological sites. They are most likely to have been caught during the late summer, when huge shoals come into coastal waters to spawn (Ayling and Cox 1982: 222). Kahawai have large scales which are removed easily when the fish is freshly caught. However, soon after they dry out they are very difficult to scale. Only 13 sites in New Zealand show catches of greater than 2% abundance (Table 5.2)

TABLE 5.2
Kahawai in New Zealand Archaeological Sites

Name of Site	MNI all species	% Kahawai
Raumati	88	27.9
Foxton, Manawatu	270	18.9
Kohika, Bay of Plenty	184	12.5
Paremata, Wellington	147	11.6
Washpool Site, Palliser Bay	771	8.2
Kokohuia, Hokianga	844	7.2
Black Rocks BR3 Black Midden, Palliser	191	6.8
Mana Island South Midden	596	6.7
Te Ika a Maru, Base of Pa, Wellington	199	4.5
Mana Island North Settlement	1206	3.5
Harataonga Bay	231	3.5
Black Rocks BR4 Crescent Midden Palliser	705	2.8
Hot Water Beach, Coromandel Peninsula	278	2.5
Houhora, Far North	2425	2.3

A common method of treating fish in European society is filleting, that is, removing the flesh of the fish so that no bones remain. It is very unlikely that pre-European Māori filleted their fish. As far as I know, the universal practice among Polynesians is to cook fish whole, and eat the flesh with the fingers. In my experience in small islands in the Pacific, people are extremely adept at avoiding small fish bones while eating and have no fear of putting flesh with bones in the mouth. Some bones are simply crunched up and swallowed. Most Europeans have an irrational fear of being choked by fish bones, and are very wary of having them in the mouth. Moreover, the head is considered a delicacy amongst many Polynesians, and given to high status people.

Regarding treatment of fish bodies by Māori, "Colenso explains that mackerel were gutted, and heads and tails were cut off; after which they were split into halves, steamed in a *hāngi*[25], dried on racks in sun and wind, then packed in large baskets for winter use" (Best 1977: 114). Although the earth oven was probably the most common method for cooking fish, they were also grilled over an open fire (Buck 1926: 634). Nicholas also refers to this method:

> Their mode of cooking it [fish] was extremely simple. After cleaning the fish very carefully, they thrust a stick through it, which being stuck in the ground near the fire, sustained it till

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[25] This is an earth oven in which fire-heated stones are placed, then vegetation to protect food from being scorched, then baskets of food, followed by mats, then earth heaped over and left for a few hours. This is the common method of cooking throughout the Pacific region.

> one side was roasted, when, the the stick being drawn up, and the other side applied in the same manner till it was sufficiently done, the whole process was finished (Nicholas 1817 (I): 236–237).

Nicholas was intrigued by another method of cooking fish which he had read in Savage's account of New Zealand, but never observed himself:

> The fish being cleaned, is enveloped in a quantity of leaves of the cabbage, and bound about with tendrils; it is then laid upon a stone that has been previously heated, upon which it is occasionally turned, so that the steam extricated from the leaves serves the purpose of boiling water. The leaves being taken off, the fish is found to be well cooked and unbroken. I have tasted them cooked in this manner by the natives, and thought them excellent (Savage 1807: 60).

Furneaux recorded in 1773 that the normal method of cooking fish was the earth oven, but they might be roasted[26] when people were in a hurry, as the following passage makes clear:

> they never take the guts out, as they prefer them to the Fish, they like-wise spit them and place them round the Fire to roast, but this is done only when they are in a hurry (Furneaux 1969: 739).

It will also be noted from this passage that Māori were particularly fond of the guts of fish. This is confirmed by Peter Bucks's observations about marblefish[27] whose guts were especially highly prized by Māori, particularly when the fish was fat, and specialised methods were used to catch them. He records:

> The entrails of the *kehe*[28] become very fat in the right season, and are better esteemed by the local people than the flesh of the fish. Hence, in the saying below, used as an invitation to a visitor, they make a display of hospitality and at the same time reserve the tit-bits for themselves:–
>
> Hoatu ki te kainga,
> Kotaku ika ki a koe,
> Ko te ngakau ki au.
>
> Go on to my home;
> My fish will be for you
> And the entrails for me
> (Buck 1926: 620).

Few Europeans will eat even the flesh of the marblefish, considering it to be most unpalatable. Cook records of Māori in Hawkes Bay "some fishing boats came off to us and sold us some stinking fish" (Cook 1968: 177). Beaglehole footnotes this passage and states "Not necessarily bad fish: probably the standard Maori food, fish cleaned and dried in the sun, which had a strong smell and taste"

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[26] Anderson had a slightly different view in 1777: "The only method of dressing their fish is roasting for they are entirely ignorant of the art of boiling" (Anderson 1967: 811).

[27] A vegetarian fish, abundant close inshore in weedy areas, *Aplodactylus arctidens*.

[28] Marblefish.

(ibid. fn. 3). Strong smelling or strong tasting food is considered a delicacy amongst many societies. Buck records a practice of partially decaying crayfish called *koura mara*, literally crayfish steeped in water.

> This is prepared by soaking the crayfish in fresh water for about three days if the water is warm, and four or five if it is colder. The test is the loosening of the shell. When it comes away easily it is termed *mahiti*. People used to crayfish will then eat them raw and enjoy them : the smell is worse than the taste. When thoroughly *mara* the fish separates into three parts—the *tuke, papa,* and *hiku*. The flesh of the legs easily separates and comes away with the *tuke*. The flesh is placed on a wooden platform and support and left to dry for a day. Two *tuke* are placed together (*karapiti*), beaten or pounded to stick together, and exposed for another day. They are again beaten, cooked in an earth oven and dried. When dry they are packed in baskets, and will keep for a year. The other parts are dealt with in a similar manner. The *papa* part is usually consumed by the family, but the *tuke* and *hiku* parts are kept in the storehouse for occasions. Crayfish preserved in this way, whilst very palatable, create a great thirst (Buck 1926: 630)[29].

Unfortunately, most of these behavioural details are not able to be inferred from archaeological sites, although preferential abundance of different body parts can provide clues on the treatment of fish after they were caught. Shawcross attempted to study this at the site of Galatea Bay in the Hauraki Gulf, and considered that up to three-quarters of the body of the fishes had been taken away elsewhere (Shawcross 1967a: Fig. 5, 113–114, 128).

This was also suggested for the Purakanui site in Otago (Anderson 1981a: 219). However, this suggestion was not based on archaeological observations, but on more general considerations. From the squares excavated at the site, the total fish MNI was 2,745 (ibid.: 206); this is scaled up to 230,000 fish after estimating the total size of the site from test pits. It is further argued that the site was only used over a short period of a few years (ibid.: 217), and that 100,000 specimens of each of the two main fish species could have been caught in 278 and 87 days respectively by a single fisherman (ibid.: 219). Clearly, a few people living at this site for a short period could not consume such large numbers of fish. It is concluded that the site was therefore likely to have been a specialised site for drying and preserving fish for later consumption (ibid.: 219). This type of argument could be applied to many sites in New Zealand, and it should not really be put forward as a conclusion to be left alone at that point, but rather as a hypothesis requiring testing using archaeological techniques.

There are abundant ethnographic records of Māori preserving fish for later use or trade with other groups[30], but only hard won direct archaeological evidence. Banks observes the following of Māori in the South island:

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[29] This method of steeping food in water was applied to sweet corn when it was introduced into New Zealand by Europeans, and gained the name *pirau* or *piro* corn, meaning rotten corn, a practice more or less abandoned because of criticism by Europeans (Buck 1950: 111), but recently revised for the niche-food market.

[30] There is no evidence of salt ever being used by Māori for assisting with drying fish or as a preservative. Beattie asserts that 'old-time Māori' never used salt (Beattie 1994: 115, 182). Preservation of fish by drying or curing was not customary in most of tropical Polynesia. Apparently only the Hawaiians, who made salt by evaporation, were using it to cure both fish and pork at first European contact (Cook 1967: 279). Following European contact, they were quick to develop a trade provisioning visiting ships with salt and salted products (Kurlansky 2003: 125; 405).

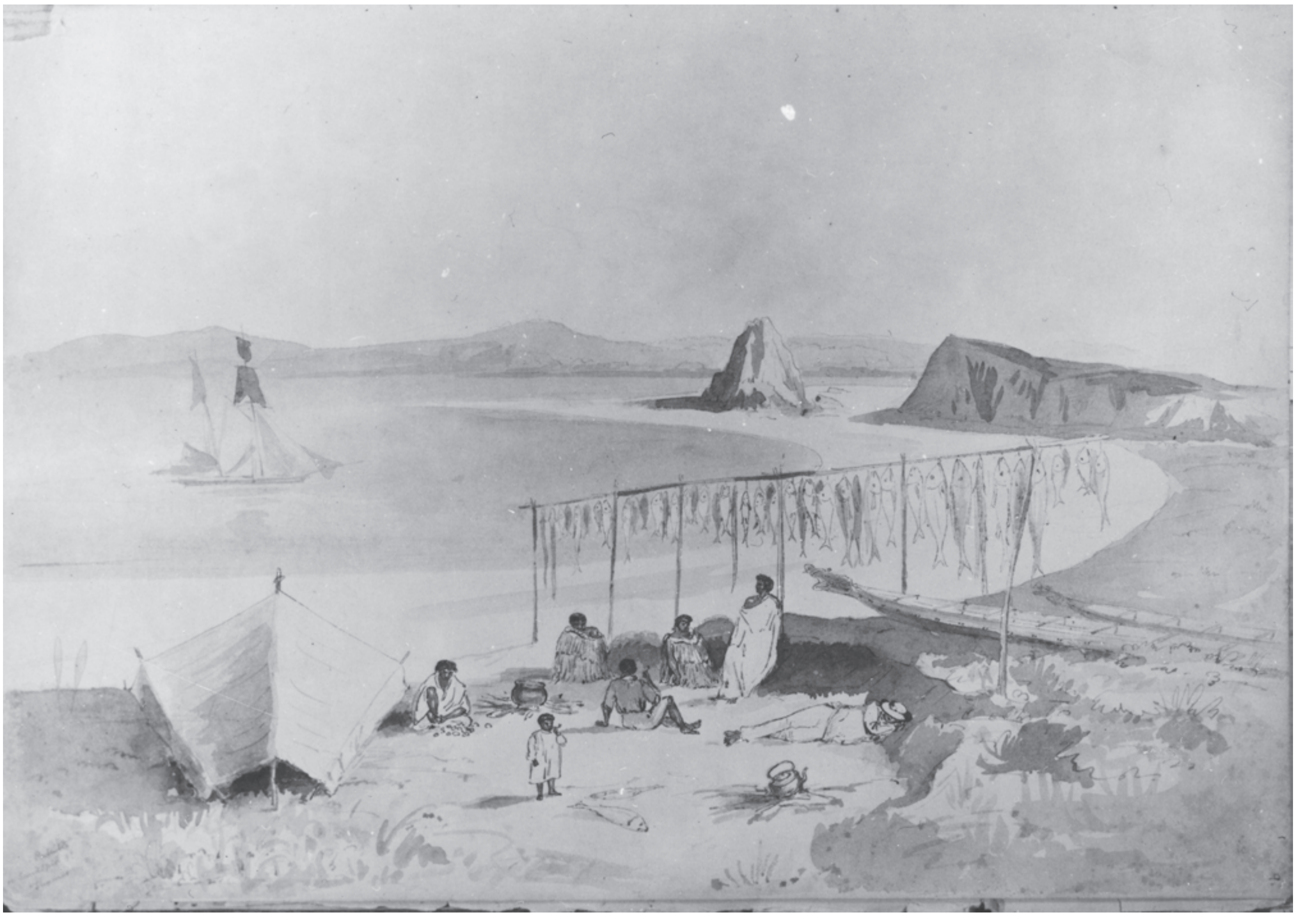

Figure 5.25: Fish being sun-dried at Pakihi or Sandspit Island, near Thames. Charles Heaphy sketch, courtesy Auckland War Memorial Museum, negative #B4827.

> To the Southward where little or nothing is planted Fern roots and fish must serve them all the Year. Here therefore we saw that they had made vast piles of Both, especialy the latter which were dryd in the sun very well, I suppose meant for winter stock when possibly Fish is not so plentifull or the trouble of catching it greater than in Winter[31] (Banks 1963 (II): 21).

Best also describes in great detail the capturing of large quantities of eels by Māori and their preservation by smoking or drying in the sun (1924: 114–115). Buck records marblefish being split in half and preserved (Buck 1926: 619, and also kahawai (ibid.: 622). Figure 5.25 shows a drying rack for fish sketched by Heaphy in the Hauraki Gulf in the nineteenth century.

Archaeological occurrences of drying racks are not common, partly because the stakes that were used for their construction were probably not designed for permanency. Some single lines of post-holes found in sites may have been drying racks, but have been incorrectly interpreted as one side of a dwelling. A double row of small paired post-holes, ten in number and 4.2 m long, at the Washpool midden site was interpreted as a drying rack (Leach 1979b: 82–83). Two further examples have been found during an excavation at Papāhīnu, an early nineteenth century Māori settlement in Manukau City, South Auckland. Like the Washpool example, both had a double row of postholes; one was 4 m long and the other 3.5 m (Foster and Sewell 1995: 28).

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[31] This appears to be an error, as the fishing would be more difficult in winter.

CONCLUSIONS

The main purpose of this chapter has been to explore the knowledge base of pre-European Māori relating to fishing technology. This is not an easy task because the subject matter is essentially intellectual. However, it finds its concrete expression in the artefacts which people fashioned, and through them we can gain glimpses of the human mind. Much as I would like to have confined this discussion to things found archaeologically, this has not been possible. As so often happens with studies of pre-European communities in New Zealand and the wider Pacific generally, recourse is made to early historic literature to fill in gaps of understanding. In one respect this is perfectly understandable; after all, as it is often remarked, the early explorers ‘caught prehistory alive’ when they first visited here. In addition, in some areas life continued much the same as it was before. However, great caution must be used in ‘filling in the gaps’ with historic ethnographic data, lest the whole attempt to understand the past merely becomes a matter of assumption rather than discovery. As much as possible, archaeology should always be concerned with discovery. Ethnographic information does have its uses though. For example, in this chapter I believe it has been shown that canoe outrigger technology was vestigial at best by the time the first Europeans arrived in New Zealand. Given the widespread use of this technology throughout the Pacific region, and the likelihood that the first Polynesian immigrants were thoroughly familiar with it, there must be a good reason for its virtual disappearance over time. The obvious conclusion is ‘no longer relevant’. This matter is intimately connected with fishing activities. The outrigger is something which brings stability to a dugout and enables far greater flexibility in where and when one can put to sea. The fact that outrigger canoes were not abundant implies that not a lot of fishing was done far out to sea.

In this chapter I have dwelt on the functional attributes of the incurved fish hook to a considerable extent, paying special attention to information gained from studies of modern steel fish hooks. In my view we do not yet have a clear understanding of something that pre-European Māori took for granted every time they made and used these hooks. We do not yet know how they functioned, and attempts to observe replicas of them catching fish underwater have failed. This is an area crying out for intelligently designed research. The studies in Korea by Professor Lee and his collaborators, and those in Norway by Bjordal, Huse, Fernö, and Løkkeborg, have put up very good signposts directing us to the right approaches. This will require collaboration with commercial fishermen and government fisheries scientists to trap and catch live specimens from relatively unaffected fish communities and bring them back to a laboratory with aquaria for experiments. This is because the fish communities in the inshore environment of New Zealand have become totally savvy to humans and their fishing activities, and no longer behave in a way which is remotely like the pre-European period.

Even if archaeologists do not understand how these hooks worked, there can be no doubt that they were extremely effective when used properly. Modern commercial fishermen, always on the lookout for any way of improving catch rates, have seized upon the circular hook form and done their own experiments with steel versions, greatly increasing catches as a result. Although these hooks are not the same thing as their ancient counterparts, there should be no doubt that the most sophisticated modern fishermen and fisheries scientists have here learned something of enormous commercial importance from pre-European people.

I have also given some attention to the question of cordage and knots. This is not often considered in written accounts of archaeological fishing, yet it is such a basic matter, arising every time a hook is attached to a fishing line today when we are fishing. Knots are really important. Buck stands out as a highly practical person who recorded the most detailed information in the fishing communities he studied, both in New Zealand and the Pacific Islands. The rare finds of cordage and knots that are made in swamps and dry caves benefit from Buck's records when it comes to rediscovering the knowledge which is locked up in these fragments.

CHAPTER 6: THE REGIONAL CHARACTER OF FISHING

INTRODUCTION

Humans have a natural tendency to want to simplify complex cultural or biological information into manageable geographical units. There is an ever-present danger that any such units that might be proposed will later become accepted as *real* and immutable; but these units are not *real*, they are artificial constructs, serving a useful purpose of simplification, which might be quite temporary. This is no less true of cultural, biocultural or biogeographical provinces, and we should try to keep a watchful eye open for this tendency to entrench regional constructs lest they take on a life of their own.

Several kinds of regional boundaries have been imposed on the map of New Zealand. The first attempt to do this for pre-European Māori culture was by Skinner (1921), who proposed a series of *Culture Areas*. In a postscript to his 1921 publication, Skinner noted that he had read a draft of his paper to the New Zealand Institute Science Congress in January that year and that during discussion, the eminent botanist Cockayne had pointed out a remarkable correspondence between Skinner's *Culture Areas* and the *Botanical Provinces* which Cockayne himself had published in the same year (Cockayne 1921). Skinner stated that he had not seen Cockayne's book at that time and had arrived at his geographical construct quite independently. Moreover, after finishing his work he consulted a map of Māori tribal boundaries and observed a close correspondence there too (Skinner 1974: 23). To these constructs we might perhaps add Powell's *Marine Provinces* (1979: 7). This all sounds very convincing and self-reinforcing until we consult the three different maps involved in this discussion. There is actually very little correspondence between Skinner's *Culture Areas* and Cockayne's *Botanical Provinces*, and the idea that either of these is similar to *Tribal Districts* is, well … stretching things just a bit too far.

Cockayne first put forward his regional classification in 1914 (Cockayne 1921: 378), and commented:

> The major divisions of the region are here designated **botanical provinces.** These are based largely upon climatic change depending on latitude. … the ground is fairly secure for their basis is the stable one of gradual change in species in proceeding from north to south (Cockayne 1921: 378–379).

In contrast to this rather firm opinion of the stability of *Botanical Provinces*, Powell was not so confident about *Marine Provinces*, and warned against "placing too much reliance upon their existence as viable entities" (Powell 1979: 7).

The pivotal concept of any regional entity is that there are some clearly defined characteristics, which tend to be shared within it and tend not to occur outside it. This is, therefore, exactly analogous to other forms of biological classification, indeed any form of classification, including linguistics. This was discussed in some detail in Chapter 3. The choice of a set of characteristics has a major determining role in the shape of whatever classificatory entities are derived. I first proposed a series of regional entities within which to examine pre-European Māori fish catches in 1993 (Leach and Boocock 1993: Figs 3, 4, 5). These were not based upon any consideration of shared characteristics, and they were certainly not derived from the basic information (fish catches of pre-European Māori). They were simply lines drawn across a map in much the same way as the boundary between Irian Jaya and Papua New Guinea, which is an arbitrary vertical line drawn across the island of New Guinea. For New Zealand, I drew horizontal lines separating arbitrary regional districts called Northern North Island, Southern North Island, Northern South Island, Southern South Island, and Chatham Islands (NNI, SNI, NSI, SSI, Chat). I then looked at the character of the fish catches in those arbitrary regional units, worked out mean values to characterise each, and gave a rough indication of any changes in them through time. This was merely exploratory research. Anderson has described this as “a first approximation of overall characteristics and regional differences in fish catches” (Anderson 1997: 3) and that is quite correct. Using these same arbitrary regional units (although Chatham Islands was omitted), Anderson extended this study. He adjusted the MNI values of these regional entities by adding newly studied assemblages and re-calculated various statistics. It must be emphasised that neither of these studies involved the deduction of regional units, they were merely assumed. What is really needed now as a second step forward is to study the database itself to see if any sets of regionally specific characteristics actually exist.

Although New Zealand is a small country in a large ocean, it has a complex landform, spread over 1,500 km from Spirits Bay in the Far North to the southern shores of Stewart Island. The Far North is sub-tropical, and the islands immediately to the south of the South Island are sub-antarctic. Tropical waters form currents which move southwards and meet sub-antarctic waters moving northwards on both the east and west coasts of New Zealand. Not surprisingly, surface sea water temperatures are variable around New Zealand, and change considerably during the annual seasonal cycle. The implications of this environmental complexity were discussed in Chapter 3. In particular, it was shown there that there are marked changes in the general abundance of different species of fish from north to south, as well as strong seasonal migrations. I also discussed a study by Francis (1996) in which he examined regional fish diversity and species associations. This led him to propose a series of eight clusters or regional groupings, three of which relate to mainland New Zealand (Fig 3.14). It might therefore be expected that fish catches by pre-European Māori might also differentiate into regional groups. This possibility will now be examined.

At the outset it must be pointed out that humans are not like mites on an orange, foraging for food using an optimal strategy of maximising gain for minimum effort. If this were so, there would be no place for human culture, and we would expect any groupings of fish catches by humans to follow exactly marine provinces determined entirely by ecological clustering. On the contrary, my expectation would be that marine provinces form only the baseline of choices for humans, not the final outcome. Upon this baseline there will be a complex interaction involving technology, material culture, basic nutritional needs, spiritual and magico-religious practices (such as food avoidance or totemic behaviour), and seasonal abundance. The final character of fish catches for any communities living in different parts of New Zealand and at different times of the year will be an amalgamation of all these interactions. We might therefore expect some gross regional patterning, perhaps following the regional clusters suggested by Francis, but superimposed upon this will be a great deal of variation from site to site.

There are several possible ways of examining our accumulated information on fish catches to see how regionalism is expressed. In this chapter I shall explore two — catch diversity, and principal components analysis.

REGIONAL CATCH DIVERSITY

At a gross level, examining catch diversity against changes in latitude would be a logical first step. Francis found strong correlation here, with 228 species in Norfolk island declining to only 6 as far south as Macquarie Island (r=-0.86). When he removed four outliers (Kermadecs Islands, Three Kings Islands, NW North Island, NW South Island) from his 16 original groups, the correlation increased to -0.99 (Francis 1996: 38). (Francis 1996: Fig. 1). This effectively leaves for consideration here Regional Group III minus the Three Kings Islands; Regional Group IV minus NW North Island but including SW North Island between Cape Egmont and Cape Farewell; and the southern and eastern part of Regional Group V (excluding NW South Island). I have also excluded Francis' Fiordland region north of Puysegur Point (Francis 1996: Fig. 1). As it happens, the database (Appendix 1) has relatively few archaeological sites in the omitted areas on the west coasts of both islands (more on this point below). The sample from the database is reduced from 126 sites to 104 (24 in Region III, 30 in Region IV, and 50 in Region V), but it is still a reasonable sample with which to test these pre-European fish catches against the observed natural fish diversity in these regions. Two measures of diversity in fish catches were considered: number of families of fish represented at these archaeological sites and the value of Shannon's H[1], using the MNI values in Appendix 1. The results are given in Table 6.1.

TABLE 6.1
Analysis of Fish Catch Diversity by Francis' Regions

Fish Family Statistics

	Region III			**Region IV**			**Region V**		
No. Species in Region	170			115			89		
No. Familes in Region	58			51			42		
No. Sites Studied	24			30			50		
Range No. Families	2	to	15	1	to	25	1	to	21
Mean	7.6	±	0.8	10.2	±	1.2	6.8	±	0.5
SD	3.9	±	0.6	6.7	±	0.9	3.7	±	0.4
Coeff. Variation	51.1	±	7.4	65.5	±	8.5	55.1	±	5.5

Student's t values

	Region IV	**Region V**
Region III	1.7, 52, NS p=.05	0.9, 72, NS p=.05
Region IV	-	2.5, 78, S p=.05

Shannon's H statistics

	Region III			**Region IV**			**Region V**		
No. Sites	24			30			50		
Range H values	0.3	to	2.6	0.0	to	3.7	0.0	to	2.8
Mean	1.6	±	0.1	2.2	±	0.2	1.6	±	0.1
SD	0.6	±	0.1	1.0	±	0.1	0.7	±	0.1
Coeff. Variation	40.1	±	5.8	44.4	±	5.7	41.4	±	4.1

Student's t values

	Region IV	**Region V**
Region III	2.8, 52, S p=.05	0.5, 72, NS p=.05
Region IV	-	2.7, 78, S p=.05

The pattern of results in Table 6.1 is quite complex, reflecting human cultural variation as well as environmental change. Archaeological sites are formed from a variety of activities; some relate to

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[1] Shannon's H statistic is frequently used as a measure of diversity in biological sciences, although it was originally developed as a measure of entropy in systems of communication (Shannon 1948; Shannon and Weaver 1949; Bell 1953: 27; Leach 1978).

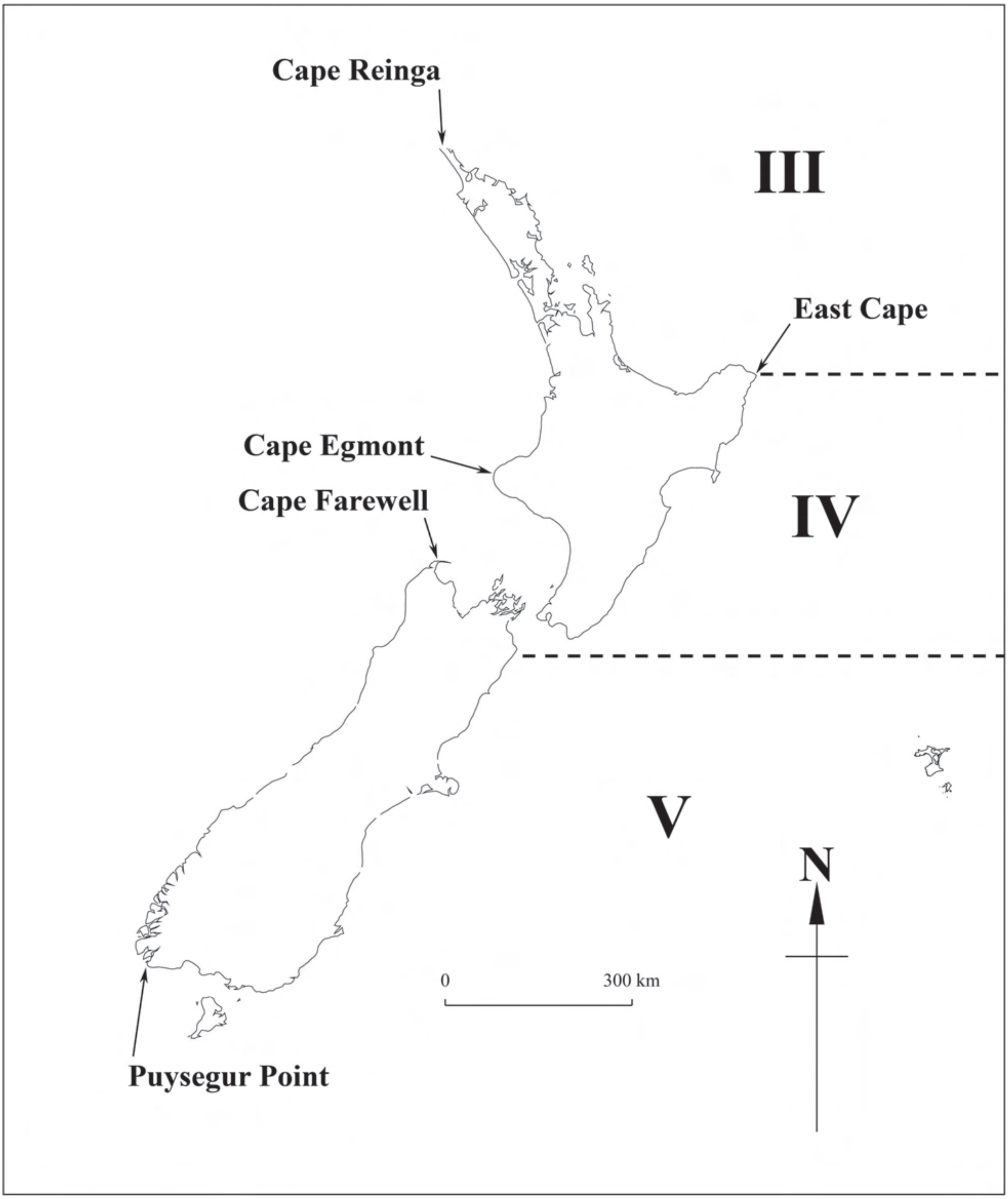

Figure 6.1: Three remaining regional groups suggested by Francis (1996), which show a very strong correlation of decreasing fish diversity with increasing latitude (see text). Archaeological sites between Cape Farewell and Cape Egmont are included in Region IV. The remaining sites on the west coast of New Zealand are excluded from Regions III and V.

villages, while others relate to specialised food harvesting sites, which take advantage of seasonal abundances. The latter can be expected to illustrate low catch diversity. Nevertheless, assuming that these sites are drawn without bias, they should also reveal any underlying regional patterns, and there are indeed some interesting results here.

For example, Table 6.1 shows a significant fall in the number of fish families represented in sites from Region IV (Cook Strait to East Cape) to Region V (South Island east coast and Chatham Islands). This pattern is illustrated in Figure 6.2. This result would be even more dramatic if the Waihora site (WAIH) in the Chatham Islands were removed from consideration. The average number of families has fallen from 10.2 to 6.8. However, it should be noted that there is also a significant rise in the number of fish families represented in sites from Region III to Region IV.

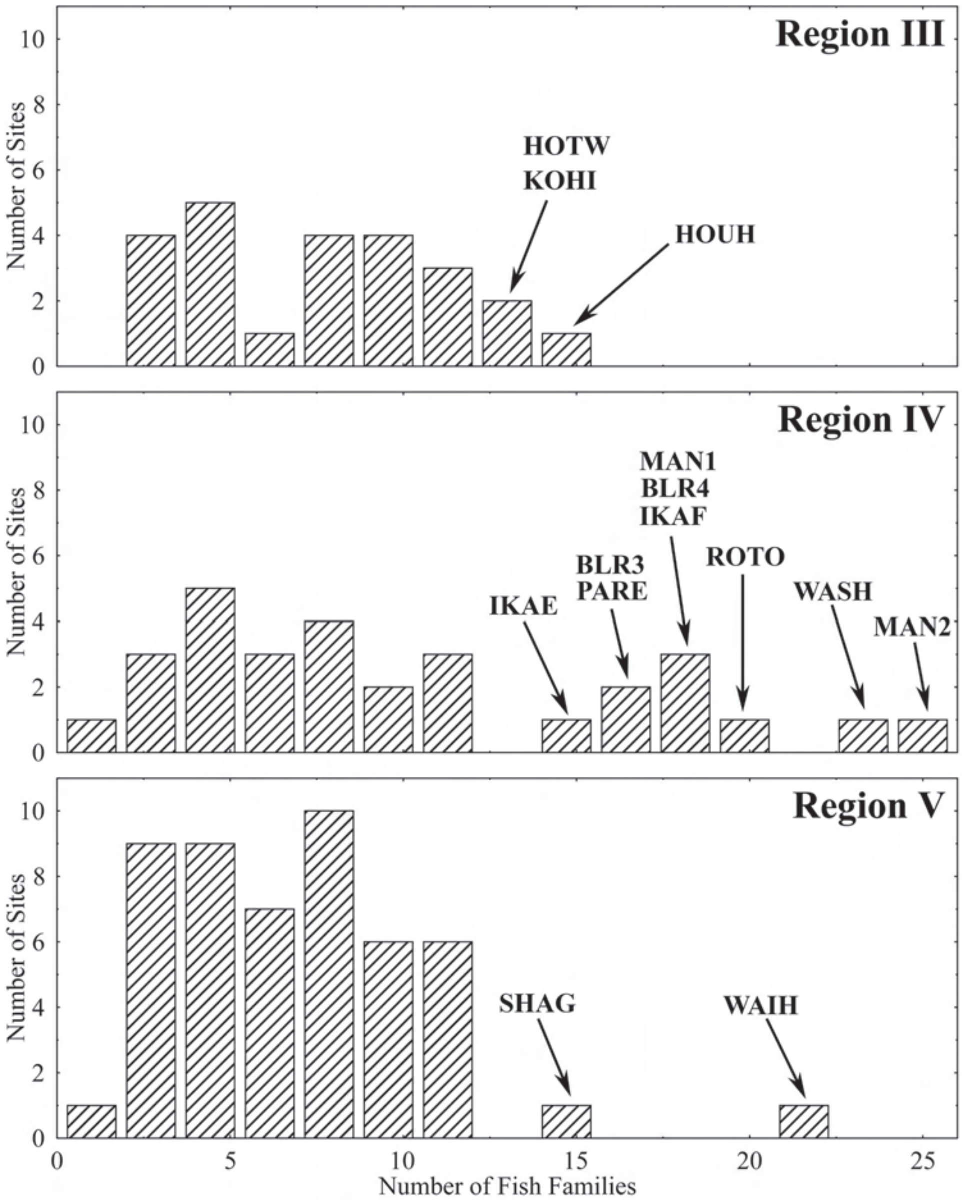

Figure 6.2: The number of fish families in sites represented in the regions shown on Figure 6.1. The site abbreviations are given in Appendix 1. Sites in Region IV show wide-ranging fishing activities.

Of special note in Region IV are the catches from Mana Island North Settlement (MAN2), Washpool Village (WASH), Rotokura (ROTO), Mana Island South Midden (MAN1), Black Rocks Crescent Midden (BLR4) and Black Midden (BLR3), Paremata (PARE), Te Ika a Maru Base of Pā (IKAF) and Eastern Flat (IKAE). These sites are all on the shores of Cook Strait, and the people at them were harvesting fish from 15 to 25 different families. The proportions of fish families at some of these sites are plotted out in Figure 6.3, and the Waihora site in the Chatham Islands is

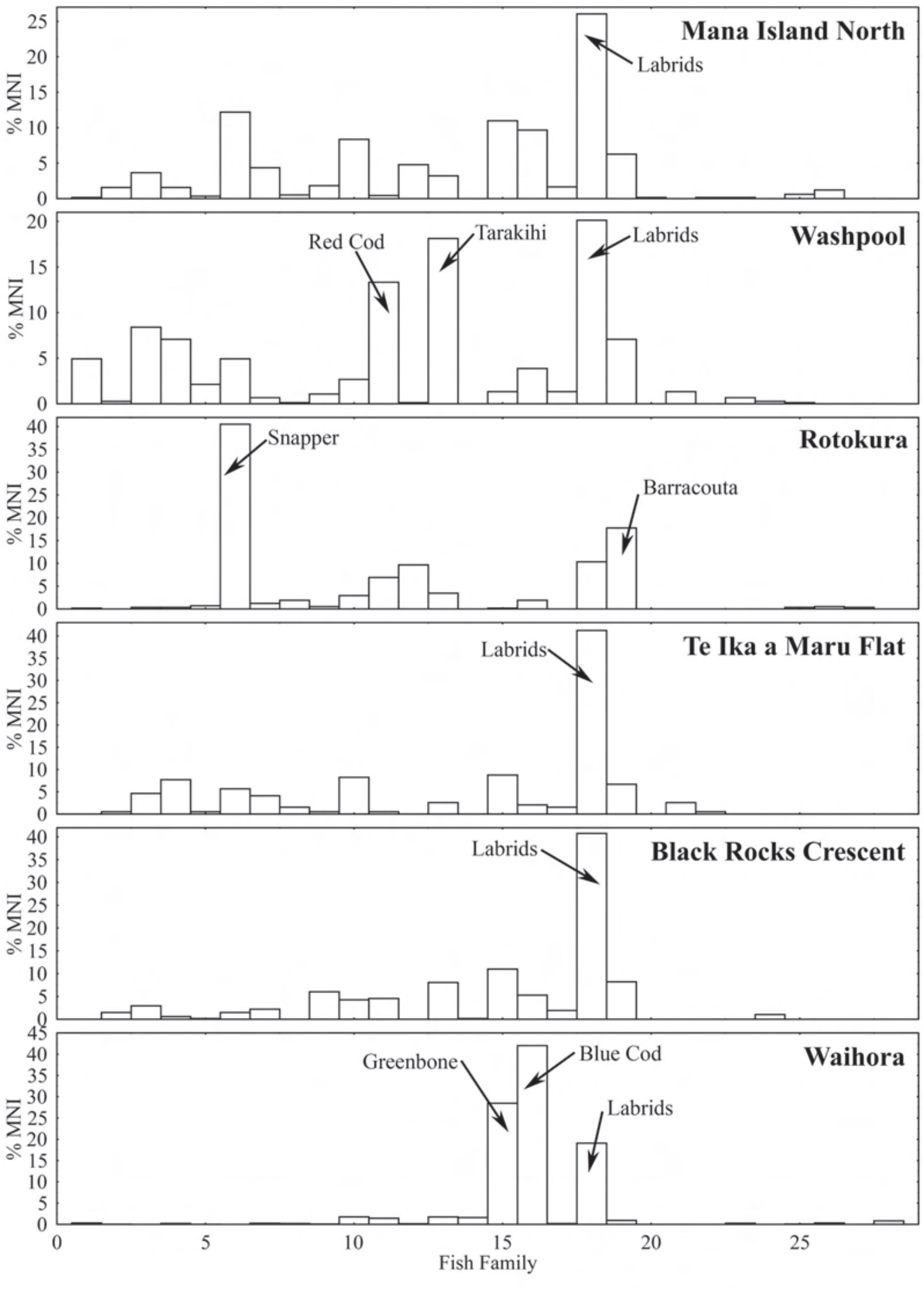

Figure 6.3: The proportions of different fish families at sites in the vicinity of Cook Strait. A few of the most abundant fish species are labelled. The Waihora site in the Chatham Islands is added at the bottom (see text).

added at the bottom for comparison. People at this site harvested 21 different families of fish, which is a large number compared with sites elsewhere in New Zealand (see Fig. 6.2); however, the site exhibits low diversity in the catch compared to other sites, as should be clear in Figure 6.3. Only three species were caught in any great abundance — greenbone, blue cod and labrids.

By comparison, the Cook Strait fishermen were wide-ranging in the fish they targeted. Figure 6.3 shows this clearly. Even at these sites, though, one or at most three fish families still dominate. For example at Mana Island North, Te Ika a Maru Flat and the Black Rocks Crescent midden, labrids stand out well above other fish types in abundance. At Rotokura it is a combination of barracouta and snapper which stands out. At the Washpool, three fish types are quite abundant — red cod, tarakihi and labrids. These catch-frequency diagrams are also interesting for the fish types which

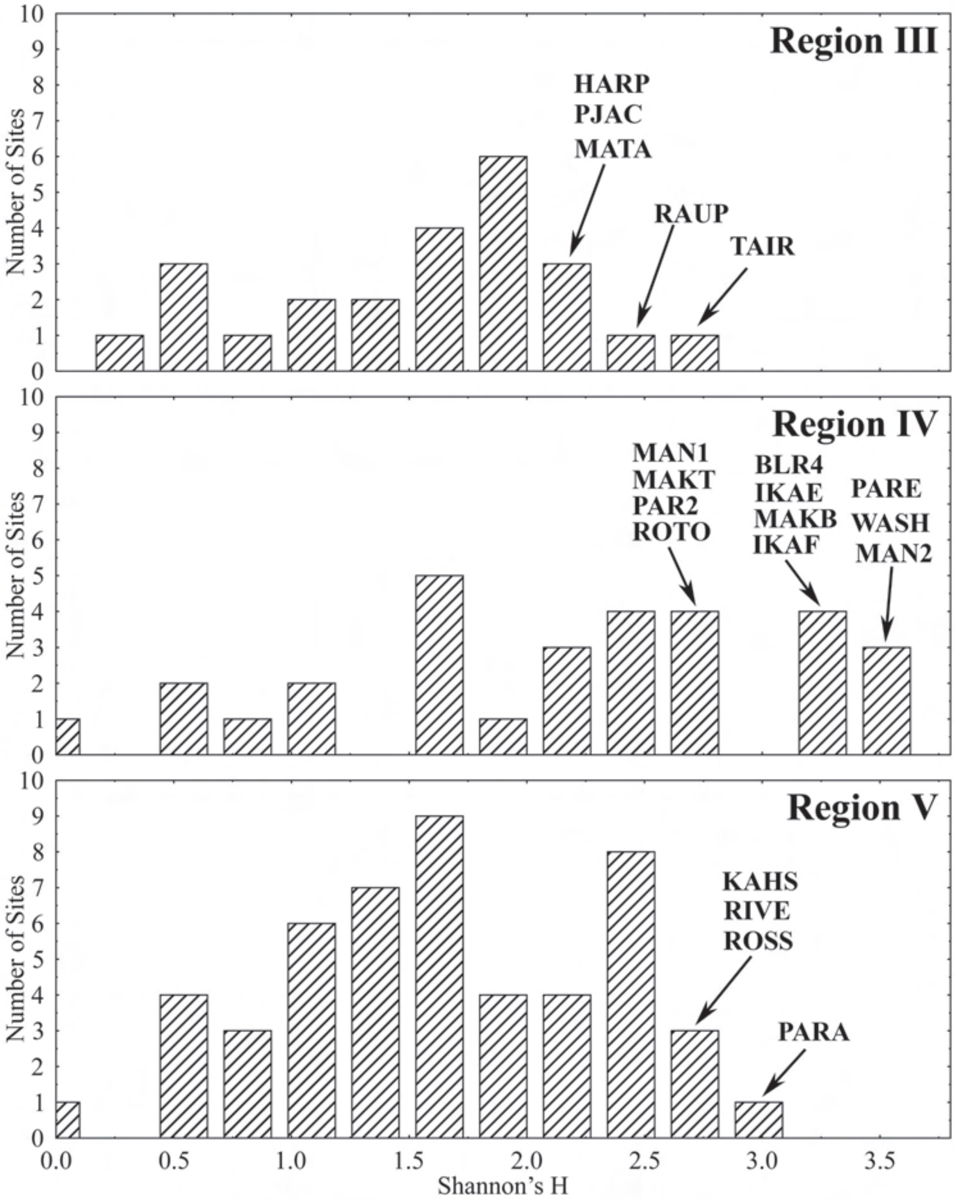

Figure 6.4: The diversity of fish catches in three regions of New Zealand shown on Figure 6.1, using Shannon's H statistic. The site abbreviations are given in Appendix 1. Archaeological sites in the vicinity of Cook Strait show the greatest diversity.

are unexpectedly low. For example, snapper has low abundance at all but Rotokura in the Cook Strait sites. This is a matter discussed further in Chapter 7, but it is noted here that snapper were highly variable in Cook Strait catches. Other sites in Cook Strait have very high abundance of snapper, but since they exhibit very low catch diversity, they are not shown in Figure 6.3. An example is the site at Foxton.

In the case of the diversity statistic, Shannon's H, there are also two statistically significant inter-regional comparisons. Moving southwards from Region III to Region IV, there is an increase in diversity from 1.6 to 2.2. This is followed by decreasing diversity moving further south from Region IV to Region V (2.2 back down to 1.6). The diversity pattern is illustrated in Figure 6.4. Seven sites in the Cook Strait area show particularly high diversity. Six of these were also high in the number of families represented (Fig. 6.2). Rotokura is not among them; the addition is Makara Beach (MAKB).

As far as catch diversity is concerned, pre-European Māori catches did not follow the environmental groupings suggested by Francis (1996) in any clear manner. This shows that even when humans are confronted with uniform environmental opportunities they do not always approach their food quest in the same way. To some readers this will appear a truism, hardly worth mentioning; but there is considerable interest amongst archaeologists in documenting the relationship between predation opportunities and the resulting harvests. Some are convinced that many human communities, particularly hunter-gatherers, follow a food-gathering strategy dubbed 'optimal foraging', whereby they gain the greatest energy benefit from the least energy input. If this were the case for pre-European Māori, we would expect their fish catches to have a reasonably close relationship with the natural groupings of the marine environment. No such simple relationship exists. Instead, we see here the complex hand of human culture. This subject is returned to in Chapter 9.

MULTIVARIATE ANALYSIS OF THE ARCHAEOLOGICAL SITES

Francis employed Principle Component Analysis (PCA) to derive his suggested regional groupings, and this can also be used on the pre-European fish catches to see if any regional or other clusters can be determined. For this purpose it is desirable to consider only the highest quality data, which in this case effectively means the largest fish catches, and also to focus attention on the main species being caught. The complete database in Appendix 1 has 126 sites and 36 fish families, totalling 40,433 MNI. I decided to select only sites where the MNI was greater than 100, and then to select only the most abundant 10 fish families[2]. This resulted in a data matrix with 55 archaeological sites and 10 fish families, totalling 35,176 MNI (87% of the original database). This data set should reveal any coarse patterns, which if necessary could be further refined with other data sub-sets. MVSP Version 6.20 was used[3] for the analysis.

The MNI data were first converted into Z-scores[4], which is a more convenient form for multivariate analysis. In the process of doing this any outliers are identified. In this case, outliers are examples

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[2] All manipulation of the data in Appendix 1 was carried out using programs personally written in Borland's MS-DOS Turbo Pascal version 5.0, 1988.

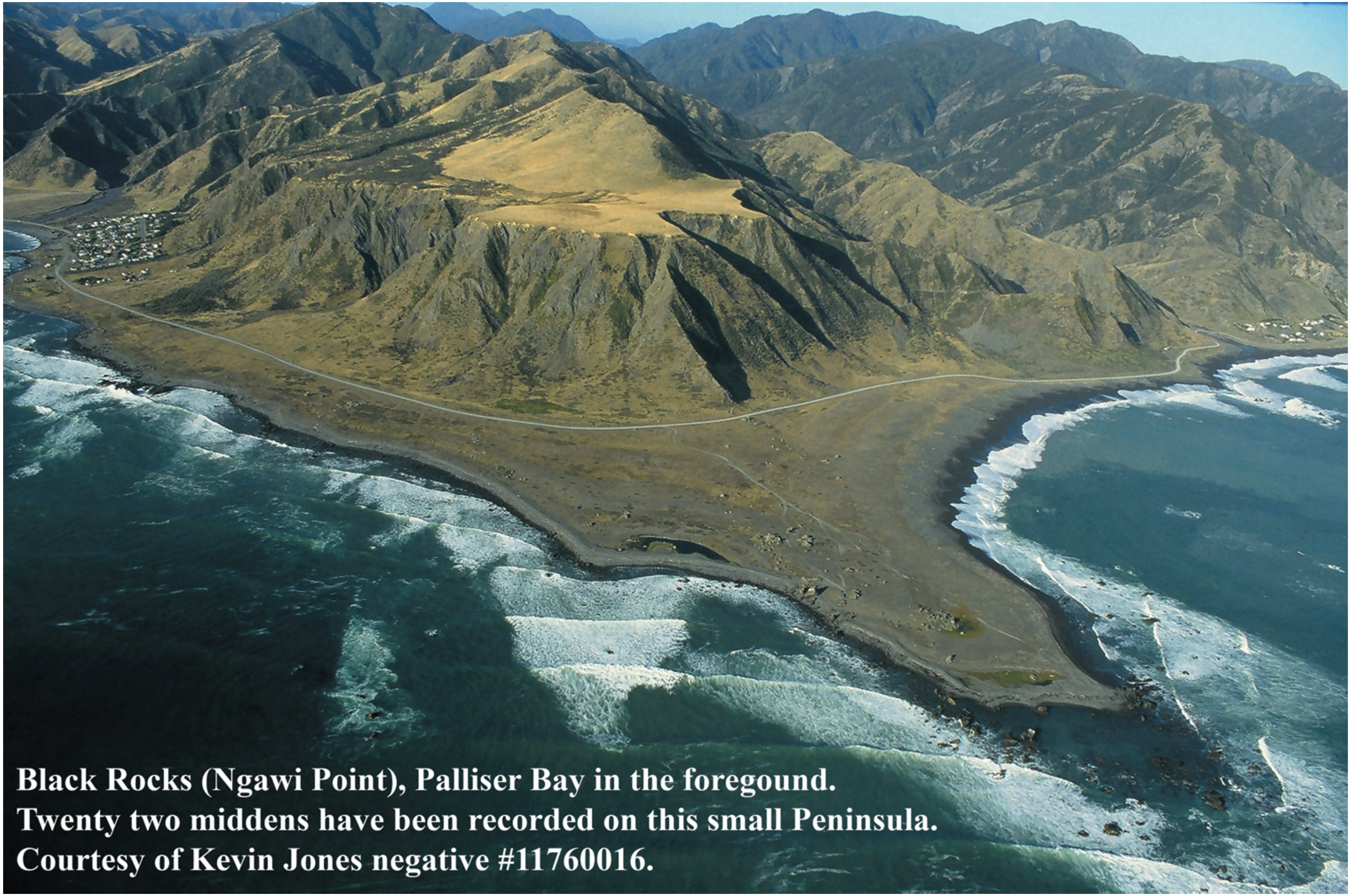
[3] Kovach's Multivariate Statistical Package (MVSP Plus) version 6.20, 1993, is an MS-DOS based program.

[4] Z-scores are also known as 'standard normal variate', 'standard normal deviate', and 'standard scores'. This is a method of transforming a data set so that the final data has a mean of zero and a standard deviation of unity. This is a more convenient form for carrying out multivariate analysis. $z = (x - \mu)/\sigma$ (Snedecor and Cochran 1967: 35–36).

A selection of typical pre-European and proto-historic Maori fish hooks. Courtesy Te Papa negative #I-6400.

The Washpool (Makotukutuku) river mouth today,
once the location of a thriving pre-European Maori settlement.
Courtesy Te Papa negative D.000269.

Reconstruction of the pre-European Maori settlement at the Washpool (Makotukutuku) river mouth, based on archaeological evidence. Drawing by Linden Cowell.



Black Rocks (Ngawi Point), Palliser Bay in the foregound.
Twenty two middens have been recorded on this small Peninsula.
Courtesy of Kevin Jones negative #11760016.

of archaeological sites where far higher (or lower) than expected catches of particular species are encountered. These are listed in Table 6.2. For example, the value of the Z-score of 3.7 for blue cod at the site of CHA in the Chatham Islands indicates that the relative abundance of blue cod at this site is 3.7 standard deviations above the mean value for all other sites being considered. These outliers are all potentially important results and there may be a quite different explanation in each case for their far higher than expected abundances.

TABLE 6.2
Unusually High Z-scores Found during Multivariate Analysis

Main species in Family	**Z-Score**	**Archaeological Site**
Blue cod	3.7	CHA
	3.3	CHB
Red cod	4.4	Fox River
	3.0	Appleby
Greenbone	4.3	Waihora
	3.8	CHB
Tarakihi	6.2	Kahiti South
Ling	6.1	Tiwai Point
Leatherjacket	3.0	Cross Creek
	6.2	Hahei
Mackerel	5.2	Matakana
	4.9	Kohika

Some notable examples should be commented on. For example, the very high proportion of blue cod in the two Chatham Islands sites, CHA and CHB, may be partly a reflection of the great abundance of this species in the Chatham Islands. Fabulous stories are told about these and other fish in the Chatham Islands, and most are probably apocryphal; but one which I can personally verify took place during archaeological fieldwork there with some students in 1973. During a lunch break it was decided to try and spear some fish with a sharpened stick, as no lines and hooks were available. The fish could be seen darting about in knee deep water, but were too fast for the students. They then tried throwing rocks at them to no avail. Finally, an old man gathered a few sea eggs and broke them with his hands in a few inches of water by the beach. The blue cod rushed into the shallows to devour the ripe gonads from the sea eggs and the old man easily kicked them out of the water and on to the beach. As many large specimens as were needed were gathered and the small ones returned to the sea.

The same explanation is offered for the high proportion of greenbone at Waihora and CHB, again two Chatham Islands archaeological sites. This species is super-abundant in the weed-rich rocky coastline along the south-west corner of the main Chatham Island where these sites are located.

Kahiti South, another Chatham Islands site, on the eastern side of the main island, shows an unusually high proportion of tarakihi. An even higher proportion is present at the nearby site of Kahiti North, but the total MNI there is only 95, which is less than the cut-off point of 100 which is being used for the multivariate analysis. It is not easy to find a simple explanation for why so many tarakihi were caught at these two sites. The coastline at these sites is a coarse sand, high energy beach, shelving quickly into relatively deep water. It is not an easy place to fish with nets. The entrance to Te Whanga Lagoon, approximately 8 km to the north, is a possible area where the tarakihi may have been caught.

Another notable feature in Table 6.2 is the high number of mackerel at Kohika and Matakana. The latter site is on an island on the outer edge of the Tauranga Harbour in the Bay of Plenty, in an area where there is high seasonal abundance of mackerel (Leach *et al*. 1994a), so this is perhaps not surprising. Kohika is on the mainland in the Bay of Plenty about 3 km inland, and therefore within easy access to coastal fishing resources. What is surprising is that other species, so abundant in the Bay of Plenty, such as snapper, have low abundance at these two sites.

Red cod features very highly at both Fox River on the west coast of the South Island and Appleby in Tasman Bay. Red cod spawns in the coldest months of winter in deep water (Ayling and Cox 1982: 142), and they are well known for schooling and migrating seasonally but irregularly. Paul suggests that these irregular movements may relate to their breeding requirements and the changing distribution of food (Paul 2000: 57). In former times, red cod were known to be especially abundant in the Otago harbour in summer months, but local fishermen relied upon their catch of the species outside the harbour in winter (Graham 1956: 168). Commercial landing figures for red cod at Akaroa and Timaru show greatest abundance in winter (Leach 1979a: 114), and at Wellington between May and July. Although Otago and Canterbury are a long way from Tasman Bay and the west coast where the Appleby and Fox River sites are located, these observations do suggest that low water temperature may be one of the triggers determining changes in local abundance. It is sugested that these high numbers of red cod at these two sites might be because sea water conditions at the period they were occupied were somewhat colder than normal. It might also be noted that Barracouta, a late winter to early spring visitor to the west coast and western Cook Strait areas (see Fig. 3.11), is also reasonably abundant at these two sites being considered, again showing that cold water conditions are bringing this species inshore. This is a topic returned to in Chapter 7.

TABLE 6.3

Eigenvector Statistics from Principal Components Analysis of Fish Assemblages

Eigenvector	**Eigenvalue**	**Percent of Total**	**Cumulative Percent**
1	12.9	22.2	22.2
2	11.0	19.0	41.2
3	6.5	11.1	52.3
4	6.0	10.4	62.6
5	5.9	10.1	72.8
6	5.3	9.1	81.8
7	4.7	8.1	90.0
8	4.2	7.2	97.2
9	1.6	2.8	100.0
10	0.01	0.001	100.0

When Principal Components Analysis (PCA) was carried out on these Z-scores (Q-Mode analysis[5]), the top 10 families of fish produced eigenvectors whose statistics are given in Table 6.3, and plotted out in Figure 6.5. The first two eigenvectors extract far more of the total variance than others and, as will be seen on the left of Figure 6.5, there is a pronounced 'scree-shape' at the third vector,

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[5] Multivariate analysis may be carried out from at least two points of view, named Q-mode and R-mode (or Q and R techniques). The primary focus in Q-mode analysis is to understand the resemblance and classification of the individual cases in the data matrix (in this case archaeological sites); whereas in R-mode it is the classification of characters or attributes which is the focus (in this case the families of fish). This distinction between Q-mode and R-mode is common to many forms of multivariate analysis (Sneath and Sokal 1973: 115–116; Miller and Kahn 1962: 293–294).

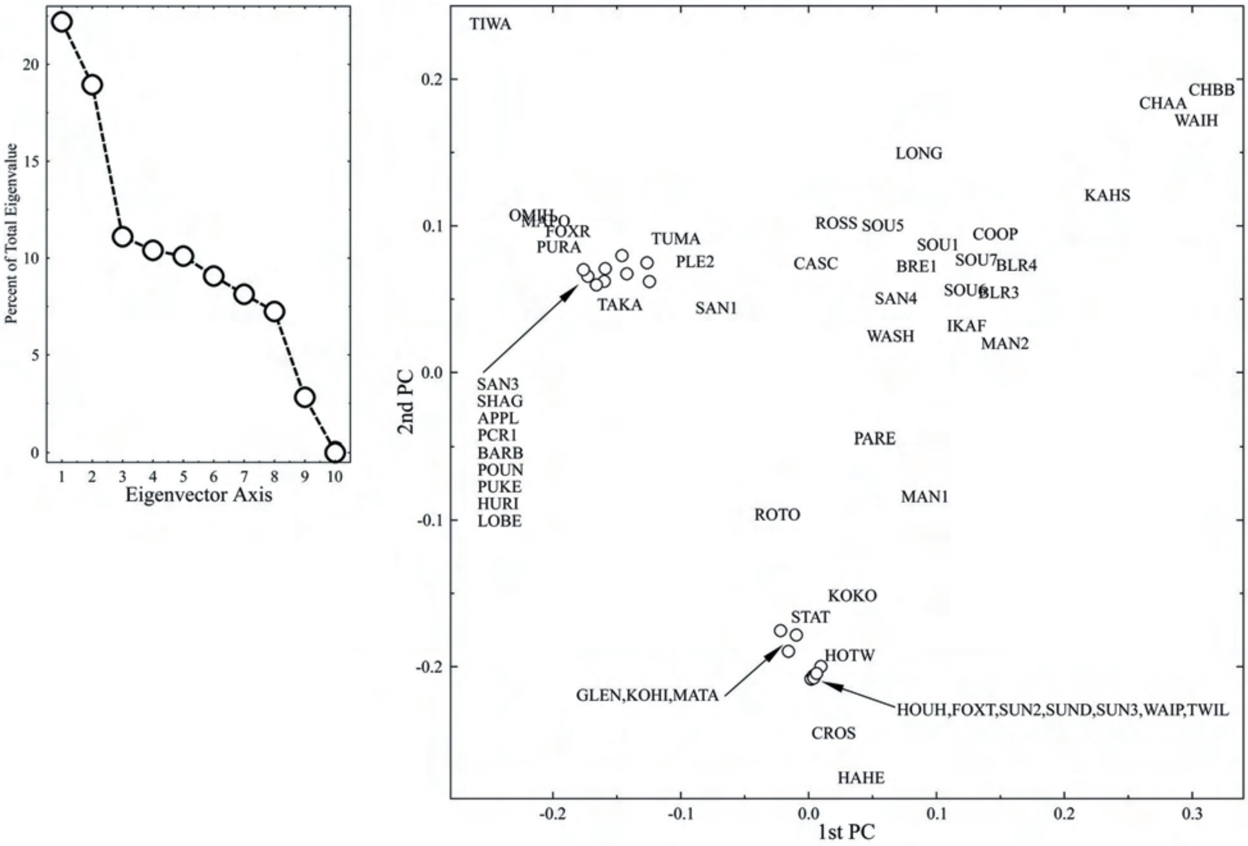

Figure 6.5: Results of principal component analysis (PCA) of fish remains of the 10 most numerous fish families from 55 sites with MNI>100. This sample has 87% of all fish remains studied. Left: scree-test of eigenvalues. Right: plot of archaeological sites, using the first two principal components. Site abbreviations are listed in Appendix 1.

although the total amount of variance captured is not as high as one would wish (52%). This indicates that these are complex data, not easily fully captured in three principal components. On the right of Figure 6.5 I plot the archaeological sites using the first two eigenvectors. This shows some loose clustering, which is perhaps a little clearer on the three dimensional plot using the first three principal components (Fig. 6.6).

> **Cluster 1:** Sites in the Foveaux Strait and Fiordland area form a loose cluster in between the Cook Strait and South Island clusters.
>
> **Cluster 2**: Sites in the Cook Strait area form a cluster, possibly with some affiliation with both Chatham Islands and Foveaux Strait and Fiordland.
>
> **Cluster 3:** Sites in the Chatham Islands plot some distance away from other sites except the Cook Strait cluster.
>
> **Cluster 4:** There is a pronounced cluster of sites in the northern North Island (the North Island cluster), with some sites in Tasman Bay intermediate between the North Island and Cook Strait Clusters.
>
> **Cluster 5:** There is a tight cluster of sites in the South Island. These are sites on the east coast from Kaikoura to South Otago.

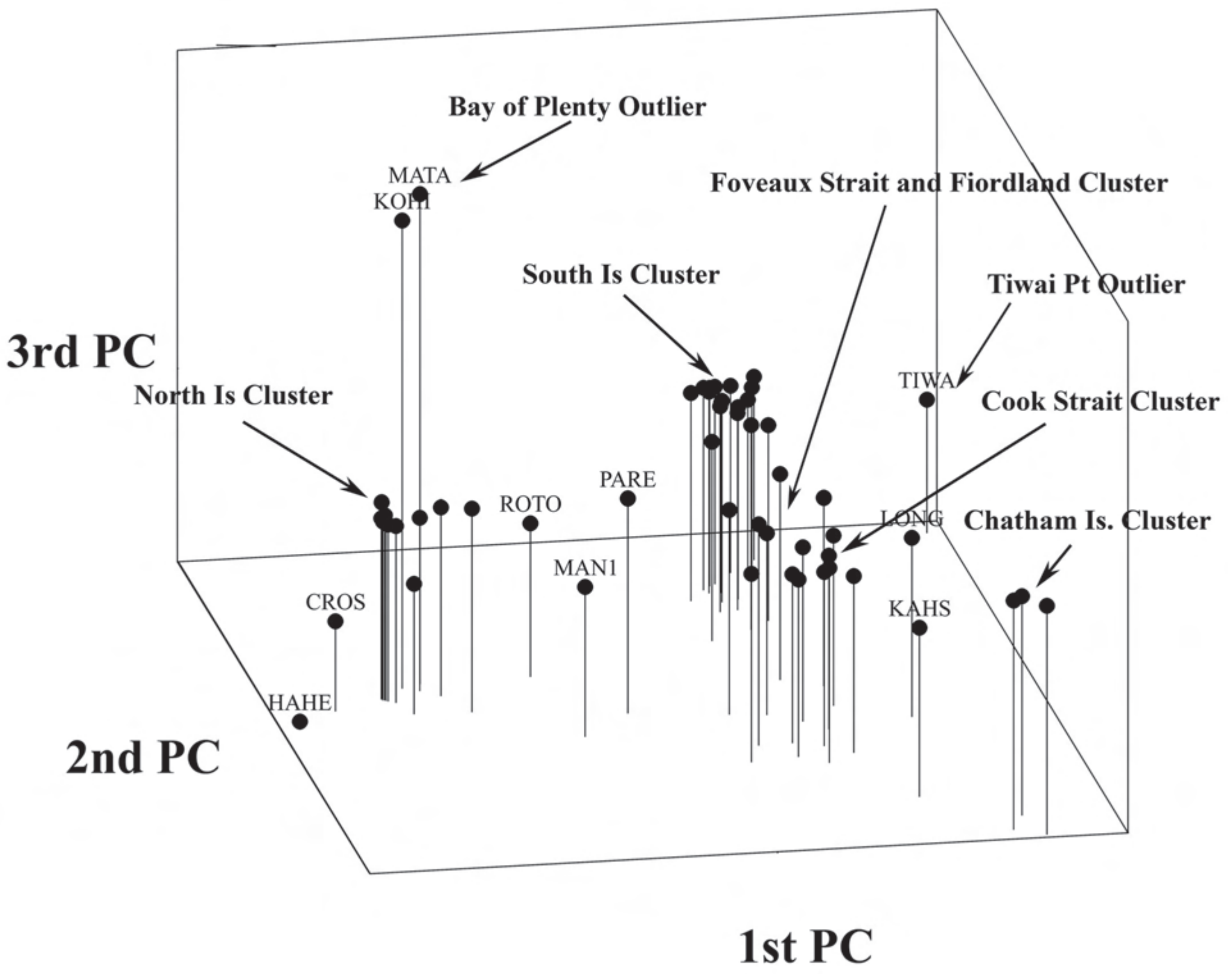

Figure 6.6: Three-dimensional plot of the first three principal components of Q-mode analysis, showing several loose clusters of archaeological sites. To avoid clutter, only sites which are outside the main clusters are labelled.

Cluster 6: Two sites in the Bay of Plenty (Matakana and Kohika) form a cluster by themselves.

Cluster 7: Tiwai Point in Southland plots a long way from anything else.

MULTIVARIATE ANALYSIS OF THE FISH FAMILIES

In Chapter 4, where I considered the species most often caught by pre-European Māori, I produced a series of maps showing the relative amount of each of these species at all the archaeological sites surveyed. These maps appear to show huge changes in the abundance of individual species from one part of New Zealand to another. They largely reflect the imprint of nature on the map of New Zealand, and one might be tempted to use this as the basis for cultural regional entities; but this would be a mistake. In looking at these maps, it is obvious, for example, that barracouta occur in far greater abundance in the east coast of the South Island, and the map in Figure 4.3 reflects this change in natural abundance by latitude. Similarly, the map in Figure 4.10, showing snapper abundance in sites, is heavily biased towards sites from Cook Strait northwards. In short, all of these maps in Chapter 4, focused as they are on individual species, clearly show regional patterns in archaeological fish catches. Would these regional patterns be an adequate basis for defining meaningful regional entities in this chapter? Not really. Although they look compelling at a very gross level, as soon as we examine more than single species, the maps unfortunately become a great deal more complex. It would be quite misleading to characterise east coast South Island pre-European communities simply as *barracouta fishermen*. The regional clusters of archaeological sites in Figure 6.6 are based on 10 families of fishes, and are a much more realistic portrayal of the regional character of pre-European fishing in New Zealand. It is complex, blending as it does human technology and cultural preferences, on top of the natural distribution of fishes.

An alternative perspective on this is the way in which the human communities in the past have caught groups of these ten families of fish in association with each other. That is, do the catches of fish show that some species are more frequently taken together? Principal Components Analysis was performed again, on the same data set (55 sites and 10 fish families), but this time in R-mode, to examine the underlying covariance of these ten fish families in the archaeological sites. As before, this is a blend of human activity and natural abundance. The results appear in Figure 6.7.

There are two obvious clusters of fish here, and three outliers.

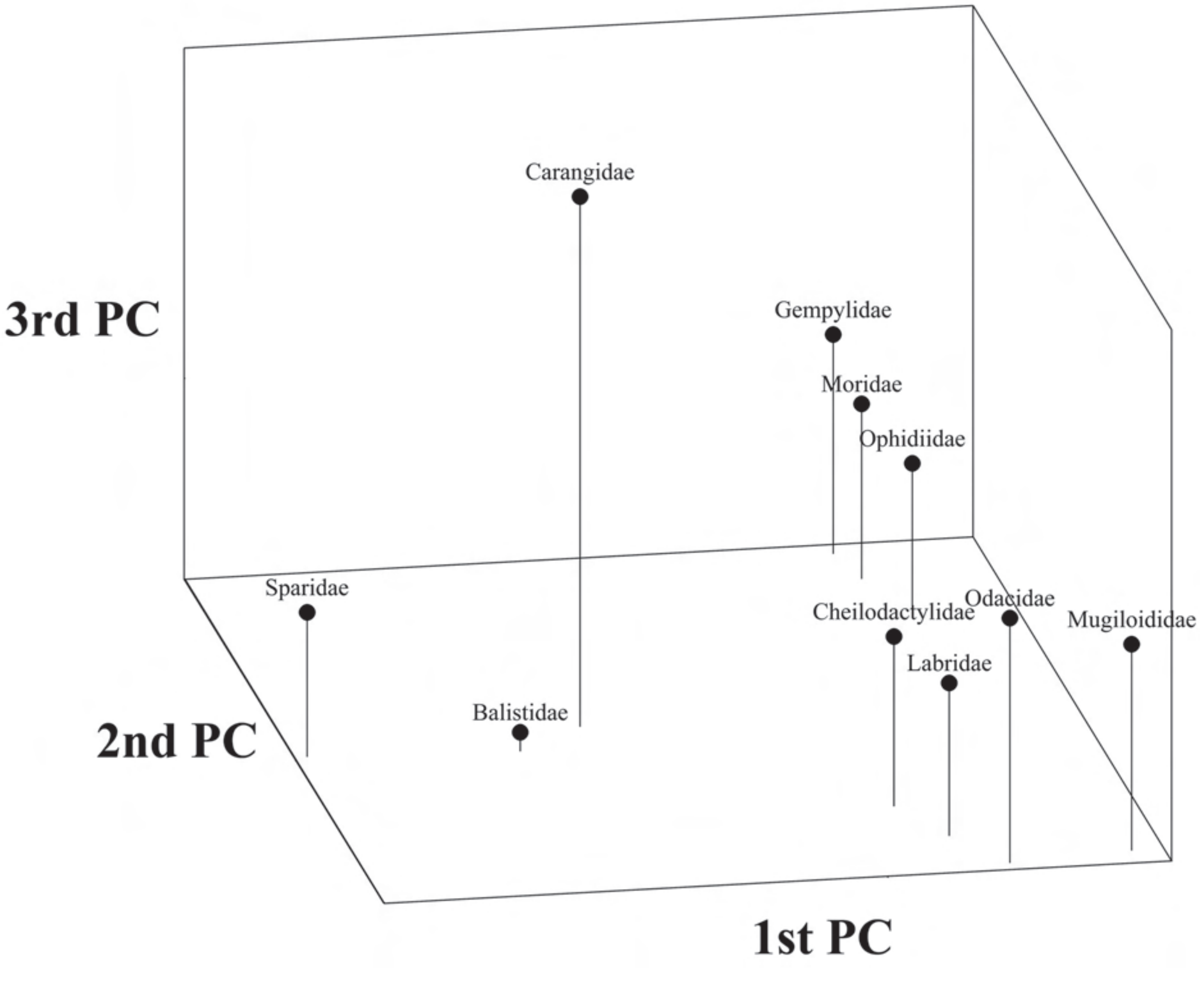

Figure 6.7: Three-dimensional plot of the first three principal components of R-mode analysis, showing several loose clusters of fish families.

The first cluster is composed of barracouta (Gempylidae), red cod (Moridae) and ling (Ophidiidae). These are the fishes that are especially common in the South Island cluster of sites.

The second cluster is composed of tarakihi (Cheilodactylidae), labrids (Labridae), greenbone (Odacidae) and blue cod (Mugiloididae). These fishes are associated with two of the clusters, notably archaeological sites in the Cook Strait region and the Chatham Islands.

Snapper (Sparidae) appears in the plot a considerable distance from these two clusters, with leatherjacket (Balistidae) being the closest fish. Snapper is the main species associated with the North Island sites, with leatherjacket characterising the outliers of Hahei and Cross Creek.

Finally, mackerel (Carangidae) also plots well away from all other fishes, and is associated with the two sites of Kohika and Matakana Island in the Bay of Plenty.

THE CHARACTER OF REGIONAL CLUSTERS

It is now possible to make some comments about the character of the regional clusters identified in these complementary forms of multivariate analysis. The first point which needs to be made is that these regional clusters are not completely constrained geographically. The best example of this is the fact that archaeological sites in three of the clusters (Cook Strait, Foveaux Strait and Fiordland, and the Chatham Islands) share more in common with each other than they do with other parts of New Zealand. These three areas are each characteristically rocky shore habitats with diverse seaweed floras supporting a rich biomass of pāua, kina, crayfish, and further up the food chain a mixed population of solitary resident species such as labrids, greenbone and blue cod. In a sense, these three clusters are really one, and might be termed a biocultural rather than regional cluster. That is, there are underlying biological reasons for the character of the fish catches, but with a strong cultural component on top of this.

I separated out the archaeological sites in each of the seven ‘regional’ clusters, and then examined the fish catches, one cluster at a time, to try and identify common features. One way of revealing this is by looking at the mean percentage of each of the ten major fish families and how this varies within and between clusters. This information is presented in Table 6.4, and illustrated without standard errors in Figure 6.8.

Although the mean percent of a type of fish in any one of these clusters is a helpful guide to what pre-European Māori were catching in each of these regions, it is important also to take note of the standard error. This enables a rough assessment of the statistical significance of any observed differences between one region and another.

1: Foveaux Strait and Fiordland. Labrids are high in abundance at sites in this cluster, averaging about 47%, with blue cod and barracouta also making a sizeable contribution to catches. The catch diversity in these sites is similar to the Chatham Islands and the outlier of Tiwai Point. It was noted in Chapter 3 (see Fig. 3.11) that barracouta are winter visitors along this coast.

2: Cook Strait: Although Figure 6.8 shows that labrids are the most common fish represented in these sites, there is greater diversity of catch in this region than in any other. No doubt this is due to the complex rocky shore environments so typical of this region. Sites in Cook Strait that are

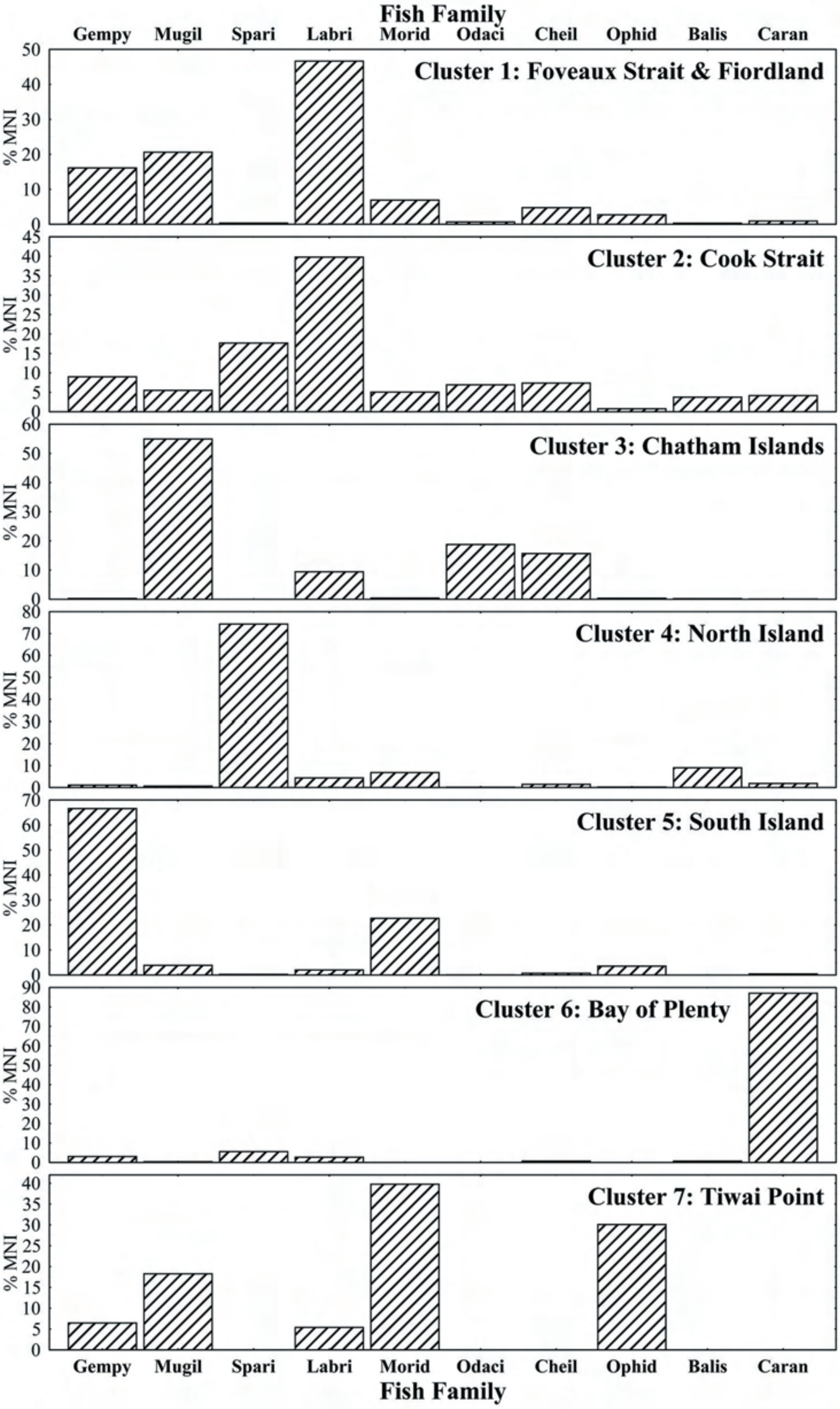

Figure 6.8: The mean percent abundances of the ten main families of fish in each of the biocultural clusters revealed by multivariate analysis.

located along sandy beaches, such as Foxton, clustered with the North Island group. Rotokura in Tasman Bay occupies a position in the multivariate analysis between the North Island and Cook Strait clusters. This site is in an area where snapper were once abundant (more on this point in Chapter 7), but the nearby rocky shore supported a wider range of fishes than is typical elsewhere in eastern Tasman Bay.

3: Chatham Islands: Sites in the Chatham Islands exhibit large numbers of blue cod, 55% on average, with greenbone, tarakihi and labrids also important. I have already alluded to the remarkable abundance of blue cod right up to the shoreline along the rocky coastline of these islands. These areas have a dense forest of seaweeds, which like Cook Strait, Foveaux Strait and Fiordland, supports rich resources of pāua, sea eggs and crayfish.

4: North Island: The North Island cluster of sites shows super-abundance of snapper, on average about 74% of MNI. This is in keeping with the large number of sandy open beaches north of Cook Strait on this island where this species is mainly located. Leatherjacket shows up as a secondary species. Several sites in the South Island clustered with these North Island sites, notably Fox River on the west coast, and three sites in Tasman Bay (The Glen, N26/214 and Appleby). This is due to the abundant snapper in these sites. Two sites on the Coromandel Peninsula are outliers to the North Island cluster: Hahei and Cross Creek. This is due to the higher abundance of leatherjacket and labrids in these sites.

TABLE 6.4
The Main Characteristics of the Identified Regional Clusters

Clusters identified are: 1 Foveaux Strait and Fiordland, 2 Cook Strait, 3 Chatham Islands, 4 North Island, 5 South Island, 6 Bay of Plenty, 7 Outlier - Tiwai Point. Column abbreviations are: Gempy = Gempylidae, Mugil = Mugiloididae, Spari = Sparidae, Labri = Labridae, Morid = Moridae, Odaci = Odacidae, Cheil = Cheilodactylidae, Ophid = Ophidiidae, Balis = Balistidae, Caran = Carangidae.

Mean Percent of MNI

	Gempy	Mugil	Spari	Labri	Morid	Odaci	Cheil	Ophid	Balis	Caran
Cluster 1	16.1	20.6	0.3	46.6	6.9	0.7	4.8	2.7	0.3	0.9
Cluster 2	9.0	5.5	17.7	39.8	5.0	6.9	7.4	0.8	3.8	4.1
Cluster 3	0.2	54.9	0.0	9.4	0.4	18.8	15.7	0.3	0.2	0.1
Cluster 4	1.1	0.6	74.3	4.4	6.8	0.1	1.5	0.2	9.0	1.9
Cluster 5	66.6	3.8	0.2	2.0	22.6	0.0	0.7	3.5	0.0	0.4
Cluster 6	3.0	0.4	5.5	2.7	0.0	0.0	0.7	0.0	0.7	87.0
Cluster 7	6.5	18.3	0.0	5.4	39.8	0.0	0.0	30.1	0.0	0.0

Standard Error[†]

	Gempy	Mugil	Spari	Labri	Morid	Odaci	Cheil	Ophid	Balis	Caran
Cluster 1	6.2	3.7	0.2	6.0	1.9	0.3	1.6	0.8	0.1	0.7
Cluster 2	2.0	1.2	5.5	6.8	2.1	2.0	2.5	0.3	1.9	1.5
Cluster 3	0.2	7.0	-	4.0	0.4	6.5	13.0	0.2	0.1	0.1
Cluster 4	0.6	0.3	8.8	1.4	6.5	0.1	0.6	0.1	5.4	0.8
Cluster 5	5.7	1.4	0.2	0.6	5.1	-	0.3	0.8	-	0.3
Cluster 6	1.6	0.4	4.3	2.0	-	-	0.7	-	0.7	2.5
Cluster 7	-	-	-	-	-	-	-	-	-	-

[†] NB: where there was insufficient data to calculate a standard error, this is given a hyphen (-)

5: South Island: Barracouta is the pre-eminent fish in this cluster of sites, averaging 67% of the MNI, with red cod also abundant at 23%. Other species have only marginal importance in terms of their abundance. As seen in Figure 3.11, barracouta are summer visitors along the eastern side of the South Island, which is where the largest number of sites in this cluster are located. Interestingly, the fish catch at Ross's Rocks in north Otago clustered with sites in the Foveaux Strait and Fiordland group rather than with other South Island sites. Conversely, two sites in the Foveaux Strait/Fiordland area clustered out of their geographic location and in the South Island group. These are the Port Craig Cave, and the Sandhill Point 3 site.

6: Bay of Plenty: Unfortunately, there are only two sites in the Bay of Plenty with information on fish catches and both are very unusual, with high abundance of mackerel. It is very surprising that neither of these sites has snapper in any number. There are significant snapper stocks in the Bay of Plenty.

7: Tiwai Point: Finally, the site at Tiwai Point must be considered an outlier from all these clusters. It has an unusually low abundance of barracouta for a site in eastern Foveaux Strait. The high representation of red cod will be due to the position of this site at the entrance of a large estuary. Red cod are well known for entering estuaries at certain seasons and can be very numerous at times. Another unusual feature of the catch at this site is the large number of ling, about 30% of the catch. Compared with all other sites in New Zealand, the Z-score for ling at this site is 6.1, which is very high. Ling does occur in smaller numbers in sites, particularly in the South Island. Although ling are primarily a deep water species, most common in the depth range of 300–500 metres (Paul 2000: 64) and are taken during modern groper fishing, Graham records them venturing into Otago Harbour at times (Graham 1956: 337 ff.). It is therefore possible that the ling at Tiwai Point were taken in Bluff harbour.

CONCLUSIONS

The purpose of this chapter was to examine what is known of pre-European Māori fish catches to see if they differentiate into meaningful regional groupings. I explored this question from two points of view. The first approach was to use Francis's regional entities, which were derived from modern distributional data of different fish species throughout New Zealand, and to see if the archaeological data conformed in any way to these existing marine groupings. The second approach was to see if any regional entities could be derived directly from the archaeological catches themselves.

Francis's regional schema provides a good starting point for any discussion about regionalism in fish catches. His regional entities were established from multivariate analysis of fish distributional data. His major finding was that diversity is highly correlated with latitude, becoming increasingly depauperate as one moves further south. When the archaeological data were examined using his regional groupings, it was found that catch diversity increased significantly from the northern to central New Zealand areas, and then decreased significantly from there southwards. This does not conform to expectations. Using these very broad regional groupings, it is clear that fishing was a more specialised activity in the northern and southern parts of New Zealand, and more generalised in the central region, especially around Cook Strait. To over-simplify a very complex picture — pre-European Māori fisherman in northern New Zealand were after snapper, southern fishermen were after barracouta, and those in between were after a much broader range of fish types.

In the second approach taken, I attempted to derive clusters of archaeological sites using multivariate analysis of the catch data, and then to see if these exhibit regional characteristics. Only the most reliable data were used for this purpose; that is, sites with an MNI greater than 100, and the 10 most abundant fish families. Seven clusters were found and each of these is essentially a regional entity. Of considerable interest is the finding that three of these clusters — Cook Strait, Chatham Islands, and Foveaux Strait and Fiordland — show shared characteristics, and to some extent merge into each other. Several archaeological sites fall into clusters which are not their correct geographical locations, and this is a clear sign that there is similarity in the characteristics of these three clusters.

The attempt to derive meaningful regional entities in this chapter, although moderately successful, is not without problems. One is that the basic information on fish catches is very unevenly distributed around New Zealand and there are huge gaps with no information at all. A glance at Figure A.1 in Appendix 1 will reveal the full extent of this problem. On the west coast of the North Island I have information from only one archaeological site (Aotea) between the Hokianga and Horowhenua. This is a huge gap in the knowledge base. The west coast of the South Island is almost equally bad with only two sites (Fox River and Bruce Bay) between Tasman Bay and Fiordland. Information is only available for two sites in the Bay of Plenty; and between Whakatane and Palliser Bay only one collection exists, from Tiromoana. Each of these gaps represents an enormous deficiency, and it is hoped that in the future they will be filled. The second problem inherent in this quest for regional groupings is that it takes no heed of changes through time[6] (the subject of the next chapter), let alone of issues concerning site function, like specialised seasonal camp sites or permanent villages. Catches from different periods are simply lumped together, as are all sites of different functional status. This analysis therefore is unashamedly broad-brush in approach.

Despite these deficiencies, it is abundantly clear that there are significant changes in fish catches from one region to another in New Zealand, and while these partly reflect natural abundance, they also reflect human culture. For this reason, the clusters which were derived are probably best referred to as biocultural regions.

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[6] It should be noted that using modern distributional data on fish types for archaeological purposes necessarily suffers from exactly the same problem, in that natural and human-induced changes in relative abundance of fish types over time are ignored.

CHAPTER 7: CHRONOLOGICAL CHANGE IN FISHING

INTRODUCTION

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

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

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

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

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

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

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

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

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

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

NATURAL ENVIRONMENTAL CHANGE

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

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

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

As far as the first question is concerned, there is excellent quantifiable information. Some of this has been described in Chapter 3. Coastal surface sea water temperatures closely follow coastal air temperature, with the air slightly cooler than the sea on average, and short-term fluctuations of air temperature are 3–4 times the standard deviation of surface sea temperatures. From studies of the subtropical convergence it has been found that there is a 5˚C change between winter and summer, and this represents a seasonal shift of 11˚ of latitude. This is a considerable change, and is the reason why fish in New Zealand waters are so strongly seasonal in abundance (See Fig. 3.5). Species tolerant of cold water move north in winter, and species intolerant of cold water move south in summer. So we can safely say that the dramatic changes in seasonal abundance of fish around New Zealand correspond to a 5˚C change in surface sea water temperature.

A second important aspect of surface sea water temperature concerns recruitment. Once again, quantifiable information is available for some species, and data for snapper were given in Chapter 4. An increase of 2.5˚C over the summer period corresponds with a ten-fold change in the abundance of one-year old fish (see Fig. 4.9) and the relationship is exponential. At 17°C, the recruitment rate for one-year old snapper is close to zero. Once again, here is a rough yardstick against which to examine archaeological data — for snapper, a 2.5°C change represents the difference between abundance and nothing for a particular region.

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

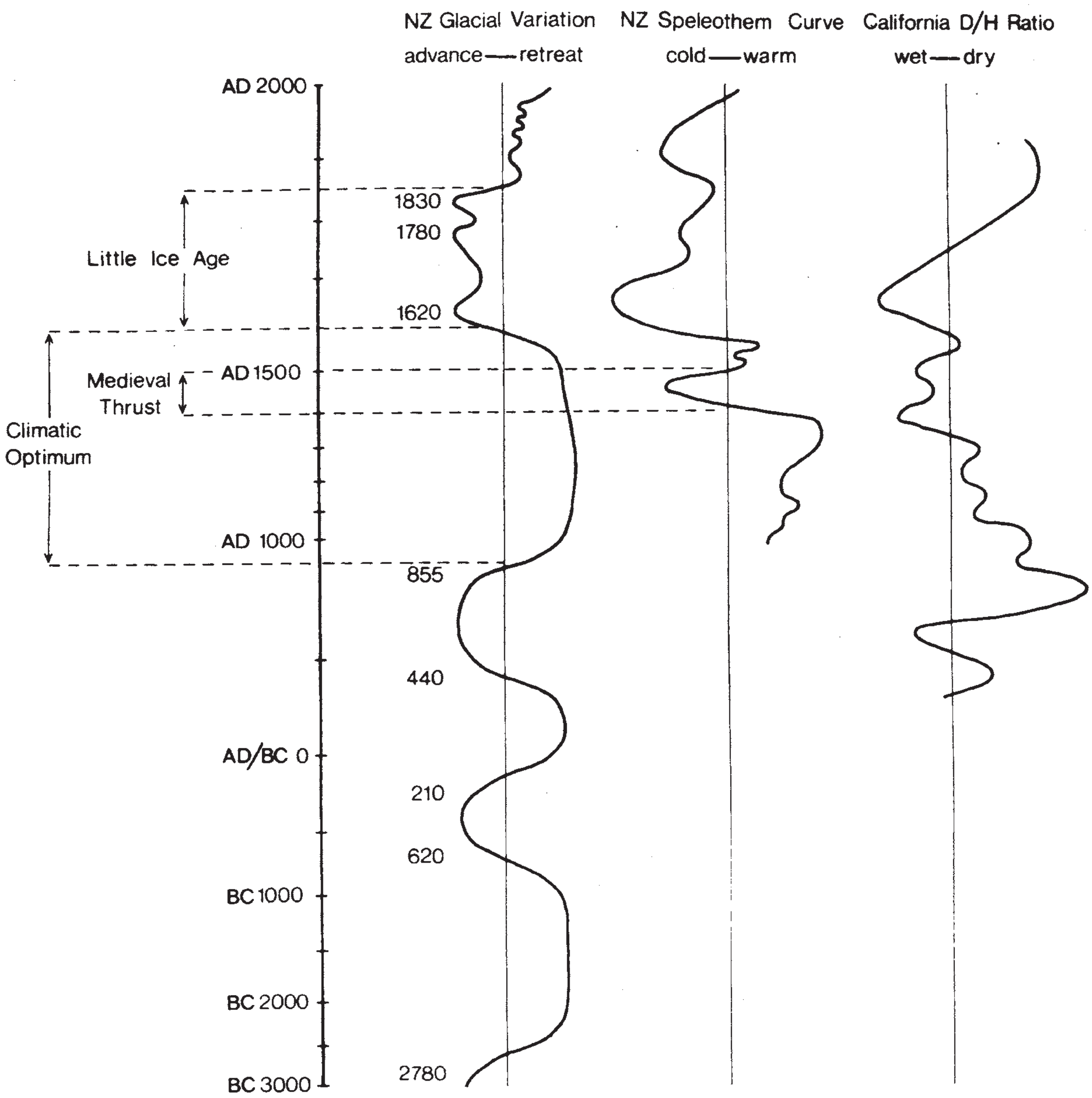

Figure 7.1: Comparison of Wilson's speleothem temperature curve with evidence of glacial advance and retreat, suggestive of a Little Ice Age and a Little Climatic Optimum in New Zealand. The D/H ratio is a proxy for rainfall. (from H.M. Leach and B.F. Leach 1979: 231).

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

Hendy and Wilson (1968) produced an uncalibrated palaeo-temperature curve from analysis of $\delta^{18}O$ isotope values on speleothems[1], which appeared to show the presence of climatic changes in New Zealand comparable to European events known as the Medieval Warm Period (sometimes called the Little Climatic Optimum) and the Little Ice Age (Lamb 1965; Fagan 2000). This isotope curve was incorporated in a review of climatic change in New Zealand by H.M. Leach and B.F. Leach (1979), suggesting that there was reasonable agreement with evidence from glacial advances and retreats in the South Island (Fig. 7.1). These two climatic events were found to be useful when interpreting the prehistory of Palliser Bay (Leach 1981; B.F. Leach and H.M. Leach 1979). The paper by H.M. Leach and B.F. Leach (1979) was roundly criticised by Burrows (1982), who suggested abandoning Euro-centric terms such as Little Ice Age in favour of developing a local framework. There is a danger of losing sight of the main objective here, which is to see if there are aspects of the climatic history over the last millennium that were of sufficient magnitude to have impacted on human culture and, in this particular case, on the fishery. Setting aside for a moment minor fluctuations in the climate curve, the two broad brush questions which we need to address here are these: During the early period of pre-European Māori occupation of New Zealand were climatic conditions especially favourable for the type of economic system which prevailed, and was there a period towards the end of the pre-European era when conditions worsened? There has been cautious acceptance by archaeologists of both these propositions (e.g., Davidson 1984: 37), but the details have been the subject of constant review.

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

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

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

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

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

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

There are now reasonable estimates of solar irradiation levels for the past 1200 years, based on a combination of ^{10}Be measurements of South Pole ice (Raisbeck *et al*. 1990) and the atmospheric ^{14}C record from tree rings (Bard *et al*. 1997) to produce a sequence of Total Solar Irradiance (Bard *et al*. 2000). The series has low frequency changes mirrored by speleothems and other proxies of climate (Mann *et al*. 2000b; see also Fig. 7.4 below).

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

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

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

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

Earliest Historical Information in New Zealand

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

> The significant features of the weather in the summer of 1769–1770 were the short-lived anticyclones, the number of low pressure systems crossing the North Island, the possible passage of deep depressions close to the south of the South Island at a time of year when they are normally far to the south of New Zealand, the prevailing disturbed west to

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

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

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

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

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

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

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

Some of the observations of snow-clad peaks from out at sea during Cook's voyages may have been the seaward Kaikoura mountains (Fig. 7.2), rather than Tapuae-o-Uenuku in the inland Kaikoura range. These are equally spectacular when covered in snow, and visible from great distances.

There are similar records by Cook of Tapuae-o-Uenuku being covered in snow in October and November 1773 (Cook 1969: 284, 580). Furneaux made a most interesting observation after rounding Cape Jackson and entering Queen Charlotte Sound on the way to Ship Cove in April 1773: "As we sailed up the Sound saw the Tops of high mountains covered with Snow, which remains there all the year" (Furneaux 1969: 737). It is uncertain which mountains Furneaux was observing

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

Figure 7.2: The snow-clad seaward Kaikoura mountains from out at sea, a view which was familiar during Captain Cook's visit to New Zealand. Photo courtesy of Rob Suisted, image #20348OP37.

here. Was this Tapuae-o-Uenuku or some of the hill peaks at the head of Queen Charlotte Sound? Snow in April in either area would be most unusual in today's conditions, and certainly would not remain all year.

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

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

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

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

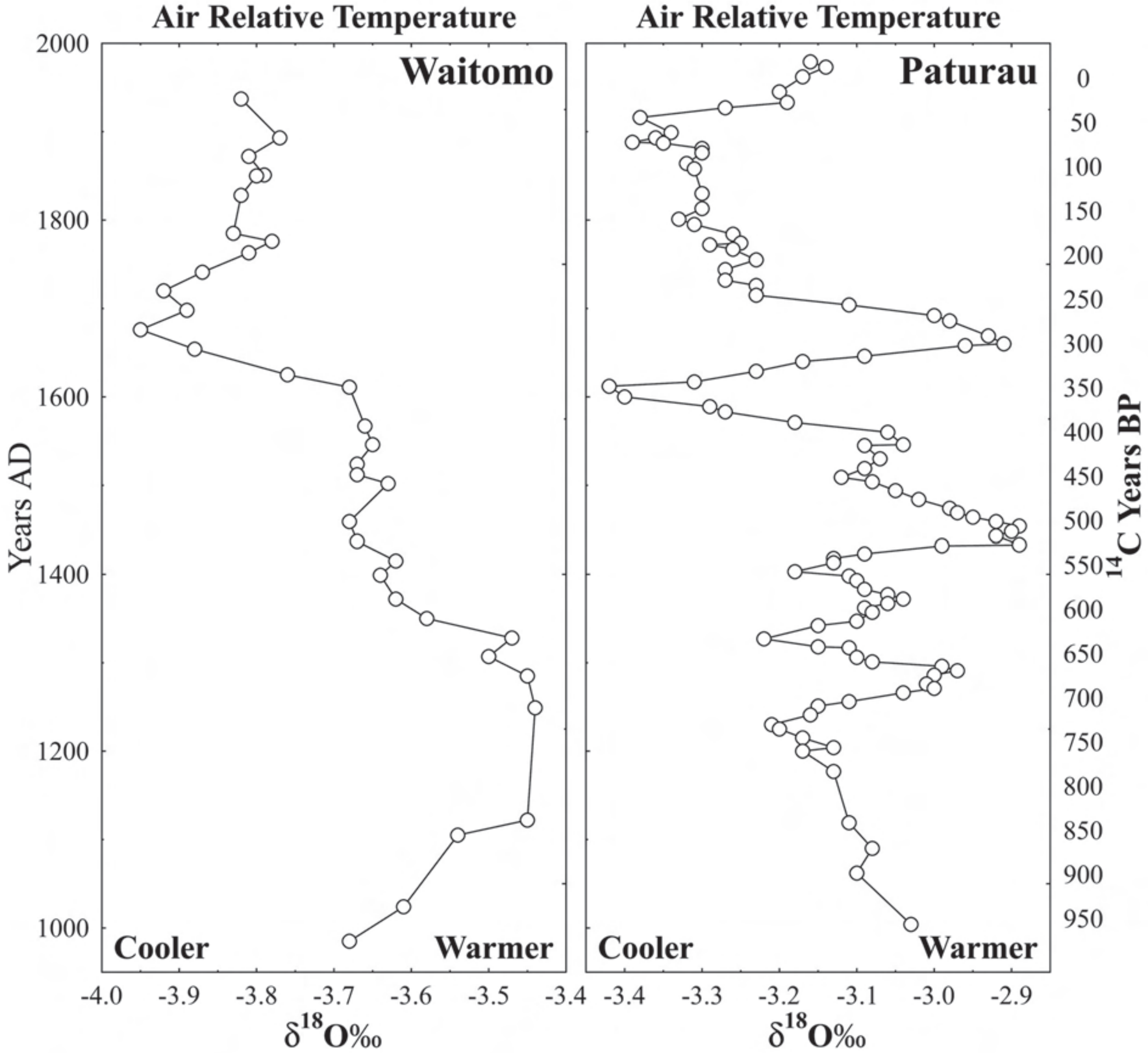

Figure 7.3: Two speleothem temperature curves from Waitomo (west central North Island) and Paturau (northwest South Island), more convincing evidence of a Little Ice Age and a Little Climatic Optimum in New Zealand (courtesy of Paul Williams).

identity of either of these two peaks from Dieffenbach's information. The taller of the two would probably be Mt Furneaux, which is the highest peak in this general vicinity at 823 m (2700 ft). Dieffenbach records:

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

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

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

Recent Speleothem Evidence in New Zealand

Considerable research has been carried out on speleothems to extract climatic data in the Holocene since the Wilson curve first appeared (Fig. 7.1). Two of these studies are of special relevance to the last thousand years. They are illustrated in Figure 7.3, and are parts of much larger time sequences (Williams *et al*. 2004, 2005). For the portion illustrated here, covering the period AD 1000 to 2000, the time sequence was obtained by interpolation using four radiocarbon dates for the Paturau curve and three for the Waitomo curve. The differences between the two curves are partly a consequence of differences in the resolution of dating and isotope analysis. The Paturau curve is more closely dated and sampled than the Waitomo one, so it is considered more reliable at this state of research on the samples. This is the reason that the two curves do not appear to be completely synchronous. For example, the most negative $\delta^{18}O$ value (coldest conditions) appears at around AD 1680 in the Waitomo curve and at about AD 1620 in the Paturau curve, but they probably occurred at the same time, so the 60 years apparent difference may not be real. “Both probably represent the influence of the Little Ice Age that may have been more strongly felt in Paturau than at Waitomo” (Williams 2005: pers. comm.).

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

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

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

Archaeological Isotope Evidence in New Zealand

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

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

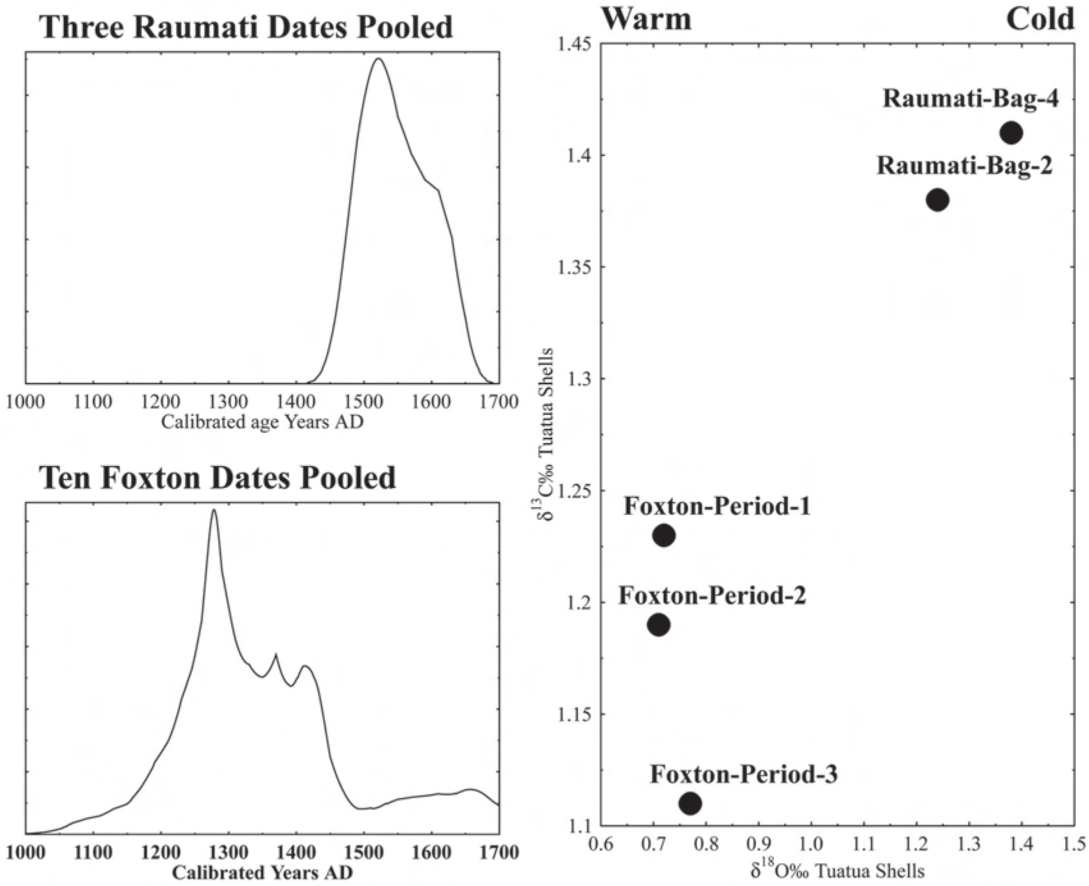

Figure 7.4: Carbon $\delta^{13}C$ and Oxygen $\delta^{18}O$ isotope results for shell samples from archaeological sites at Foxton and Raumati, together with the pooled radiocarbon dates (from Leach *et al*. 2000a: 32, 35).

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

The results of this analysis are illustrated in Figure 7.4.

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

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

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

$$T^{\circ}C = 16.9 - 4.2*(dc-dw) + 0.13*(dc-dw)^2, \text{ where } dw=0.15$$

The estimated mean integrated sea water temperatures in which the shells lived at these two sites are presented in Table 7.1.

TABLE 7.1

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

Cat.No.	**Provenance**	**$\delta^{18}O$**	**$\delta^{13}C$**	**Raw °C**	**Corrected °C**
AK995	Raumati Bag 4	1.38	1.41	11.4	11.4
AK994	Raumati Bag 2	1.24	1.38	11.9	11.9
AJ631	Foxton Period 3 (Late)	0.77	1.11	13.7	14.3
AK992	Foxton Period 2 (Early)	0.71	1.19	14.0	14.6
AK993	Foxton Period 1 (Early ?)	0.72	1.23	13.9	14.5

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

Further information has been obtained from a series of shell middens, investigated during salvage work at Site R25/13 at Pukenamu near Te Horo, 17 km north of the Raumati site. At the time of the investigation, the site appeared as a series of shell midden scatters about the slopes of a low,

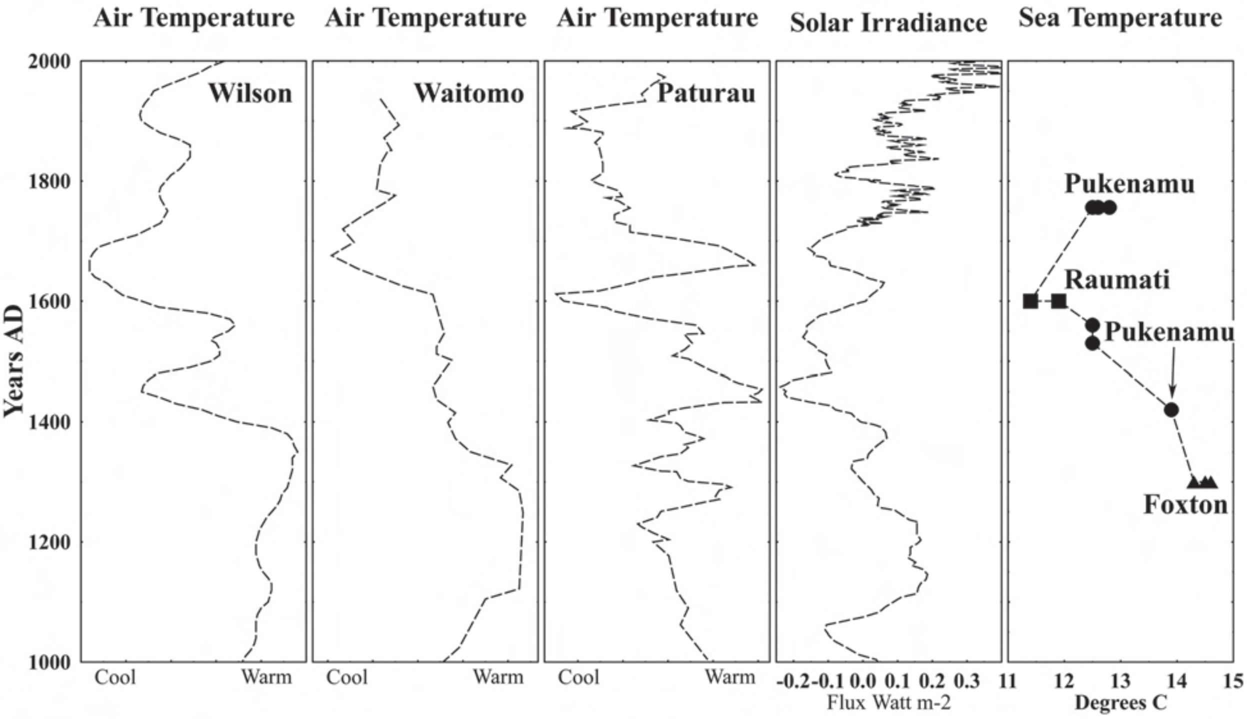

Figure 7.5: Integrated annual surface sea water temperature values for the Horowhenua coastline from analysis of δ^{18}O in archaeological specimens of tuatua at different periods of time (right), compared with several assessments of air temperature and solar irradiance over the same period. See text for details.

largely unconsolidated, dune system. The surface of much of the area under investigation had already been modified by bulldozer activity. Six discrete midden areas (A to F) were recorded. Intact midden was sampled at Areas B and C. Area F consisted of 11 small patches of midden; most of these were sampled. Four radiocarbon dates were obtained from three middens (Area B, upper and lower layers, Area C, and Midden 3 in Area F). Midden 3 was the oldest, closest to Foxton in age; the two layers of Midden B were close to Raumati, and Area C returned a date of late prehistoric or early historic age. Mean integrated sea temperatures were obtained for six shell samples from these dated contexts. These additional analyses are consistent with the results obtained from Foxton and Raumati.

These archaeological proxies for surface sea water temperatures are plotted out in Figure 7.5, along with the three speleothem curves discussed above, and the solar irradiance curve (after Mann *et al*. 2005, raw data available from IGBP PAGES/World data center for Paleoclimatology Date Contribution Series # 2005-035).

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

Other archaeological clues in New Zealand

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

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

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

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

In any event, a drop in water temperature of 2.6˚C would result in snapper reproduction ceasing (Paul 2005: pers. comm.). A population of increasingly large fish might survive for 30–50 years, but they would then die out or move north. The present-day Tasman Bay snapper population is genetically isolated from breeding populations further north (Bernal-Ramírez *et al.* 2003: 567) and in cold years spawning success is poor to nil. Bearing in mind the exponential relationship between recruitment rate and temperature (see Fig. 4.9), this population is especially vulnerable to changes in surface sea water temperatures. A lowering of annual temperature of 2.6˚ C would mean that conditions in Cook Strait would be approximating those more typical of central and southern South Island waters, where spawning of snapper does not occur and adults are very rare. The snapper population in Tasman Bay exhibits low genetic diversity (Hauser *et al.* 2002: 11745). The reason for this is unclear, although fishing pressure during the historic era will have contributed. One further possibility is 'founder effect' — re-seeding of the area by a small immigrant group from further north following the Little Ice Age.

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

Conclusion

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

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

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

BROAD CHANGES IN CATCH COMPOSITION

In order to consider any possible changes through time on a broad front, we need to group the information from sites into some suitable time slots. There are formidable problems in doing this, but one must be tough minded and try to forge ahead despite this. In Appendix 1, I have listed the 126 sites for which we have reasonable fishing information, and the 36 fish families identified in assemblages from these sites. A time period has been assigned to each site. Most of these follow the discussion about chronology in Leach and Boocock (1993), where broad trends in fishing were considered, using 84 sites for which information was available at that time. This has been swelled by further research since 1993; other age assessments are provided by Anderson (1997). The categories into which I have grouped the sites are:

1. **Early Prehistoric**. Before AD 1500, loosely corresponding to what is referred to as the Archaic Period, or New Zealand East Polynesian Culture.

2. **Late Prehistoric**. After AD 1500 and before AD 1769, loosely corresponding to what is referred to as Classic Māori culture.

3 **Protohistoric**. After AD 1769 and before AD 1840. Māori settlements during early European times.

Appendix 1 also provides the MNI of 36 fish families in each of these sites. This is given as a matrix of figures at the end of the appendix. There are many ways in which this basic matrix of data could be examined to see if there are any significant changes through time in New Zealand as a

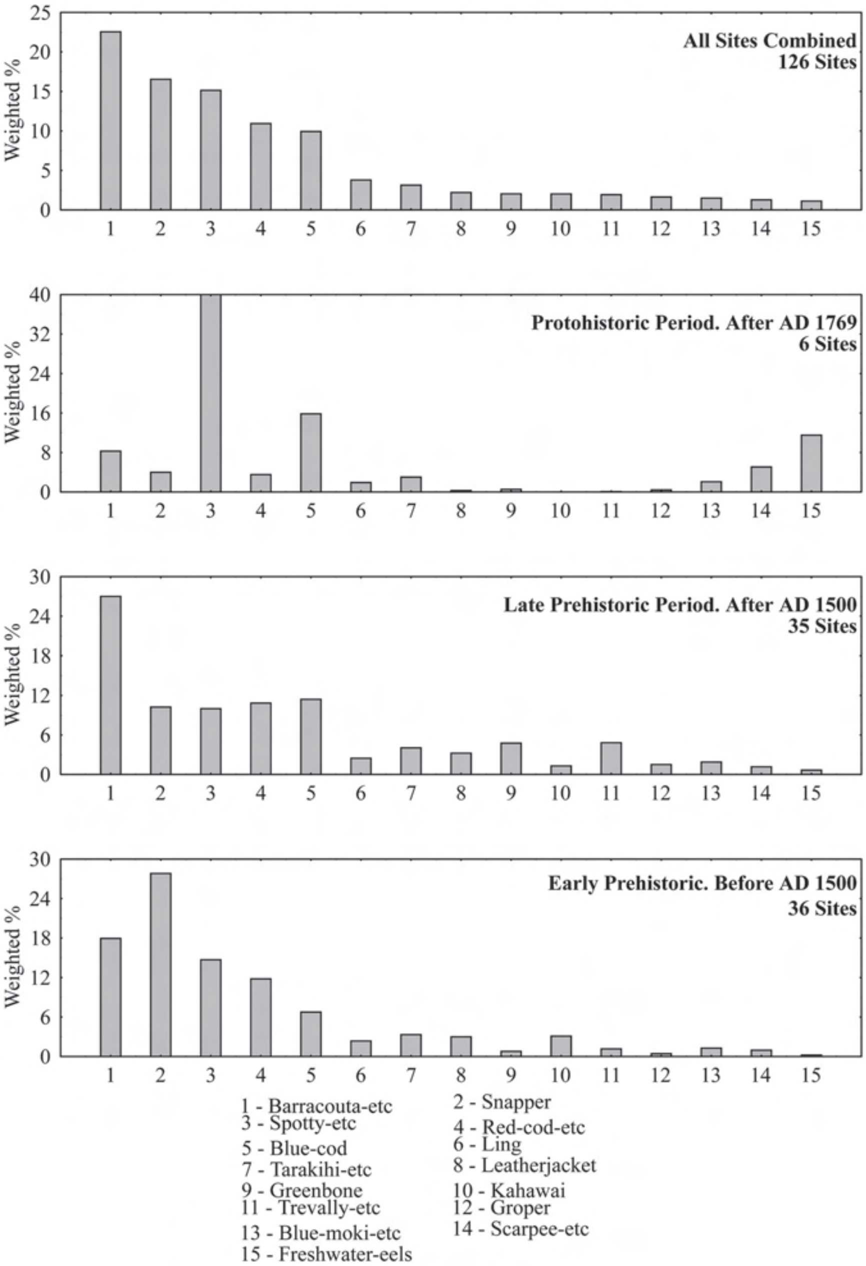

Figure 7.6: The relative abundance of different fish types for three periods. At the top is the overall abundance when all 126 sites are combined. The percentage values are simple unweighted means, giving equal emphasis to all assemblages with an MNI greater than 40. Such an analysis is not considered very useful. The alternative of examining change through time for small regional units is preferable.

whole, and there are problems with each technique. Several difficulties need to be kept in mind. For example, there can be wild fluctuations in relative abundance of different fish types at the same period in sites near to each other in one region. These reflect changing abundance of different fish seasonally; the sites involved are specialised fishing camps, rather than year-round settlements. Moreover, some assemblages are very small and these should be give less weight than large samples in working out aggregated percentages.

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

In the end I chose a fairly simple approach. The matrix in Appendix 1 was split into three parts, one for each age group. The percentage matrices were calculated for each in turn, after first extracting data relating to elasmobranchs and unidentified teleostomi and rejecting any sites with an MNI of less than 40. The simple unweighted mean percentage for each family was then calculated for each of the three matrices. The results for the 15 most abundant fish types are given in Figure 7.6. In theory, the weighted mean method should always be preferred, though in practice the choice of samples with which to calculate it is a crucial matter. We will shortly see that this type of broad-brush study is fundamentally flawed, because the mix of samples making up the major groupings is not appropriate, and neither weighted nor unweighted means would alleviate this problem. I have chosen the simple unweighted means in this case to illustrate just how misleading it can be when unlike samples are combined into major groups.

At first glance, Figure 7.6 does indeed show some interesting fluctuations over time, but whether these can be considered as major New Zealand-wide changes in fishing is another matter. The bottom bar graph shows the pattern for the Early Prehistoric, and it is evident that of the five most important fish types, snapper dominates, with 27%. This falls to 10% in the Middle period. Further inspection of the data which make up this trend shows that in the Early Prehistoric, the mean snapper catch is 50% in the North Island, but only 5% in the South Island. The particular mix of sites from each island is what makes up the overall mean of 27% snapper for the Early Prehistoric. This is not a very satisfactory situation (the mean is a poor representative of the range of values, which are effectively bi-modal). Similarly, the lower figure of 10% for the Middle Period snapper is made up of North Island sites averaging 26% and South Island sites averaging 0.5%. This shows just how easy it would be to misinterpret apparent trends of this kind completely.

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

The same form of statistical scenario can be put together for barracouta fishing. Figure 7.6 shows what appears to be a large change from the Early to Middle Period of 18% to 27% of the catch. Once again, we can break this down into North and South Islands. In the North Island, there is a rise from 2.2% to 5.2%, and in the South Island from 34% to 49%. One could easily calculate the standard error of these percentage differences to test for 'statistical' significance in the trends. However, I do not think this is wise. It might inadvertently lend weight to the idea that statistical testing was the most suitable way of confirming or rejecting a theory of change here, and I do not think this is an appropriate test at all. Once again, I suggest that there is no substitute for careful study of the chronological sequence of changes affecting small localised pre-European communities in New Zealand.

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

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

Method 1	The weighted mean (Snedecor and Cochran (1967: 521), and the standard error of proportion (ibid.: 210).
Method 2	The weighted mean with minimum variance (Leach 1972: 115).
Method 3	The simple mean and standard error of the mean.
Method 4	The simple mean and standard error of the mean proportions (Manly 1989 pers. comm.). The standard error is calculated thus: $\mathrm{sqrt}((\Sigma((SE\text{-}P_i)^2))/N^2)$, where $SE\text{-}P_i..P_n$ are the series of standard errors of proportions.

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

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

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

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

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

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

In order to examine this possibility I extracted the most reliable information from Appendix 1 by ignoring assemblages with MNI of less than 100 fish and calculated a well-known measure of diversity known as Shannon’s H statistic (Shannon 1948; Peet 1975) for the remaining 56 sites. These are plotted out in Fig. 7.7. The mean values were: Early Prehistoric 1.36, Late Prehistoric

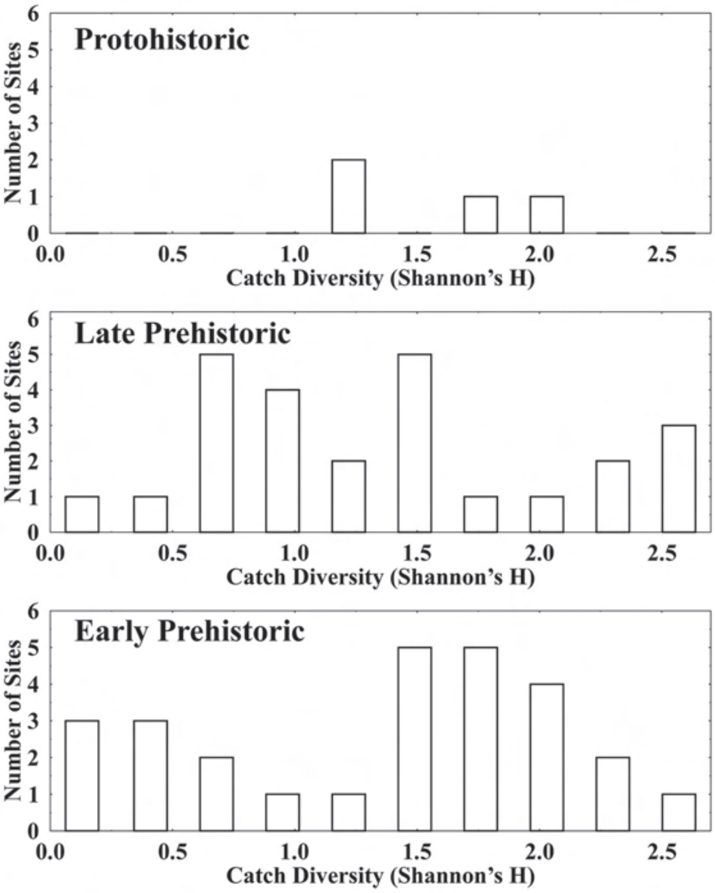

Figure 7.7: The diversity of fish catches varies a great deal from one archaeological site to another, but does not show any significant trend over time.

1.35 and Protohistoric 1.63. It is clear from Fig. 7.7 that there is wide variation at each period and no obvious trend over time. The number of fish families caught ranged from 3–10 in the first two periods and 7–8 in the last.

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

It may have been noticed in Fig. 7.5 that there is apparently a notable rise in freshwater eel numbers in the Protohistoric period from a small proportion in both earlier periods. Is this 'real'? The first thing which must be said is that the bar chart for the Protohistoric period combines information from very few sites; but it is basically all the archaeological evidence we have of any quality for this period. Nevertheless, it can hardly be considered a good sample of Māori fishing in the Protohistoric era up to AD 1840, and much more knowledge is needed in the future. As far as freshwater eel is concerned, there is a dearth of information in archaeological sites of any period. As Marshall has pointed out, the common dogma invoked to explain this is that eel bones are soft and easily decay in archaeological sites (Marshall 1987: 56). This is manifestly untrue, as there are numerous archaeological sites throughout the world with abundant eel remains (Wheeler and Jones 1989: 164). For example, in one early mesolithic site on the north coast of Spain sixty percent of a sample of 7,000 fish bones were of freshwater eel (Izquierdo and Brinkhuizen 1994: 403). Closer to home, eel bones occur in abundance in some sites in the Pacific too (see below).

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

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

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

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

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

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

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

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

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

1: Pre-European archaeological evidence suggests eels were very infrequently caught and eaten.

2: There are clear signs, at least amongst some South Island Māori in the early historic period, that taking eels for food was considered extremely dangerous, and special precautions were required to ensure personal safety.

3: From the nineteenth century onwards eels were subjected to mass harvesting by Māori in several parts of the North and South Islands, and distributed as an important trade item.

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

Where have eel bones been found in New Zealand? They have been identified in only 20 of the 126 sites studied. The details are provided in Table 7.2.

TABLE 7.2
Eel Bones in New Zealand Archaeological Sites
Asterisked items (*) indicate identifications confirmed by myself

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

In this Table I note the sites where I can verify the identifications to be correct. Some of the others may possibly be marine eels; I have not personally checked these identifications. It will be noticed that a number of the sites are in the Chatham Islands. We should not expect that food avoidance customs would necessarily be the same among Māori and Moriori. However, the figures are also fairly low in the Chatham Islands. When these figures are plotted out (Fig. 7.8) there do seem to be signs of an increase over time, but the number of data points is pitifully small.

It should be noted that both the simple and weighted means are provided in Table 7.2, as discussed above. The two values are substantially different in each case. The weighted mean gives greater credence to large samples, and is therefore more representative of the entire series. However, it also reveals a weakness inherent in combining values from different archaeological sites separated by considerable distances. The communities which were responsible for the deposits may have had quite different approaches to gathering food. Combining them together statistically will not fairly represent any one of them. Once again, this shows that in examining changes through time it is preferable to give far greater attention to individual regional sequences.

Another interesting aspect about eel exploitation is an initial indication that only very small eels were being taken at some of these sites. The mass eel harvesting described in nineteenth century records involved an abundance of large fat females attempting to migrate out to sea for spawning. This does not seem to be indicated in the few bones we have from archaeological sites. I have started a modern comparative collection, with 88 specimens so far, measuring up to 1200 mm long, and extracted their cranial bones. Comparison of these with the relatively large archaeological collections from Parewanui and the Washpool suggests that only very small eels are represented in those sites. Such eels are more often seen in small, fast-flowing streams. The bones are certainly not from the very large mature eels involved in the spawning migration. There is obviously a great deal still be to be learned about eel exploitation in early New Zealand, but the signs so far suggest that mass harvesting of large eels was a very late phenomenon.

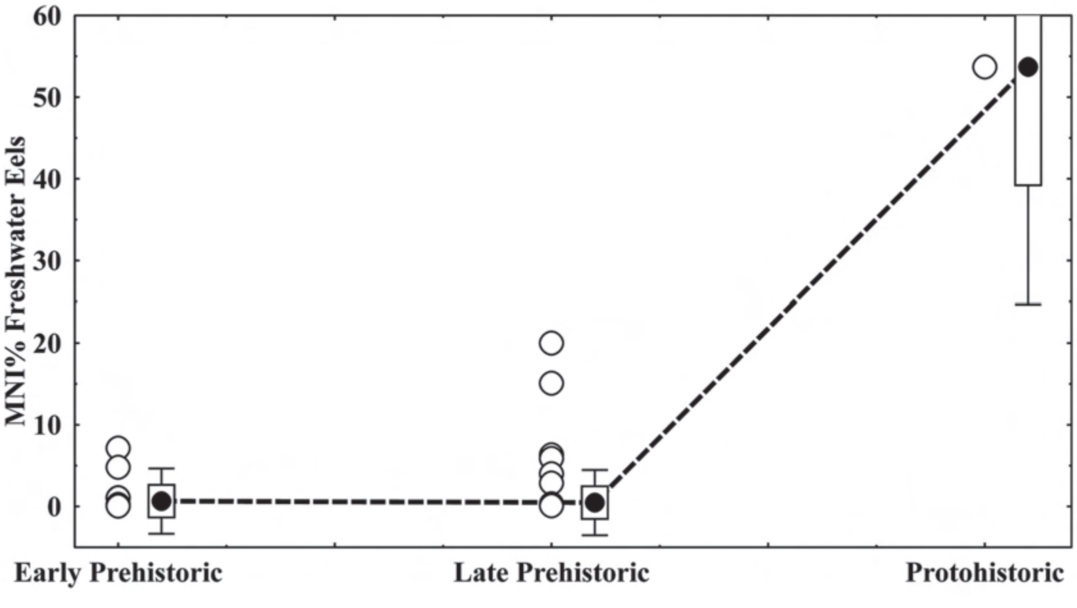

Figure 7.8: Eel bones are found in very few New Zealand archaeological sites, occurring in only 20 of 126 sites studied. There appears to be an increase in exploitation of eels over time.

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

LOCAL CHANGES IN CATCH COMPOSITION

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

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

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

Long Beach

This site is immediately north of Dunedin, just outside the entrance to Otago Harbour. It is a long bay showing seaward shoreline development. Older archaeological deposits are found at the rear of the present beach and sand dune formation. In one area a site was located and excavated which had

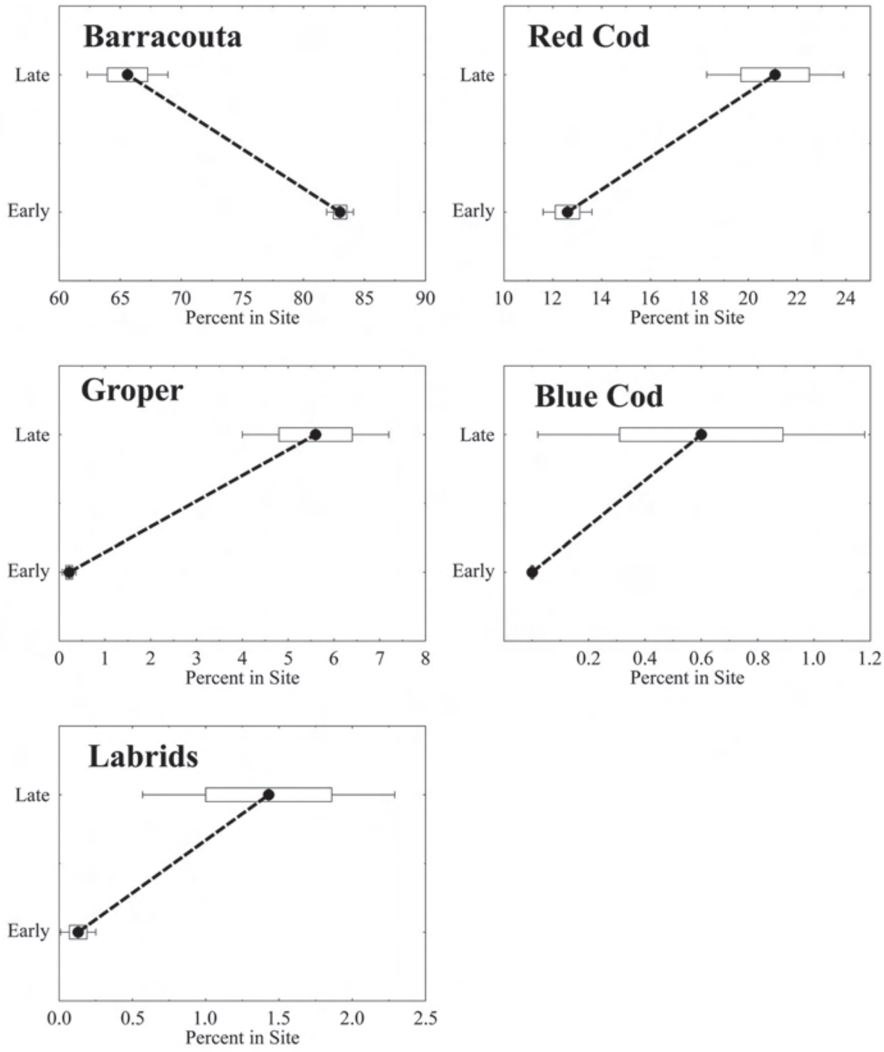

Figure 7.9: Changes over time in relative abundance of five fish types at Long Beach, Otago. All changes are significant at 95% confidence limits.

been occupied both early and late in the sequence. It is not suggested that there was continuous occupation, but cultural debris from lower layers had clear Archaic affinities and Classic Māori artefacts were present in upper layers. Fish bone was abundant in all layers in the site, and has been studied in detail, first by Fyfe (1982), and later in the Archaeozoology Laboratory at the Museum of New Zealand (Leach and Boocock 1993).

Long Beach has the greatest amount of fish bone of any site so far excavated in New Zealand. Table 7.3 lists the remains securely dated to early and late contexts. This explains why the figures given in Appendix 1 are not quite the same as those presented here. The total MNI for the site was 5770, of which 5456 could reliably be allocated to a specific time period. Only seven other sites in New Zealand have produced fish MNI above 1,000 individuals: CHB, Chatham Islands, 4978; Waihora, Chatham Islands, 4197; Purakanui Inlet, Otago, 2745; Houhora, Northland, 2425; Shag River Mouth, Otago, 2134; Mana Island North, Cook Strait, 1206; and Breaksea Sound, Fiordland, 1153.

TABLE 7.3
Long Beach Fish MNI and Percentages

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

Eight types of fish are represented in the early period at Long Beach and nine in the late period. Only five of these are in any great abundance, showing that the people inhabiting this area were fairly specialised in their exploitation of marine fish. No freshwater eels are present, even though there is a swampy area inland of the site which is a favoured environment for eels. Some fish types show considerable change in relative abundance over time (Fig. 7.9). Barracouta shows a clear decline in importance. This is associated with a rise in red cod, groper, blue cod and labrids. The barracouta would have been taken by lure from canoes, and the lower abundance could be related to a decrease in opportunities to go to sea for this form of fishing. As discussed in Chapter 4, these fish move inshore during summer months in this area. Leach and Anderson (1979a) hypothesised that bad sea conditions later in the pre-European sequence led to greater focus on inshore species such as labrids. This may be the case at Long Beach, where there is a decrease in barracouta and an increase in labrids. These would have been taken off the rocky headlands on either side of Long Beach. It is interesting that groper is a significant component of fish catches later in the sequence. Groper are very poorly represented in the archaeological record throughout New Zealand; this is generally taken as an indication that deep water offshore fishing was not a common pursuit of pre-European Māori. Contrary to this view, groper could easily be caught off rocky headlands in the early historic period, before inshore resources generally were depleted by Europeans. The groper at Long Beach could well have been taken off the nearby rocky headlands rather than in deep offshore waters. The significant rise in the frequency of red cod can also be taken to indicate increased emphasis on fishing off the two adjacent headlands.

Shag River Mouth

The Shag River Mouth site, situated on the sand spit at the mouth of the Shag River in north Otago, is one of the best known archaeological sites in southern New Zealand. It was first excavated during the 1870s, during the controversy about the relationship between moa-hunter and Māori, and has been the scene of numerous subsequent investigations. Between 1987 and 1989 a series of excavations was carried out under the direction of Anderson, Allingham and Smith (Anderson *et al.* (eds) 1996). These centred in two main areas: a high dune towards the southern and landward end of the sand spit, and the northern and inner edge of the low-lying sand flat on the inner side of the dune, although extensive test pitting was carried out over much of the site. Cultural deposits were relatively shallow on the sand flat, but deep stratigraphy was encountered in the high dune, where seven distinct occupation layers were separated by layers of wind-blown sand.

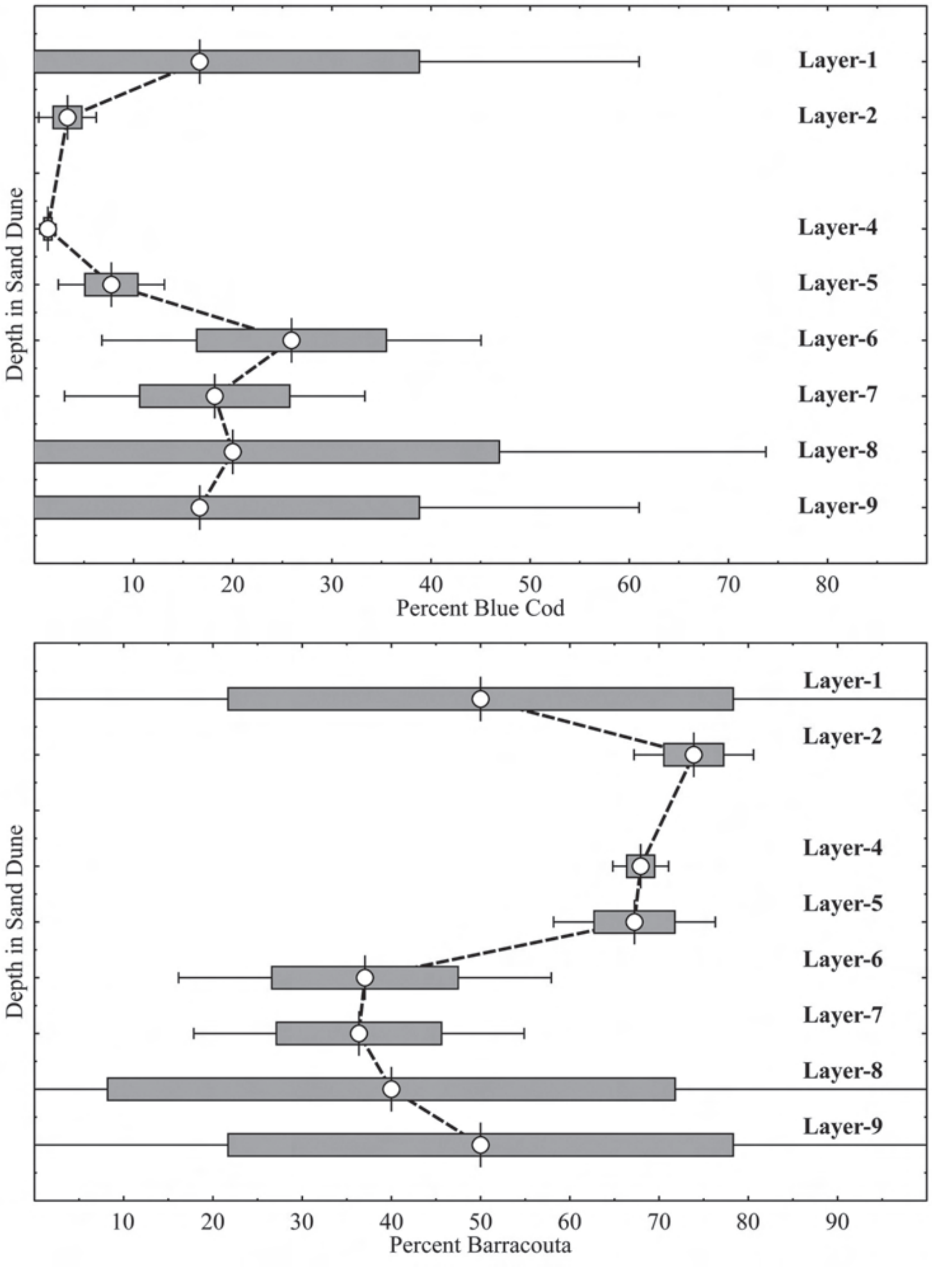

Figure 7.10: Changes over time in relative abundance of blue cod and barracouta at Shag River Mouth, Otago.

Table 7.4 shows the relative abundance of fish families in the total catch from the dune excavation. A wider range of families is represented than at Long Beach, and several families besides barracouta and red cod were making a reasonable contribution to the catch. Even so, barracouta still dominate, at a level comparable to that in the late catch at Long Beach.

In spite of the apparently very short duration of settlement at this site, there are 10 intact stratigraphic layers in the excavated area known as SM/C: Dune. This provides an excellent opportunity to observe short term variability in catches. It needs to be noted that Layer 1 consisted of clean wind-deposited sand. Sparse weathered cultural material was recovered from two stained sand lenses within it, well above the main midden deposit (Anderson and Allingham 1996: 40). It is therefore a moot point whether Layer 1 should be included when examining the time series.

Anderson and Smith suggest that there was a change in fishing strategy from a primary focus on baited hooks over rocky ground and reefs towards deliberate targeting of pelagic schools, notably barracouta (Anderson and Smith 1996b: 244). The former strategy is particularly evident in the catches of blue cod, wrasse and trumpeter. When the relative abundance of barracouta and blue cod is examined along with their standard errors (Fig. 7.10) the supposed changes are not so easy to confirm. However, there certainly does seem to be a shift at Layer 5, continuing to Layer 2. Given the short-term nature of occupation at the site and the strong inshore movement of barracouta in Otago waters over summer, this stratigraphic sequence of changing dominance of barracouta could represent seasonal changes.

TABLE 7.4
Fish MNI at Shag River Mouth, Dune Excavation
(all provenances combined)

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

Black Rocks

Black Rocks is a headland near Cape Palliser in the southernmost part of the North Island. The area consists of a sandy flat below steep cliffs. Large rocks extend out to sea for about 300 m. This rocky promontory has dense seaweed in places and is rich in marine food. There are a number of middens scattered over the flat, four of which were excavated by Anderson (1973, 1979). Three yielded quantities of fish bone. The MNI and percentages are provided in Table 7.5, after figures for elasmobranchs and unidentified teleostomi were extracted. There are no signs of permanent habitation on Black Rocks Point itself, and the middens are believed to be specialised food processing camps occupied by people from one of the nearby valleys where villages were located.

As with Long Beach, some notable trends through time can be detected in these figures. The three sites form a chronological sequence, established by a combination of radiocarbon and conchiolin dating (Anderson 1973: Fig. 19). The latter technique examines the amount of residual conchiolin in protein-rich shellfish species as a guide to their relative age. BR3 (the Black Midden) is the earliest site, closely followed by BR4 (the Crescent Midden). BR2 (the Pond Midden) is considerably later. The first two sites are Archaic in cultural affiliations; the Pond Midden dates to the period of Classic Māori culture. Figure 7.11 shows the changing proportions of four fish types over time. Not all the observed changes have such clear statistical significance as at Long Beach, but they are interesting nevertheless. The contributions of both labrids and snapper to the fish catch appear to decline, while blue cod and greenbone rise in importance.

TABLE 7.5
Black Rocks Fish MNI and Percentages

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

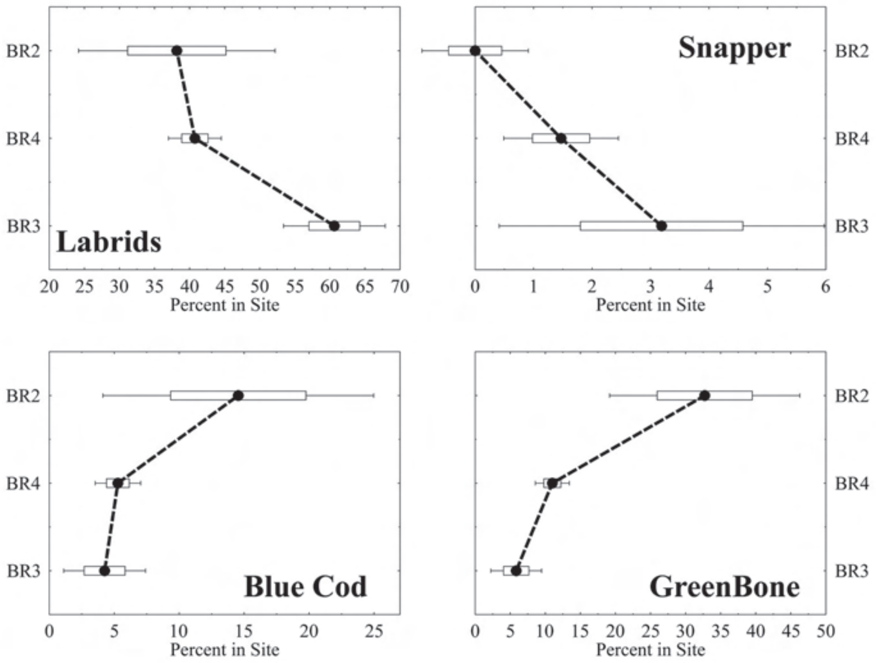

Figure 7.11: The changing character of fish catches at Black Rocks, Palliser Bay. There are signs here that labrids and snapper declined over time, and that blue cod and greenbone increased in importance. The 65% and 95% confidence limits are shown. Not all changes are statistically significant.

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

Washpool

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

The site contained several stratigraphic layers. Midden had been deposited regularly over a considerable length of time, spanning most of the pre-European period. The layers are grouped into three periods. Fish remains belonging to 20 families were present, with a combined MNI of 698 (Leach 1979a). The relative abundance of the catch at different periods is presented in Table 7.6 and illustrated in Fig. 7.12, in which only the first 15 families are shown. Apart from some minor fluctuations, the catches show remarkable uniformity over a very long period, although the catch pattern is significantly different statistically between Levels I and II (Leach 1979a: 121). The figures for labrids and tarakihi appear to show a change in relative dominance from Level I to Level II, and then back again at Level III. However, these changes by themselves are not numerically significant. Two factors probably combine to explain this uniformity in catch. One is that a large open beach area of the kind where the Washpool site is located would have experienced little or no impact from the small resident population, believed to be about 30 people (B.F. Leach and H.M. Leach 1979: 266). The second is that, unlike Black Rocks, this area does seem to have been permanently settled. Any seasonal changes in abundance would therefore be smoothed over by the continuous dumping of midden over long periods. The long period of build-up at this site is confirmed by Archaic artefacts in early levels and late radiocarbon dates for upper levels.

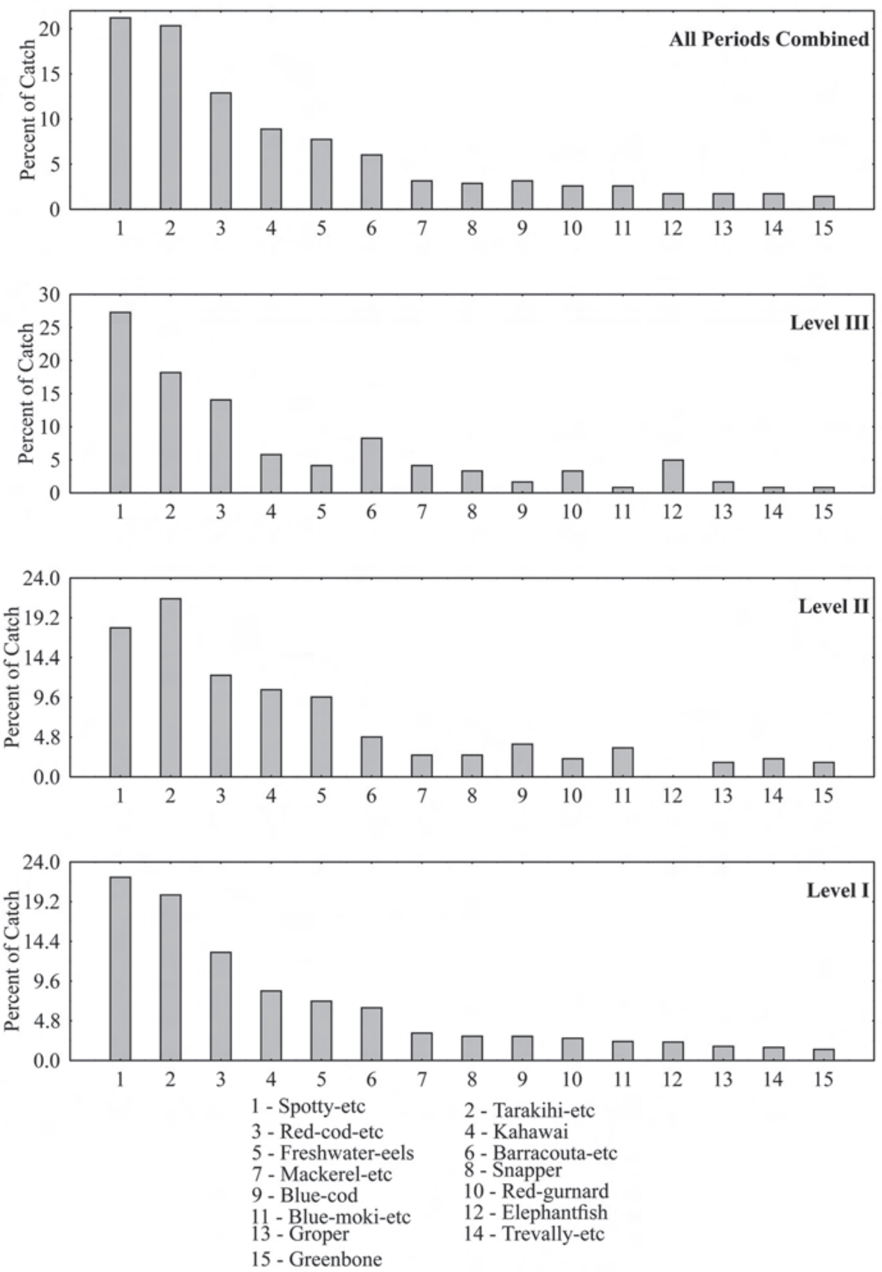

Figure 7.12: Fish catches from three different time periods at the Washpool Site, Palliser Bay. This illustrates considerable uniformity over a long period, but with some small changes between Levels I and II.

When the different fish types are grouped into those which are more easily taken in shallow inshore waters and those which probably required baited long line fishing from a canoe offshore (Fig. 7.12) a modest change over time can be seen in favour of inshore activities (Leach 1979a: 122). This fits well with the pattern of environmental changes which have been reconstructed for Palliser Bay. It is suggested that generally stable conditions there gave way to poorer weather later in the pre-European sequence, which would have made canoe-based fishing more difficult.

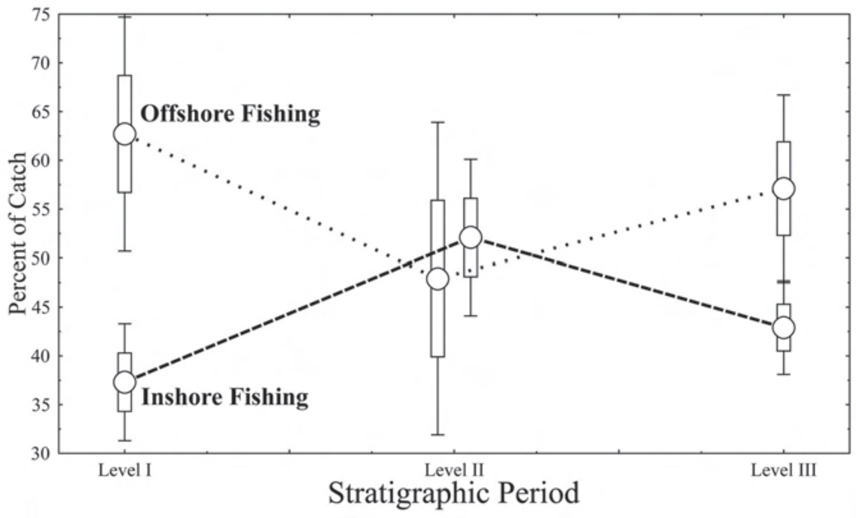

Figure 7.13: The balance between fish types taken inshore and offshore at the Washpool Site shows some tendency to change over time.

TABLE 7.6
Washpool Fish MNI and Percentages

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

Mana Island

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

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

Excavations were carried out in two parts of the beach ridge (Horwood 1991) and fish remains were abundant in both (Horwood *et al.* 1998). The larger northern excavation contained a relatively deep stratified deposit. The layers can be grouped as upper (predominantly or entirely an historically documented occupation by a group of Ngāti Toa in the first half of the nineteenth century) and lower, a considerably earlier pre-European occupation. The southern excavation contains material dating to the same period as the early horizons in the northern excavation and the two have been combined for the purpose of the present study. When the relative abundance of fish types is calculated (Table 7.7) and plotted out (Figs 7.14, 7.15) a surprising amount of change is revealed.

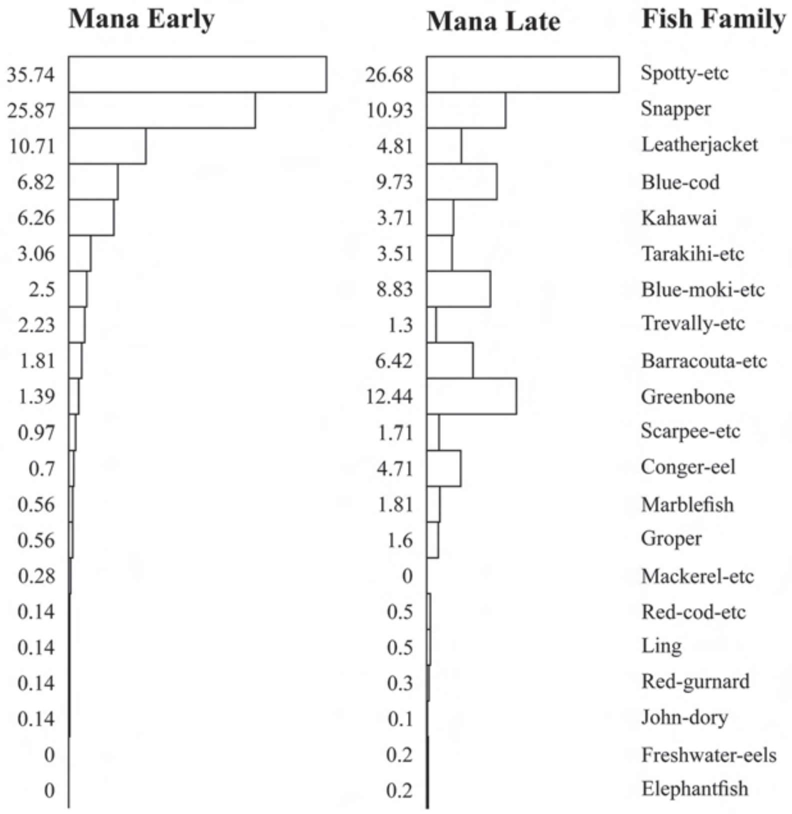

Figure 7.14: Changing relative abundance of fish types at Mana Island over time.

TABLE 7.7
Mana Island Fish MNI and Percentages

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

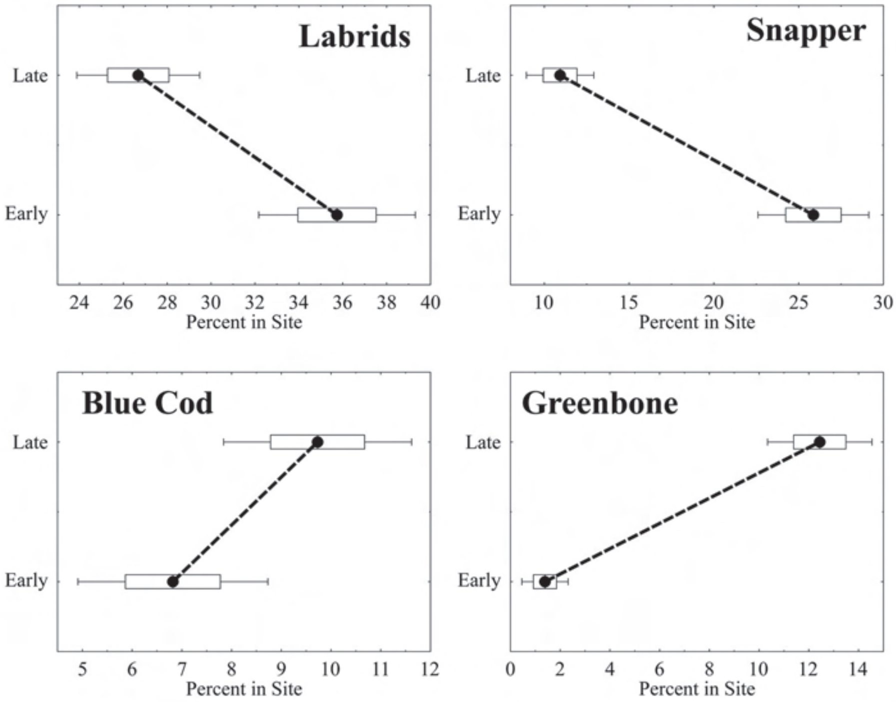

Figure 7.15: There are substantial changes in the abundance of several fish types at Mana Island over time. Labrids and snapper decrease while blue cod and greenbone increase.

The pattern of change evident in Fig. 7.14 contrasts sharply with that at the Washpool (Fig. 7.12), which showed considerable continuity. There is a far wider range of fishing opportunities at Mana Island than at the Washpool, and it is possible that some of this observed change reflects experimentation and the development of new or improved fishing skills over time. In Fig. 7.15, four fish types are singled out to illustrate the extent of change indicated at Mana Island. Labrids decrease in abundance from 36% of the catch during the early occupation of the Island to 27% in the nineteenth century. Snapper also decrease significantly from 26% to 11%. By contrast, blue cod and greenbone increase, the latter from 2% to 12%. The pattern in Fig. 7.15 is exactly the same as was observed at Black Rocks (Fig. 7.11). These two sites are both near rocky broken ground on the northern edge of Cook Strait, and the strikingly similar patterns at the two sites must be significant. The changes illustrated in Fig. 7.15 are not the only ones which are notable. Blue moki increases significantly from 3% to 9% over the same period.

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

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

Finally, right at the bottom of Fig. 7.14 is a small blip representing freshwater eels. None are present in the early period, but in the late part of the occupation there is an MNI of 2.

Kokohuia

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

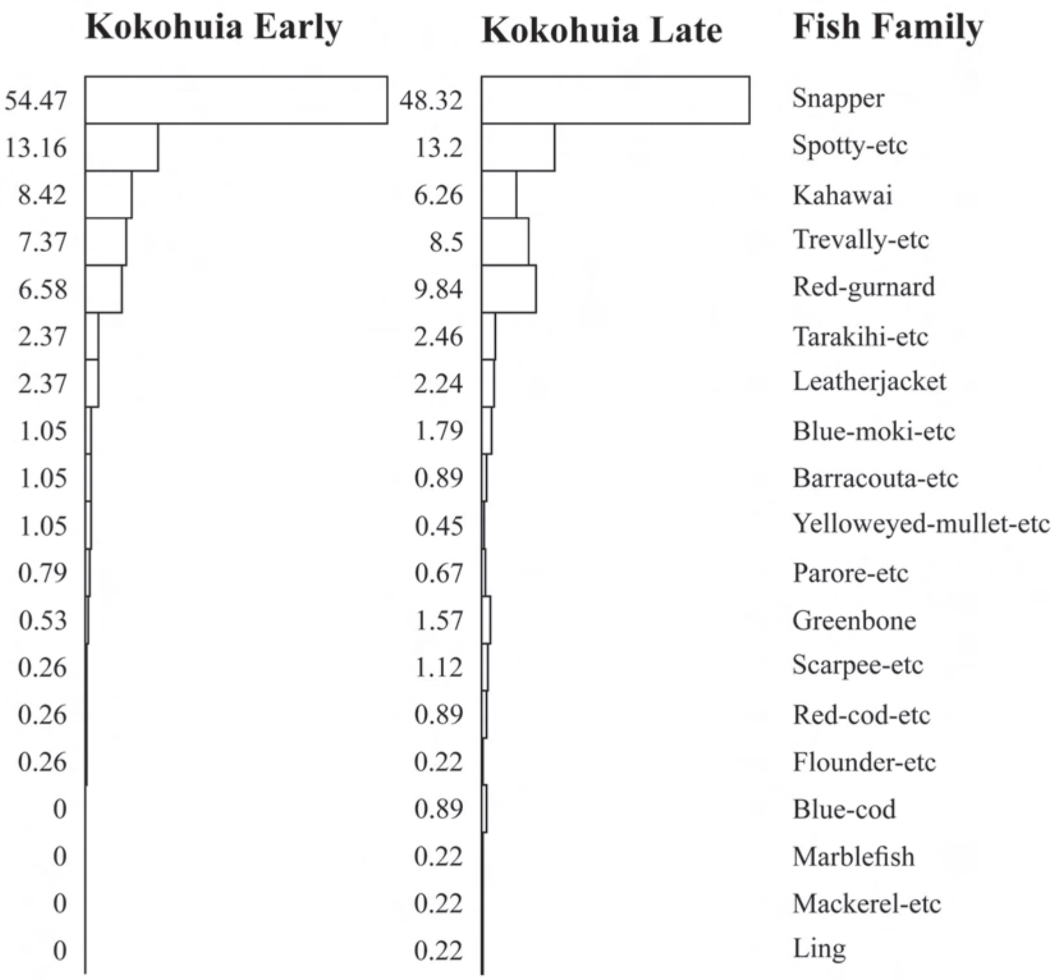

Figure 7.16: The relative abundance of fish types at Kokohuia shows very little change over time.

occupation. How far apart these are in time is disputed. However, the two stratigraphic units provide a useful series with which to investigate any change.

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

Changes in relative abundance (Table 7.8) are plotted out in Figures 7.16 and 7.17. Figure 7.16 shows that the fish catches at the two periods are very similar. The most abundant fish by far is snapper, followed by labrids and kahawai. Statistical testing of the two series reveals only three fish types which might show changes (Fig. 7.17). These are significant at one standard error, but not two. Gurnard appears to increase somewhat, along with blue cod, and snapper may have fallen in abundance.

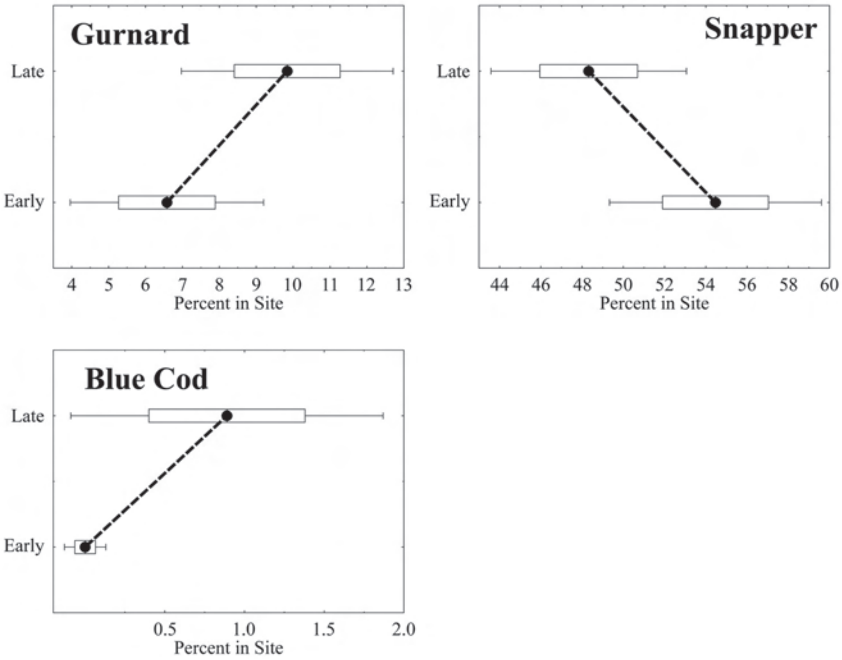

Figure 7.17: There are only three probable changes in the abundance of fish types at Kokohuia. These are significant at one but not two standard errors.

TABLE 7.8
Kokohuia Fish MNI and Percentages

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

Discussion

In this section I have examined the possibility that careful study of individual archaeological sites, or of several sites which show that there has been occupation in the same locality over a sustained period of time, might reveal changes in fish catch abundances. Few such sites exist, because of the mobile nature of pre-European Māori society; however, where they do, we have been able to see some interesting changes through time. I have summarised these in Table 7.9 and Figure 7.18. It must be remembered that these patterns arise from only a few sites which could be examined in this way, and the patterns may include important seasonal effects, which are difficult to factor out.

TABLE 7.9
Rise and Fall in Abundance of Fish at Different Archaeological Sites

The Nett value in the right hand column is calculated from the Table giving +2 or -2 for rises or falls which have 95% confidence, and +1 or -1 for rises or falls with 68% confidence.

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

Species	**Rise 95%**	**Rise 68%**	**Fall 95%**	**Fall 68%**	**Nett Rise-Fall**
Greenbone	BR32,BR2,MI	BR34	-	-	7
Blue cod	LB	BR42,MI,KO	-	-	5
Groper	LB	MI	-	-	3
Elephantfish	WP12	WP13,MI	-	WP23	3
Conger eel	MI	-	-	-	2
Blue moki	MI	LB	-	WP12	2
Black cod	-	LB,BR32	-	-	2
Trevally	-	BR34	-	-	1
Scarpee	BR34	-	-	BR42	1
Red gurnard	-	KO	-	-	1
Marblefish	-	MI	-	-	1
Freshwater eels	-	WP23,MI	-	WP12	1
Barracouta	BR34,MI	-	LB	BR42	1
Hoki	-	BR34	-	BR42	0
Red cod	LB	-	BR42	BR32	-1
Mackerel	-	-	-	MI	-1
Ling	-	-	-	BR34	-1
Leatherjacket	-	-	MI	-	-2
Tarakihi	-	BR34	BR32,BR42	-	-3
Labrids	LB	WP12	BR34,BR32,MI	-	-3
Snapper	-	-	MI	BR32,BR42,KO	-5
Kahawai	-	-	BR32,BR42	BR34,WP12,MI	-7

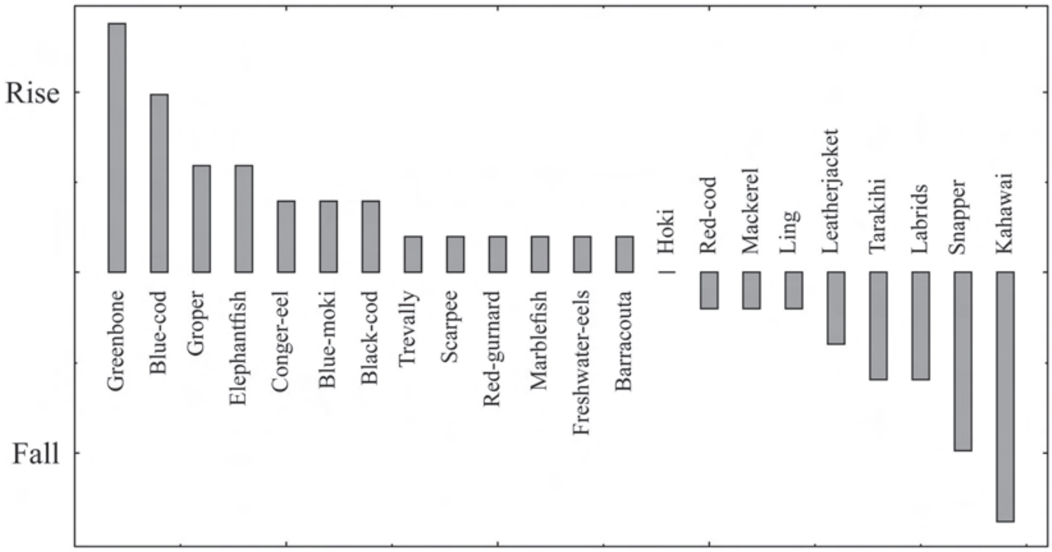

Figure 7.18: Fish types on the left hand side have risen in abundance over the pre-European period in New Zealand, while those on the right hand side have fallen. These patterns are observed in the few sites which have evidence of sustained or periodic occupation of one locality.

Greenbone stands out as one fish which has increased in importance over time, at least in the Cook Strait area. This could well be a result of discovering effective means of capturing these fish. As mentioned above, the custom of gill-netting appears not to have been employed in the Pacific, possibly because of the extreme clarity of water in the tropics. The use of drag nets does have a respectable antiquity in the Pacific, and by the time of European contact in New Zealand was a spectacular activity. However, these types of nets cannot be used in weed-infested rocky areas where greenbone live. It is therefore possible that gill-nets were developed in New Zealand somewhat later in the sequence. If this is so, it would also account for the apparent rise in importance of blue moki over time. These fish inhabit similar areas to greenbone and are difficult to catch on a baited hook. A few of these types of fish can be caught with hoop nets dragged slowly through weed, which is the technique Buck described for capturing marblefish (Buck 1926).

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

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

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

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

LOCAL CHANGES IN FISH SIZE

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

For New Zealand, to my knowledge there were no published size frequency histograms from archaeological sites for any species in a time sequence until 1994 (Leach and Boocock 1994), and this research actually showed an increase in mean size. It is not a simple matter to arrive at a trustworthy size frequency diagram of a prehistoric catch, but the background research on modern comparative material has now been completed for a few of the more common species in New Zealand (Table 7.10). This section draws upon this work to examine the possibility that there were significant changes over time in New Zealand.

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

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

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

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

TABLE 7.10
Fish Species whose Bones have been Studied Allometrically
for Live Length and Weight estimates

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

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

Barracouta

Among the 35 families of fish which occur in New Zealand archaeological sites, there are very few species which might be adversely affected by intensive pre-European fishing. Of the species which are most abundant in archaeological sites, barracouta is not likely to have been much affected by the advent of Polynesians. As discussed in Chapter 4, barracouta is highly seasonal in its appearance in inshore shallow waters. Adults appear, in the south-eastern regions at least, during the summer to autumn months, and during winter to spring months in western parts of Foveaux Strait and along both east and west coasts north of about Banks Peninsula to nearly the top of the North Island (Fig. 3.11). The current estimates (Annala 1994: 33–34) of MCY (Maximum Constant Yield) for barracouta are (tonne per annum):

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

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

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

The large number of measurements available meant that variations in estimates of fork length based on different parts of the anatomy could be investigated, and this was explored by Leach *et al.* (1999b) and Leach and Davidson (2001a). It was found that the spread of mean values in fork length, derived from different parts of the anatomy and from both whole and broken bones, is about 20 mm overall. This must be seen in perspective. The mean and standard deviation of the fork length of the Long Beach barracouta catch as a whole are 795 mm and 51 mm (Table 7.11). The variation observed amongst these different parts of the anatomy is therefore less than 3% of the mean, and less than half of the standard deviation.

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

There are several interesting features about the fish sizes at these two sites. Both archaeological catches show a strong dominance of very large and therefore old fishes. These catches can be compared with modern trawl data from southern New Zealand and the Chatham Islands (Fig. 7.19). The modal peaks in both early and late archaeological periods are well above the largest modal peaks for Chatham Island surveys, and similar to the largest peak in Southern New Zealand surveys. Unfortunately, we do not have any information on the size frequency distribution of the fish that migrate to inshore shallow waters today for comparison with the pre-European data[3]. However, on the strength of what is presented here, it would appear that very old individuals were being preferentially caught. It is not easy to decide whether this is because these were the only fish available for catching, or whether the technique for capturing the fish favoured only the largest individuals.

At Long Beach, two significant changes can be detected over time. The mean fork length decreased by 20 mm, and the standard deviation increased by 15.3 mm. The absolute size of these changes may not appear large, but they are both highly significant statistically. A broader range of somewhat

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

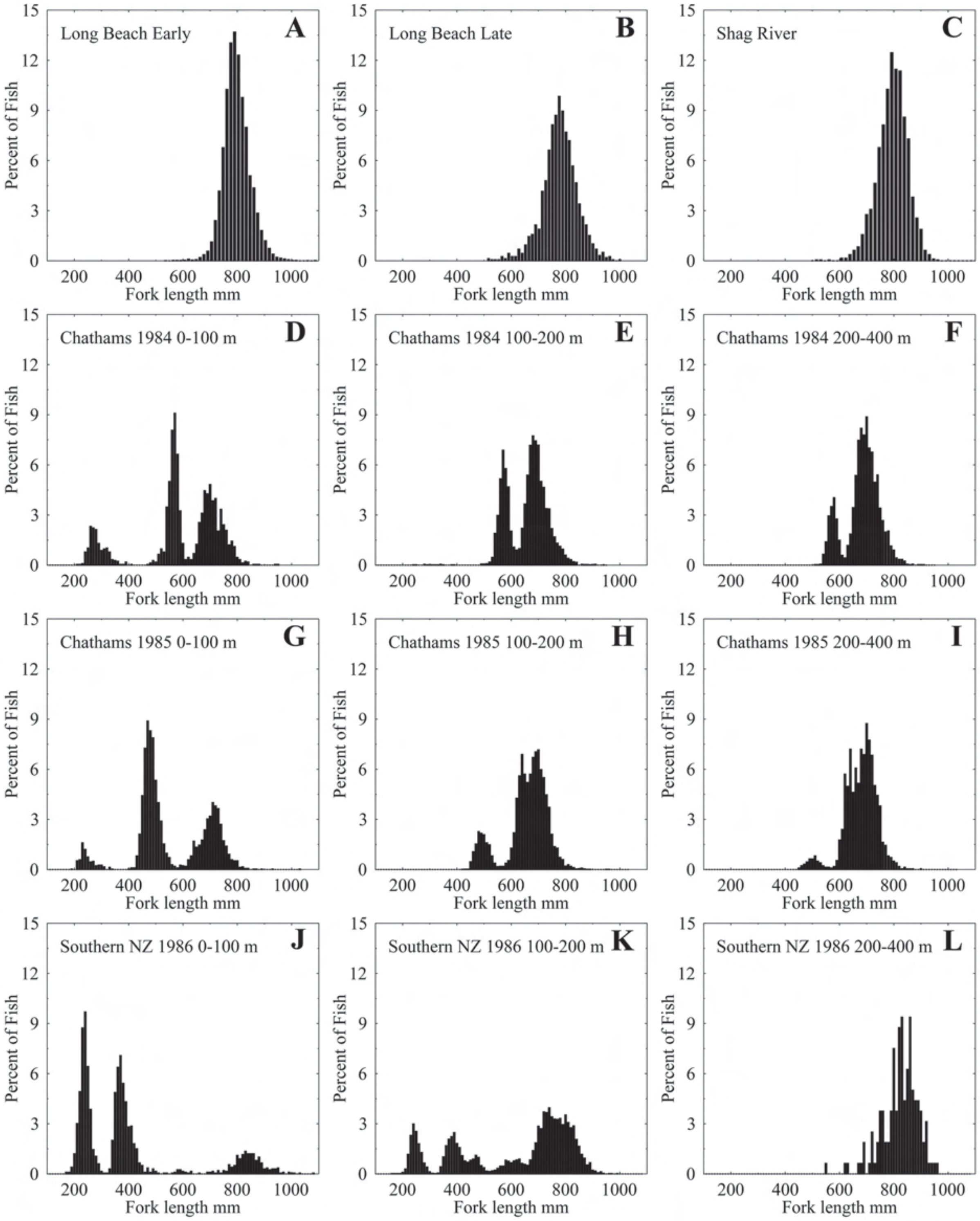

Figure 7.19: Pre-European barracouta catches compared with modern trawl data for the species.

smaller fish were being caught later in time. In view of the very large maximum constant yield for this species, it is hard to imagine that pre-European catches could have been responsible for this lowering in the mean size over time[4]. It is much more likely that we are observing a natural biological change over the period involved. Fluctuation in growth rate, caused by changes in sea water temperature, is a possible reason. This could be confirmed by aging and carrying out $^{16}O/^{18}O$ analysis on otoliths. Unfortunately, otoliths from barracouta are often unreadable for aging, as many as 59% being rejected from individuals over 80 cm (Hurst and Bagley 1987: 20).

TABLE 7.11
Fork Lengths of Archaeological Barracouta

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

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

The figures for mean fork length in the various layers in the dune at Shag River Mouth are plotted in Figure 7.20 (from Table 7.11). Although the standard errors are large and there is considerable overlap, there seems to be a trend towards decreasing size over time. It is very difficult to know how to interpret this. The apparent trend could be entirely due to chance, given the large size of the standard errors. However, it is certainly intriguing.

In the case of Long Beach, there is no such ambiguity — here the barracouta mean size decreases by 20 mm (Table 7.11) and is highly significant (Student's t = 11.89 with 14,841 degrees of freedom). Moreover, the standard deviation increases by 15.3 mm over time. This is again highly significant (standard error = 1.1 mm).

Barracouta grow very quickly for the first few years of their life, so it is possible to determine their age from fork length with reasonable accuracy. Hurst and Bagley (1987: 20) provide suitable mean and standard deviation figures, and those for ages three to ten years are plotted out over the top of the size-frequency diagrams of the Long Beach and Shag River barracouta fish catches in Figure 7.21 (left). It is clear from this that the fish being captured were all relatively old individuals. This is also apparent in Figure 7.19, where the modern research trawl data are shown.

It is possible to decompose a size-frequency diagram where there is a mixture of age components like this. A considerable amount has been published on the subject (Everitt and Hand 1981;

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

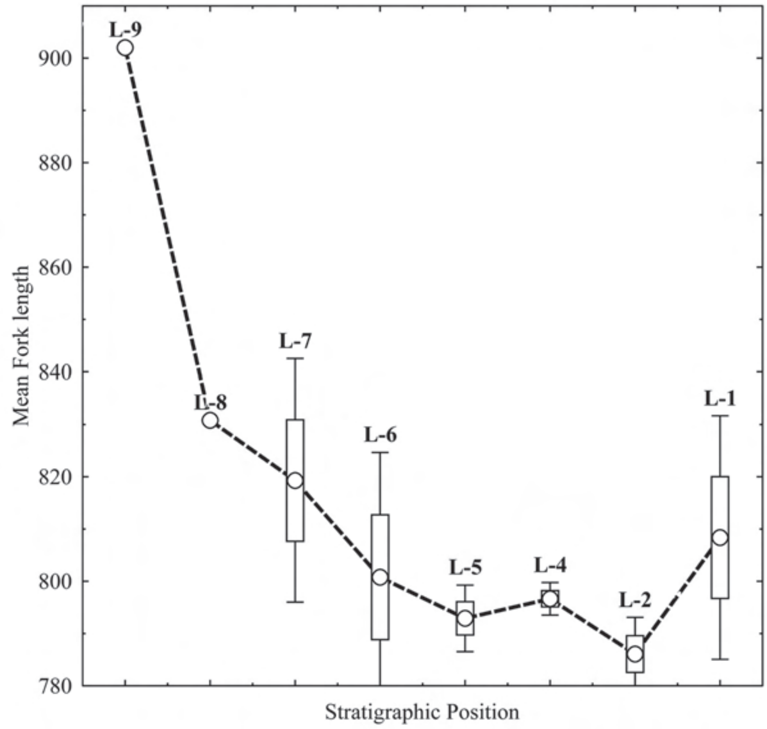

Figure 7.20: The mean fork length of barracouta catches from different stratigraphic layers in the sand dune sequence at Shag River Mouth. There are signs of decreasing size over time, but establishing statistical significance is made difficult by small sample size for some layers.

Macdonald 1987; Macdonald and Pitcher 1979; McLachlan and Basford 1988; Schnute and Fournier 1980; Titterington *et al.* 1985). Peter Macdonald at McMaster University in Canada has developed an algorithm which is now widely used for separating age grades of fish from trawl catch data. By using the MIX software iteratively until the χ^2 value is lowest, indicating the best fit, the proportions of the different age grades in the barracouta catches may be estimated. I used the MIX program (version 3.0) to separate out the age components in the catch diagram from Long Beach (early and late assemblages) and Shag River Mouth. The results are provided in Table 7.12 and Figure 7.21 (right).

TABLE 7.12
Percentage Age Composition of Archaeological Barracouta

Age in Years	**Long Beach Early**	**Long Beach Late**	**Shag River Mouth**
3	0.1	1.5	0.3
4	0.4	5.4	1.2
5	1.0	4.8	6.7
6	4.7	28.8	0.7
7	46.8	14.7	0.0†
8	31.8	30.9	95.2
9	14.1	14.9	1.7
10	1.1	0.0†	0.0†
Totals	**100.0**	**101.0**	**105.8**

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

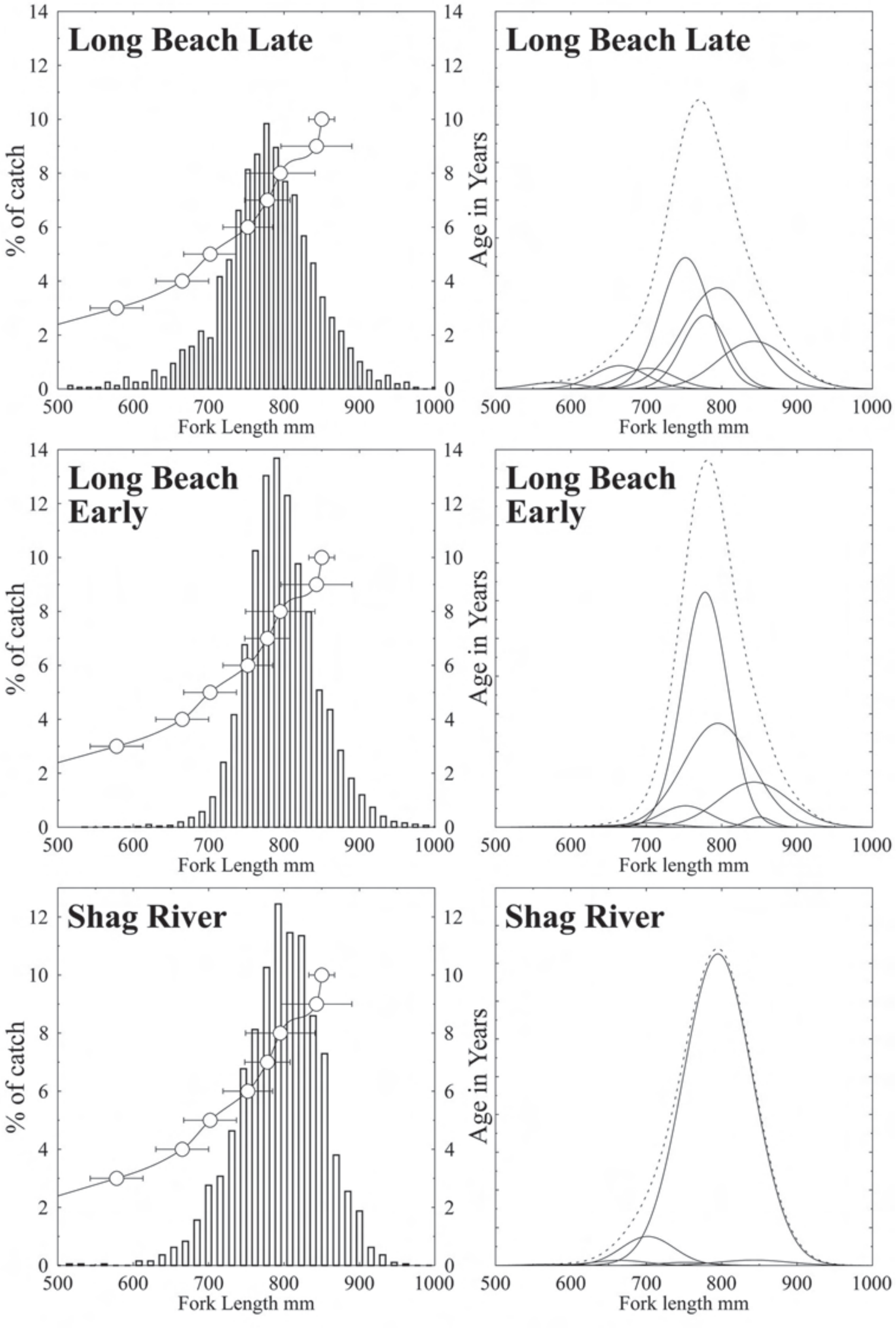

Figure 7.21: Size-frequency diagrams of barracouta catches at Long Beach and Shag River Mouth. Left: The modern age/length growth curve of barracouta is superimposed on each catch diagram. Right: Each catch is decomposed into its constituent age grades. The late catch from Long Beach shows a more even mix of fishes of four ages, whereas the earlier catches at both Long Beach and Shag River Mouth show much greater dominance of one age grade, with only one or two other ages in the mix. This is particularly marked at Shag River Mouth.

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

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

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

Snapper

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

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

Although snapper occurs in great abundance in many North Island sites, there are so far only four sites in which it is possible to investigate size changes through time. These are Kokohuia in Northland, Mana Island and Foxton near Wellington, and Rotokura in Tasman Bay. The statistical information about the various catches is provided in Table 7.13 and size-frequency diagrams in Figure 7.22.

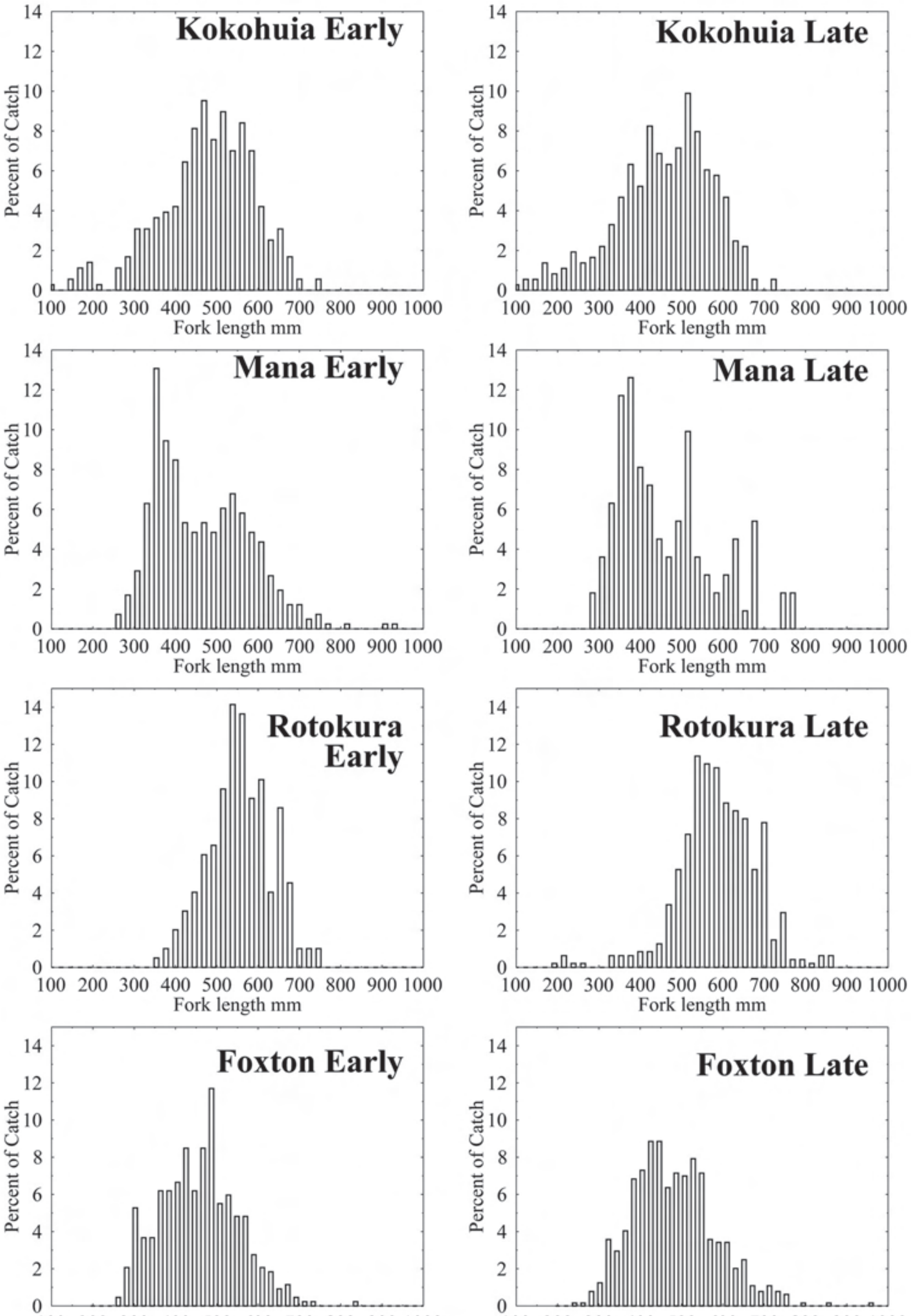

Figure 7.22: Pre-European Snapper catches from four archaeological sites where change through time can be explored. Rotokura from Leach and Boocock 1994: 77; Foxton from Davidson *et al*. 2001: 84.

TABLE 7.13
Pre-European Snapper Fork Length mm at Several Sites

Kokohuia		**Early**			**Late**	
N		357			364	
Range	102	to	756	106	to	734
Mean	476.5	±	6.0	457.9	±	6.2
SD	113.2	±	4.2	117.5	±	4.4
g1/w1	-0.6	and	5.9	-0.5	and	5.8
g2/w2	3.4	and	1.7	3.1	and	0.3

Mana Island		**Early**			**Late**	
N		413			111	
Range	266	to	939	285	to	777
Mean	463.9	±	5.6	463.3	±	11.4
SD	115.0	±	4.0	120.4	±	8.0
g1/w1	0.7	and	7.0	0.7	and	3.8
g2/w2	3.3	and	1.3	2.7	and	0.5

Foxton		**Early**			**Late**	
N		436			644	
Range	254	to	836	239	to	953
Mean	456.5	±	4.6	481.6	±	3.9
SD	96.1	±	3.2	101.4	±	2.8
g1/w1	0.3	and	4.7	0.5	and	7.8
g2/w2	3.0	and	0.1	3.5	and	3.0

Rotokura		**Early**			**Late**	
N		198			475	
Range	362	to	746	188.2	to	870.1
Mean	556.9	±	5.4	586.9	±	4.4
SD	76.5	±	3.8	97.7	±	3.1
g1/w1	-0.0	and	1.4	-0.5	and	6.4
g2/w2	2.7	and	0.5	5.0	and	9.1

At Kokohuia there is no significant difference between the earlier and later snapper catches. It will be recalled in the earlier discussion in this chapter that there was possible evidence for a slight fall in relative abundance of snapper at this site, and that this shadowed similar trends at Mana Island and Black Rocks. The time gap between the two stratigraphic horizons at Kokohuia may not be very great (Fig. 7.23), but Schmidt, who did the dating, believes it is significant, since it is based on pooling a large number of dates. Taylor, who excavated the site, believes the different phases of occupation were deposited close together in time. His opinion is based on the general similarity of occupation debris and structures in the site. Whatever is the case, as shown above, the types of fish caught and their relative abundances are very similar in the two stratigraphic horizons. Moreover, for the snapper catch in particular, the two size-frequency distributions are almost identical. Inspection of Fig. 7.22 and the data in Table 7.13 shows that the statistics for the two independent archaeological samples are remarkably similar. The two means, standard deviations, skewness and kurtosis statistics are all within one standard error of each other.

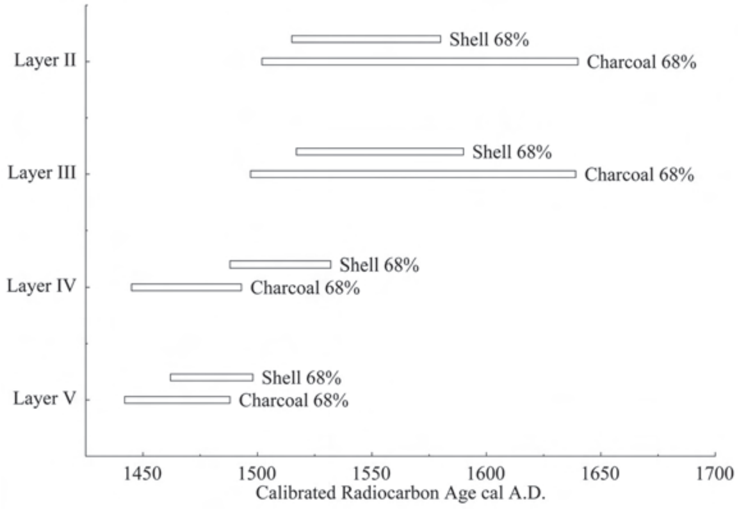

Figure 7.23: Pooled calibrated radiocarbon ages for Kokohuia. After Leach *et al*. 1997a: Fig. 4. Layers II and III are 'Late' and Layers IV and V are 'Early'.

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

It may be noticed in the size-frequency catch diagrams in Fig. 7.22 that some very small fish were being taken at Kokohuia. The smallest fish in the sample is only 102 mm fork length, and quite a few fish in both stratigraphic horizons are less than 300 mm fork length, in contrast to the other three sites, where such small fish were not taken. This may indicate that seine nets were being used in the Hokianga harbour for capturing snapper. In any event, there are no signs of bimodality in the Kokohuia catches. There is, however, statistically significant negative skewness in both the Kokohuia assemblages. Once again, this looks like evidence of seine netting. On the other hand, at Mana Island and Foxton, the distributions show significant positive skewness, clear evidence that small fish are not being taken. There are two possibilities — one is that any small fish captured were returned, and the other is that baited hooks were more frequently used and small fish were not being caught. As will be seen in Chapter 9, it is not a Polynesian custom to return small fish and pre-European Māori were no exception to this. The use of baited hooks is the preferred explanation.

At Mana Island, there are clear signs of bimodality in both early and late assemblages, with the two peaks at 350 and 540 mm in the early sample, and 360 and 515 mm in the second. As with

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

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

The last site to be considered which has two samples separated in time is at Rotokura in Tasman Bay. These are two very interesting catches. It can be seen in Fig. 7.22 that the early catch has a lot more fish in the left tail of the distribution than the later sample; that is, fish which are less than 500 mm. In addition, the later sample has a lot more fish in the right tail of the distribution; that is, fish greater than 600 mm fork length. These differences are manifest in the statistical data too (Table 7.13). The early sample has no significant skewness, but the later one has a small but highly significant negative skewness. This may at first glance appear to contradict the comment above that there are fewer smaller fish in this distribution, but this is not so. The non-normality arises precisely because there are too few smaller fish in the distribution. The left tail extends out further than in the earlier sample, but has fewer fish in it. The later sample also has a highly significant leptokurtic shape, whereas the earlier sample has normal kurtosis. Finally, the mean size is significantly greater in the later sample than the earlier one.

In this respect, the catches at Rotokura in Tasman Bay are somewhat unusual. The reason may lie in the nature of the Tasman Bay population of snapper itself. Tasman Bay is close to the southern limit of the distribution of snapper in New Zealand, and is well known amongst fishermen and fisheries scientists as having an unusual population. Snapper tend to be rather larger in these waters than further north. Another anomaly, which may be particularly important in the present discussion, is that the recruitment of year classes has been found to be highly irregular. This may be partly related to the generally cooler waters than further north. There is a tendency towards a patchy distribution of different sized snapper in Tasman Bay, and over periods of 50 years or more the population can get older with very little recruitment of younger individuals. This is especially likely if such a period coincides with slightly cooler conditions than normally prevail, such as in the Little Ice Age. As this older, larger population dies out, it will be replaced by a considerably smaller population. In such a way, it is easy to see that Tasman Bay can have dramatic shifts in mean fish

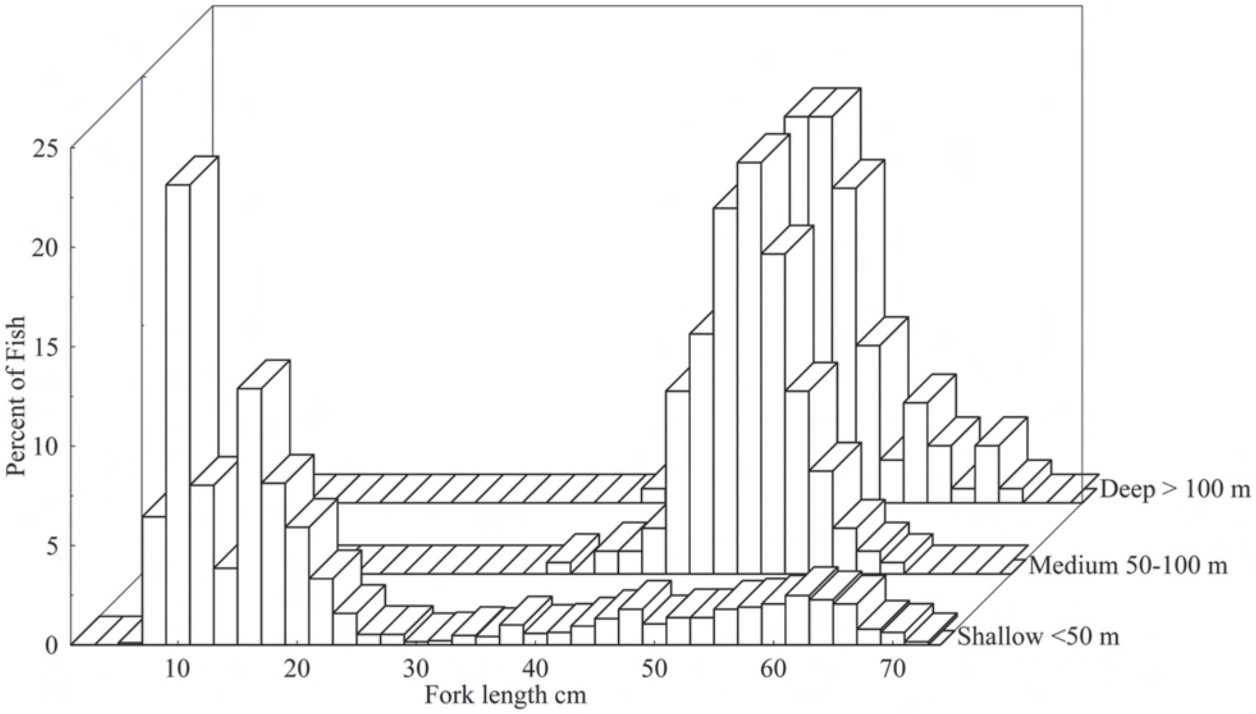

Figure 7.24: Modern snapper sizes in the vicinity of Tasman Bay from trawls in three depth ranges (after Leach and Boocock 1994: 76).

size over significant archaeological time. Such a phenomenon may not apply further north in New Zealand to the same extent.

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

Figure 7.24 presents size-frequency curves for modern Tasman Bay snapper, based on research trawls in different depths of water. It can be seen that there are abundant juveniles in shallow waters, but also larger individuals. In both medium and deep waters in the bay, the distributions are unimodal with mean fork lengths of 510 and 520 mm, increasing slightly with depth. The mean values for the archaeological samples are 557 and 587 mm, increasing later in time. Clearly, the pre-European people in this area were able to harvest snapper at the larger end of the modern distribution.

Blue Cod

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

Region	**tonne per annum**
BCO1: Auckland	15
BCO2: Central East	5
BC03: South East Coast	55
BC04: South East Chathams Rise	525
BCO5: Southland and Sub-Antarctic	565
BC07: Challenger	85
BC08: Central Egmont	40

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

Although live catch information has been reconstructed for this species from quite a few sites, sufficiently large samples have been more difficult to obtain. There are good samples from the two sites on Mana Island and especially important ones in the Chatham Islands (Table 7.14). However, there is an additional problem here in that radiocarbon dates do not reliably place the three sites in chronological order (Table 7.15). This is fundamental when considering change through time. There is no published information on the extent of any inbuilt age in the samples dated, and given their close proximity in time, this is a great disadvantage. Sutton (1980: 80) presents a case that all these sites in the Point Durham area of the Chatham Islands were part of one cultural system; that is, each site was a different specialised functional entity within the activities of one community. This implies that any differences between the dates for the sites is due to small statistical variation rather than representative of significant temporal difference. There is, however, an important difference between real and effective temporal contemporaneity. These sites could actually be 50 or 100 years apart in time and still effectively be part of the same functioning social system. If they are indeed 50 or 100 years apart, this is an important time gap when studying human impact on the local marine environment. Moreover, if they are exactly contemporary, then any differences between the catch data from the various sites, no matter how small or large, is of considerable interest because it may indicate partitioning of the catch according to social rank or other criteria. In short, precise dating of these sites, while it may not have been possible when the excavations were carried out, is of great interest now. It would be very useful to re-visit this problem in the future.

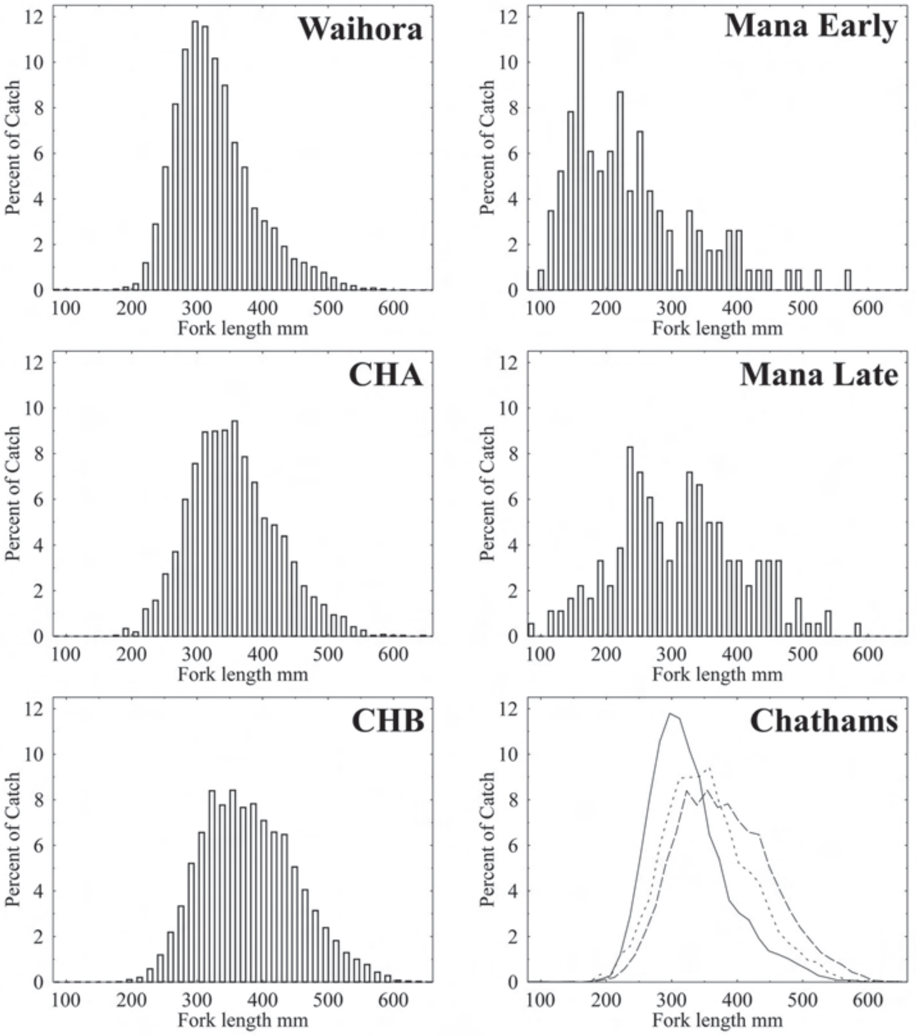

Figure 7.25: Pre-European blue cod catches from three sites in the Chatham Islands and two time periods on Mana Island. The catches from the Chatham Island sites are superimposed bottom right. After Leach *et al*. 2000b: 129.

TABLE 7.14
Pre-European Blue Cod Fork Lengths (in mm) at Several Sites

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

TABLE 7.15
Chatham Island Radiocarbon Dates (charcoal)
(From Sutton 1976 and Smith 1997: pers. comm.)

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

The fish bone assemblages from these sites in the Chatham Islands are very large, containing not only quantities of blue cod, but also of labrids and greenbone, and the sites show all the signs of being short duration settlements. They therefore offer an exceptional opportunity for detailed study. In the absence of fine control over chronology this possibility is frustrated to some extent, but it is still very useful to point out the characteristics of the assemblages. There are important differences in the dispersion characteristics of the blue cod assemblages from these three sites (Figs 7.25, 7.26, Table 7.14).

These three archaeological sites in the Chatham Islands are quite close to each other near Point Durham. Waihora is thought to be the central village of the site complex, and CHA and CHB are 780 m and 1140 m respectively from the main village. Waihora is closest to the coastline, the other

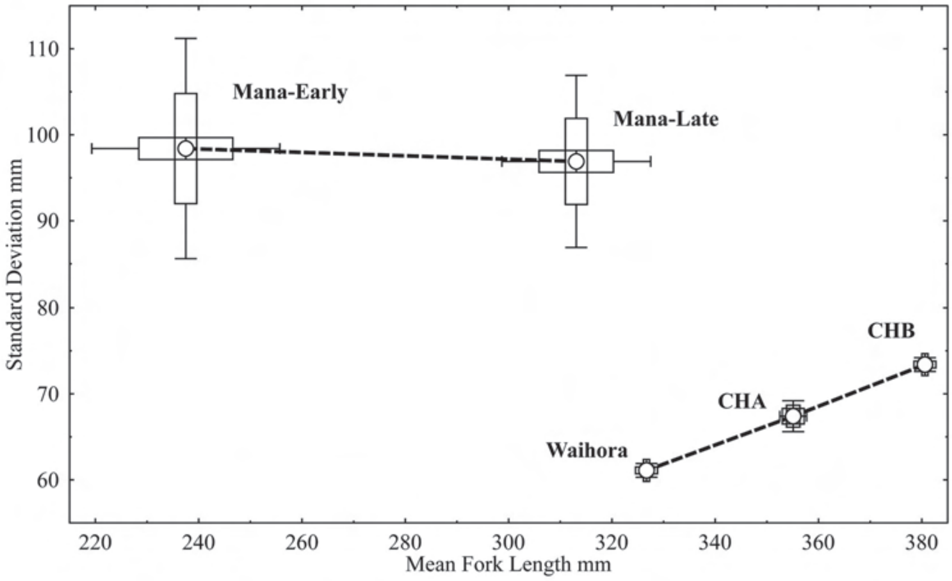

Figure 7.26: Time trends in dispersion characteristics of blue cod catches at Mana Island and three Chatham Island sites. From Leach *et al*. 2000b: 134 and Leach and Davidson 2001a: 155.

two sites being situated somewhat further inland. It will be readily observed in Table 7.14 that the mean fork length for blue cod is largest at CHB, followed by CHA, and smallest at Waihora. The differences are highly significant. The change in central tendency is clearly seen in Figure 7.25 and it will also be observed that the right hand shoulder (the largest fish) of the curves steadily diminishes from CHB to CHA to Waihora. This is illustrated in the bottom right of Figure 7.25, where the three curves are superimposed. This shape change is partly reflected in a uniform lowering of the standard deviation from one site to the other.

When these changes are plotted out in Figure 7.26, the trend in characteristics from one site to another is striking. It is tempting to think that this might follow a time series, but there is no concrete evidence for this.

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

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

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

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

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

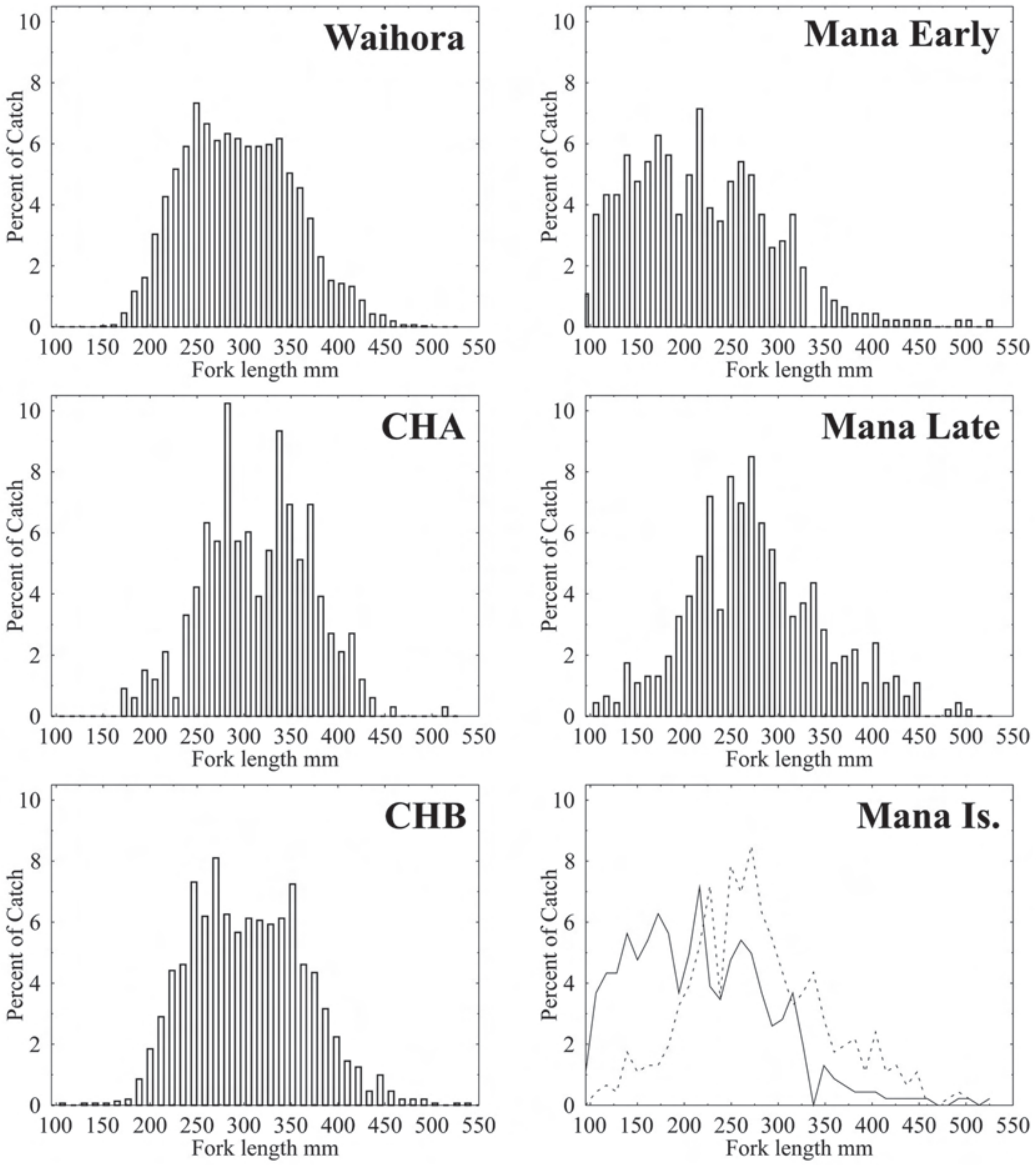

Figure 7.27: Pre-European labrid catches from three sites in the Chatham Islands and Mana Island. The two Mana Island sites are superimposed at bottom right. From Leach *et al*. 1999a: 124.

Labrids

These fish are very widespread throughout New Zealand, but are not sought after as food by modern Māori or Europeans. They are extremely easy to catch, and are often used as bait for catching other fish. Since they are not a species of any commercial interest there is no information on biomass or Maximum Constant Yield. This is a great pity because in some respects this fish is an excellent one for monitoring human environmental impact. It is argued by Leach and Anderson (1979a) that this species would be heavily exploited in times of food shortage and poor sea conditions when other species are hard to capture. Their presence therefore can be a useful guide to adverse environmental conditions. They live in shallow inshore waters where there is rock and weed, and can be taken with very small hooks, or with hoop nets amongst rough ground. There are several common species, which are very difficult to differentiate osteologically, and this may complicate analysis of size-frequency diagrams, because over time there may have been change in relative abundance of the different species taken, particularly if people were able to fish in somewhat deeper water where larger species are found. Pre-European catches have been reconstructed for a number of New Zealand and Chatham Islands sites in which there is some evidence of localised chronology. These sites have all been discussed previously. A selection of data on labrids is presented in Table 7.16 and Figures 7.27, 7.28, 7.29.

TABLE 7.16
Pre-European Labrid Fork Lengths (in mm) at Several Sites

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

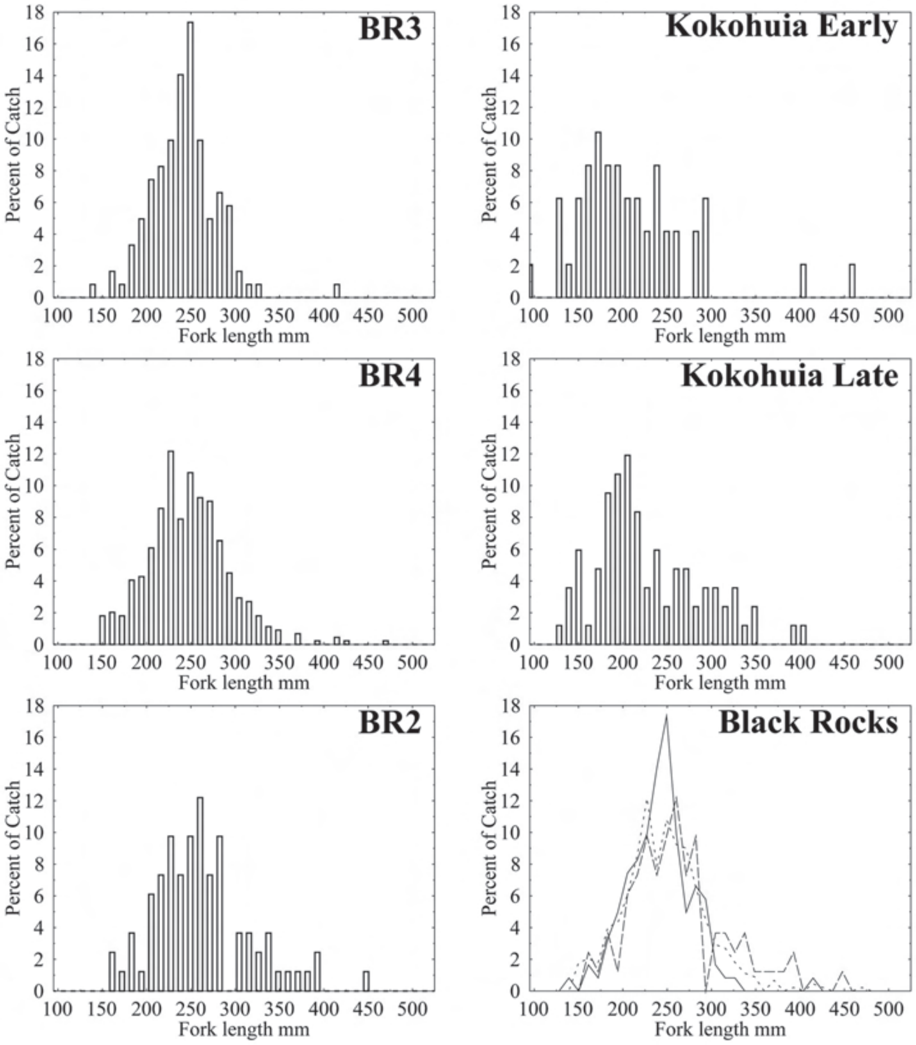

Figure 7.28: Pre-European labrid catches from Kokohuia and Black Rocks. The catches from the three sites at Black Rocks are superimposed at bottom right. From Leach *et al*. 1999a: 125.

There are signs here of the same phenomenon seen in blue cod, namely that early fish catches at a locality had more small fish than later catches, leading to an increase in mean size over time. This is very clearly seen in Fig. 7.27. The Mana Island Early fish catch has a large shoulder on the left hand side of the distribution, which has all but disappeared in the Mana Island late catch. This pattern is evident when the various assemblages are plotted out in Fig. 7.29. The Black Rocks assemblages are particularly interesting because the dating evidence for BR3 and BR4 indicates that they are very close together in time, although BR4 is slightly later. The BR2 site, however, is much later, and represents re-use of the area after a period of depopulation. It has been shown that during the interregnum at Black Rocks, shellfish regained their earlier size, but crayfish did not (Leach and Anderson 1979b). It would appear from Fig. 7.29 that labrids increased in mean size through time.

Finally, the two Kokohuia samples also appear to show an increase in mean labrid size over time, though small sample sizes result in overlap at two standard errors. In view of Taylor's opinion about continuity of occupation at this site, despite the radiocarbon dates, Kokohuia may be the best example in this study of human impact on a labrid population over a short period of time.

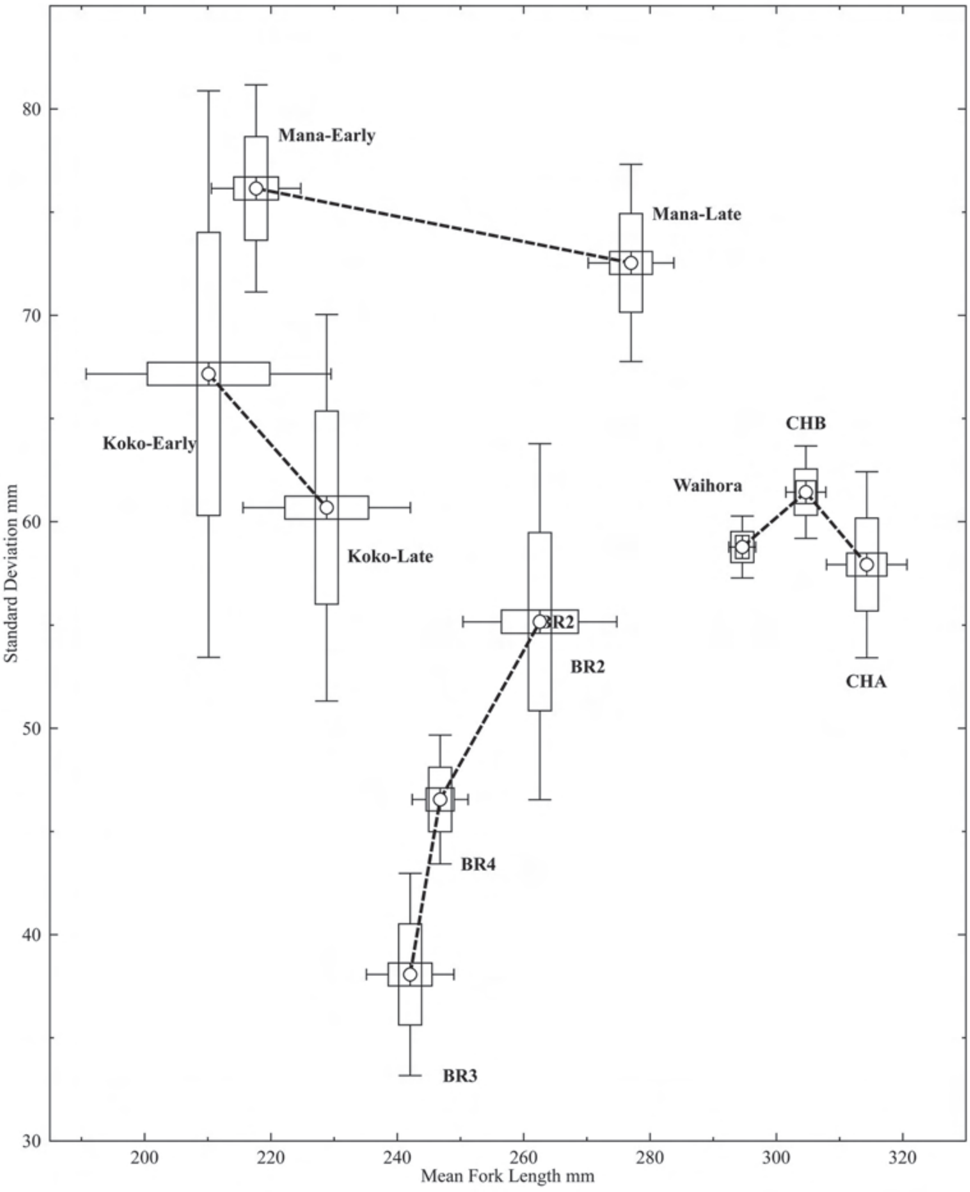

Figure 7.29: Time trends in dispersion characteristics of labrid catches in several archaeological sites. From Leach and Davidson 2001a: 156.

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

Fortunately, only three species are common throughout most of New Zealand, and each of these has a slightly different size-frequency distribution. This makes it possible to use Peter Macdonald’s MIX algorithm for decomposing such mixtures into their constituent parts (discussed above). This has

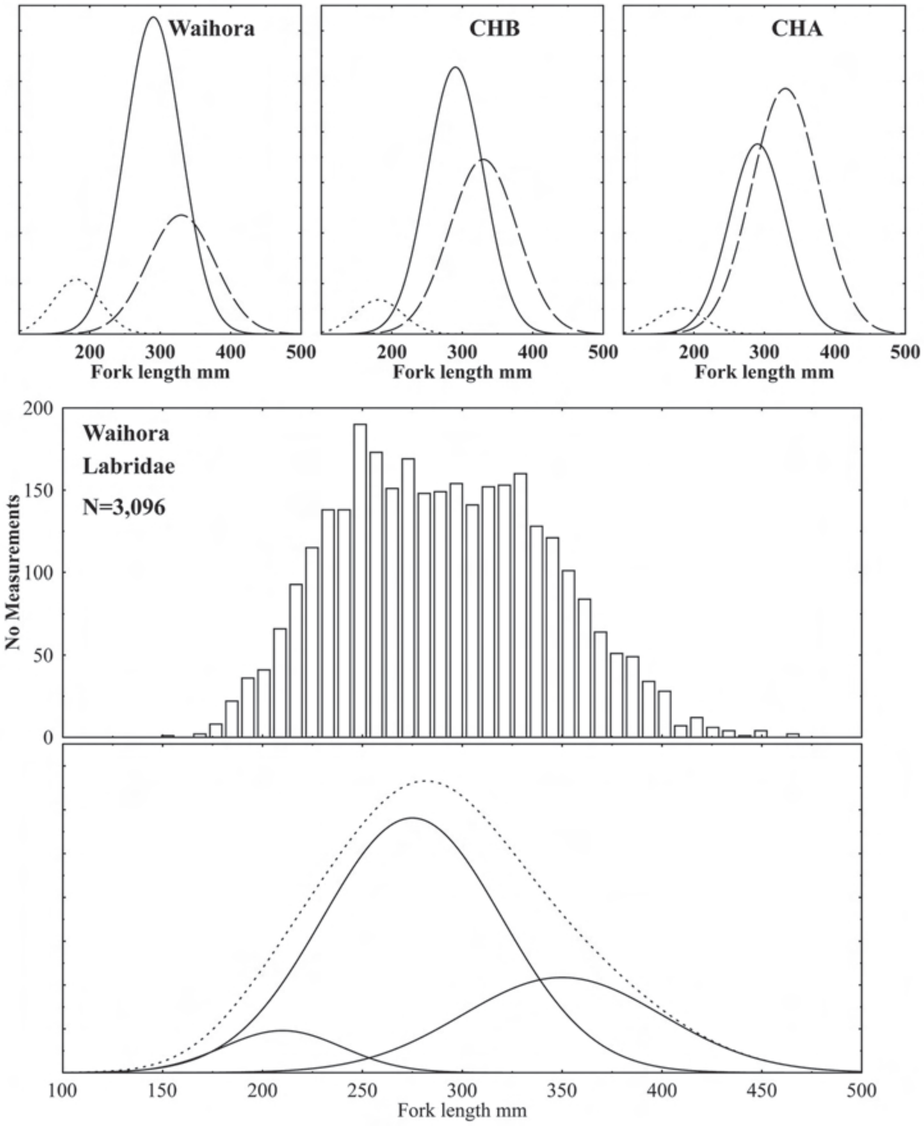

Figure 7.30: Three labrid species in sites at the Chatham Islands. Upper: The three labrid species separated from all three Chatham Island sites (see text). From Leach *et al*. 1999a: 127. Centre: All labrids, unseparated, from Waihora. Lower: Waihora labrids separated into three species.

been attempted for the three archaeological sites in the Chatham Islands just mentioned (Fig. 7.30). On the middle of this Figure is shown the size-frequency histogram of the large catch from Waihora, and below it the distributions of the three species which are assumed to be present after separating them using MIX. At the top of the Figure is shown the separate distributions for the three archaeological sites. MIX estimates the proportion of each species in each of the distributions (Table 7.17, and this can be used to calculate biomass at each site (Leach *et al*. 1999a: 132 ff.).

TABLE 7.17
Percentage of each Labrid species in three Chatham Islands Sites

Common Name	**Waihora**	**CHA**	**CHB**
spotty	9.1 ± 0.6	4.3 ± 1.4	5.7 ± 0.7
scarlet wrasse	62.7 ± 2.0	37.6 ± 6.8	52.8 ± 3.1
banded wrasse	28.2 ± 1.9	58.2 ± 6.6	41.4 ± 3.0

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

CONCLUSIONS

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

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

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

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

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

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

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

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

Barracouta from Long Beach show the opposite trend — in this case there is a decrease in mean size over time. When these catches are decomposed into the constituent age grades it is found that the early catches are composed of a small number of ages classes, and are dominated by old fish. Conversely, the more recent catch, close to the end of the pre-European period at this site, shows a much more even mixture of a large number of age grades. Barracouta migrate into inshore waters during summer in this part of south-eastern South Island and can be mass harvested from canoes.

They are caught with a lure and one has no control over what sized fish is caught. It seems unlikely that people would throw away specimens 750 mm long and yet keep 800 mm fish. I am forced to conclude that harvesting practices are not involved in this apparent shift through time in catch composition.

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

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

CHAPTER 8: FISH AND OTHER MARINE FOODS IN DIET AND ECONOMY

INTRODUCTION

In April 1965 an excavation took place on Ponui Island in the Hauraki Gulf which changed the whole approach of examining midden debris in New Zealand (Fig. 8.1). This was at a small site at Galatea Bay, excavated by Terrell and Shawcross with 25 students and some volunteers over a period of about ten days (Terrell 1967: 33–34). The excavation itself was not especially significant, but the treatment of the faunal collection obtained from it was (Shawcross 1967a). Shawcross pointed out that although middens had been used before in New Zealand as a means of studying changes in human economy, no-one had followed the example set by Grahame Clark in his treatment of the Mesolithic site at Starr Carr in England, where a systematic attempt was made to follow a sequence of quantitative research leading to an estimate of population size and length of occupation. This involved first quantifying the bone debris; from that quantifying meat weight; from that quantifying caloric food energy; and then, with the assistance of ethnographic parallel, arriving at reasonable inferences about population. The usefulness of such a methodology had previously been pointed out by Davidson who, citing research in California, argued that a similar approach in midden research could be undertaken in New Zealand (Davidson 1964: 191–195). Shawcross noted that little attention had been given in the past to sources of errors along this quantitative path, something which he intended to address with the Galatea Bay midden (Shawcross 1967a: 108).

Figure 8.1: The Galatea Bay excavation on Ponui Island, Hauraki Gulf, New Zealand. Photo courtesy of Karel Peters and the Anthropology Department Photographic Archive, Ponui Island Negative 27, University of Auckland. (Previously published by Terrell 1967: Plate 1, and Shawcross 1967a: Plate IX.)

In his research at Galatea Bay and later at Houhora, Shawcross laid the foundations of economic prehistory in New Zealand (Shawcross 1972). I will discuss the specific achievements of Galatea Bay and Houhora in more detail below, but at this point I want to draw attention to the fact that until 1967, archaeologists in New Zealand had not given serious attention to quantitative aspects of subsistence economy which took into account nutritional aspects of diet. There was, however, a serious misunderstanding about human dietary requirements in this early research. This has not really been corrected in any subsequent research by New Zealand archaeologists interested in subsistence economics — more on this matter shortly. Previous quantitative research on middens in New Zealand, such as at the Tairua site (Smart and Green 1962) and the Undefended Settlement at Kauri Point (Green 1963) was aimed at seriation of middens into chronological sequence using relative abundance of different species. By giving careful attention to variation within any one midden site, Davidson showed that single samples from middens like Tairua and Kauri Point could not be used for seriation because the internal variation was at least as great as that between the sites themselves (Davidson (1964: 93–108). There are numerous other adverse implications of taking only small samples from middens; 40 years later, many archaeologists still seem to be ignorant of these.

Shawcross was particularly interested in investigating human population size and, as part of this, the carrying capacity of the land, by exploring the dynamics of human harvesting and natural replenishment of biological populations, especially those of marine organisms. For example, in his paper, ‘An evaluation of the theoretical capacity of a New Zealand harbour to carry a human population’ he states: “The aim of this paper is to establish a limiting factor in the estimate of the size of a human population subsisting by means of shellfish gathering” (Shawcross 1967b: 3). Did Shawcross really think that humans actually lived on shellfish alone? Absolutely not; however, he clearly did not think that plant foods, for example, were necessarily very important for a successful economic system. On this subject he had this to say:

> It is also unnecessary to assume that any group ever existed on an entirely shellfish diet, indeed, the body of Ethnographic literature as well as recent Archaeological research argues against this. On the other hand, it is difficult to establish the relative importance of other foods, especially vegetable ones, for no adequate observations were made in the early days of European contact and many of these foods leave no surviving evidence. However, it may be cautiously put forward that cultivated crops can never have held the dominant position here which they have in more tropical parts of Polynesia, for suitable combinations of soils and climate are not widespread. The same restrictions are to some extent true even for the fern root but it is suggested that this plant is a counterpart to the shellfish (Shawcross 1967b: 8–9).

Although not clearly stated, this leaves an impression that there was a school of thought at the time that humans could survive on protein-rich foods alone, and Shawcross certainly came to appreciate that shellfish in particular was a much under-acknowledged source of food energy for pre-European Māori. The Galatea Bay research showed that 92% of the energy represented by faunal remains was supplied by shellfish alone (Shawcross 1970: 283). There is no doubt that Shawcross was vitally concerned with the issue of how pre-European Māori were able to obtain a nutritionally satisfactory diet. In one instance, when considering “The value of the [fish] catch in a balanced diet” he noted “So far, the catch has been discussed in terms of energy, but it is desirable that it should be examined for its dietary value” (Shawcross 1967a: 120). The dietary factors he tabulated were: caloric energy, protein, iron, calcium, vitamin A, thiamine, riboflavin, niacin, and ascorbic acid (ibid.: 121). He commented on several deficiencies in the tabulated values and concluded “The absence of these substances, which would result from an entirely fish diet, could cause eye troubles and decrease in the resistance of the mucous membranes to infection” amongst other possible maladies (ibid.).

The reconstruction of the “nutritional value of the foods in the [Galatea Bay] midden” (Shawcross 1967a: 123) is summarised in Table 8.1

TABLE 8.1
The Reconstructed Nutritional Ingredients of the Galatea Bay Midden
(based on Shawcross 1967a: 123)

	Shellfish	**Fish**	**Mammals**	**Total**	**Energy†**
Protein	540.7 kg	24.9 kg	1.8 kg	567.4 kg	2,269,440 kcal
	70.3%	86.7%	25.7%	70.5%	63.8%
Fat	59.1 kg	3.8 kg	5.2 kg	68.1 kg	613,296 kcal
	7.7%	13.3%	74.3%	8.5%	17.2%
Carbohydrate	169.0 kg	-	-	169.0 kg	675,840 kcal
	22.0%	-	-	21.0%	19.0%
Total	**768.8 kg**	**28.7 kg**	**7.0 kg**	**804.5 kg**	**3,558,576 kcal**
	100.0	**100.0**	**100.0**	**100.0**	**100.0**

† To convert Shawcross’s weights to caloric energy here I used the normally recognised figures of 4, 9 and 4 kcal/g for protein, fat and carbohydrate respectively (Davidson *et al.* 1972: 10).

Shawcross was only too aware that middens in New Zealand contained no useful quantitative information relating to many additional foods that early ethnographic observations made clear were part of regular Māori diet. He mentions crayfish, crabs, sea urchins, vegetable foods including seaweeds, fern root, kūmara, etc. (Shawcross 1967a: 126). But he also noted the following:

> On the other hand, Grahame Clarke was able to ignore for practical purposes the importance of vegetable foods at the large mammal-hunting camp of Star Carr.… In the case of New Zealand the importance of plant foods is well enough documented, but impossible to quantify alongside the sea animal foods,… It is therefore not possible to arrive at more than a very general estimate that the plant foods would supply an amount of energy probably equal to that derived from animal foods, though the range of variation could lie between nothing and double that quantity (Shawcross 1967a: 126–128).

The reference to *nothing* seems a fairly clear statement that humans could survive on a wholly marine diet of fish and shellfish. Other than problems arising from vitamin deficiency in the reconstructed diet for Galatea Bay, Shawcross made no additional comments and suggested nothing untoward about its nutritional adequacy. In point of fact, as will be explained in this chapter, such a diet would result in starvation. This is not a matter of not enough food, it is a matter of not enough of the correct balance of ingredients. Humans cannot survive for long periods on a protein-rich diet of the kind suggested in Table 8.1. The proposed Galatea Bay diet, with 64% caloric energy deriving from protein, would rapidly lead to death. Shawcross is not the only archaeologist who mistakenly under-appreciated the importance of non-protein foods in human diet. For example, Buchanan expressed the view that 90% or more of human dietary needs could be derived from protein (Buchanan 1987, cited by Noli and Avery 1988: 397; see also Cook 1946 and Greengo 1952).

I suspect that many archaeologists who are devoted to economic prehistory do not understand very well the basic requirements of human nutrition and, as a result, many of their reconstructions of past subsistence behaviour would have been impossible in reality. In this respect, I have to confess profound ignorance myself until recently. A series of publications relating to the subsistence economics of people living in harsh arctic and semi-arctic environments was a revelation to me which began when I read an account of the Copper Eskimos following the Canadian Arctic Expedition 1913–1918 (Jennes 1923). This was followed by a seminal paper by John Speth, published in the *Journal of Anthropological Archaeology* (Speth 1990). Other useful papers on the same subject are by Speth (1983), Speth and Spielmann (1983), Noli and Avery (1988), Draper (1977, 1980) and, especially important, by Stefansson (1957). Until I read these publications I believed, in my ignorance, that people who were unfortunate enough to be shipwrecked on an island in the tropical Pacific, where the only significant food was from the sea, would be able to sustain themselves indefinitely, assuming of course they had an adequate command of the necessary technology to harvest the sea's resources. I now realise that this would be extremely difficult unless large quantities of either starchy food or fat were also available. Humans cannot live on fish and shellfish alone. Returning to the Galatea Bay example — the people who lived there would quickly have starved on the diet suggested in Table 8.1.

The problem of a protein-rich diet, depleted of either carbohydrate or fat, is graphically described by Stefansson in his *Arctic Manual* as 'rabbit starvation':

> If you are transferred suddenly from a diet normal in fat to one consisting wholly of rabbit you eat bigger and bigger meals for the first few days until at the end of about a week you are eating in pounds three or four times as much as you were at the beginning of the week. By that time you are showing both signs of starvation and of protein poisoning. You eat numerous meals; you feel hungry at the end of each; you are in discomfort through distention of the stomach with so much food and you begin to feel a vague restlessness. Diarrhoea will start in from a week to 10 days and will not be relieved unless you secure fat. Death will result after several weeks (Stefansson 1957: 234).

The disastrous consequences of trying to live on lean meat are vividly summarised from numerous historical and ethnographic sources by Speth and Spielmann (1983: 3–5). As we will see below, some pre-European human communities in southern New Zealand and the nearby Chatham Islands had severe environmental limitations placed upon them with scant access to carbohydrate foods, and this led to a highly unusual diet, unprecedented in the tropical and south Pacific region. For this reason, it is useful to explore some of the basic dietary requirements of humans in some detail.

SOME BASIC ASPECTS OF HUMAN DIET

Humans require certain key ingredients in their diet — protein, fat, carbohydrates, minerals, vitamins, and water. Actually, the real requirements are somewhat more basic than this list of high level ingredients. At a lower level the requirements are essential amino acids (EAA), essential fatty acids (EFA), caloric energy (most of which must come from a source other than protein), vitamins, minerals and water.

Protein and Essential Amino Acids

Protein is required because it is one of the best sources of certain amino acids which are essential in human diet. There are 20 amino acids. Plants are able to synthesise all of these into their own protein from simple carbon and nitrogen compounds. Humans and other animals, on the other hand, cannot synthesise half of these amino acids[1] and must therefore take them in as food. Moreover, they must be present simultaneously in the correct relative amounts for efficient protein synthesis to occur in humans. Any amino acids left over are then metabolised for energy. If one or more of these essential amino acids is present in a lower amount than required, the utilisation of all the others is reduced by a corresponding amount. The essential amino acids are listed in Table 8.2, together with the recommended daily amounts required.

TABLE 8.2
Essential Amino Acids and Recommended Daily Amounts for Adult Males
(from Scrimshaw and Young 1976: 62)

	Amino acid	**Required g/day**
1,2	phenylalanine, tyrosine	1.1
3	lysine	0.8
4	histidine	?
5	isoleucine	0.7
6	leucine	1.0
7	valine	0.8
8,9	methionine, cysteine	1.1
10	tryptophan	0.3
11	threonine	0.5
Total		**6.3**

Fish flesh is a particularly good source of these amino acids, in contrast to most plant foods, such as kūmara, which are relatively poor sources.

Fat, Oil or Lipids

The term fat[2] covers a large range of chemical substances called lipids or fatty acids, each of which has its own distinctive physical and chemical properties. Human fat is composed of about 20 fatty acids and with a few important exceptions all these can be synthesised without the need to ingest them as food. These exceptions are known as *essential fatty acids* or EFA. The reason for this curiosity is the absence among mammals of certain enzymes and should not concern us here. However, it is important to realise that both modern and pre-European human communities must have ready access to these essential fatty acids if they are to be healthy and, ultimately, to survive. The two most important essential fatty acids are known as linoleic acid (LA) and linolenic acid (LNA). These must be part of the diet of humans. A third fatty acid, known as arachidonic acid (AA), is also very important in human metabolism and cannot be synthesised. It is relatively rare in foods. Fortunately, the human body can readily convert linoleic acid to arachidonic acid, although vitamin B6 is required for this conversion. So, from the point of view of assessing potential human foods, there are actually three fatty acids which can be considered essential, but if the first two are present in diet, the third can be disregarded.

At this point I should note that the nomenclature of fatty acids is very confusing. There are at least four different systems. However, in the simplest form we can note that the number of carbon atoms

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[1] There is disagreement as to exactly how many of these are essential, but at least 8, and up to 11.

[2] Fat and oil are only distinguished by whether they are solid/semi-solid or liquid at room temperature.

is designated, followed by a colon which designates the number of double bonds. Thus, linoleic acid is written as 18:2, linolenic as 18:3, and arachidonic as 20:4.

Sometimes another symbol is used to designate where in the carbon chain these double bonds occur. This serves to differentiate different forms of, for example, linolenic acid as follows:

18:2n-6	linoleic	LA	Omega 6
18:3n-3	α linolenic	ALA	Omega 3
18:3n-6	γ linolenic	GLA	Omega 6
20:4n-6	arachidonic	AA	Omega 6

It can be seen from this that α linolenic acid is sometimes referred to as Omega 3 essential fatty acid, and the others as Omega 6 essential fatty acids. Great emphasis is being given these days to finding dietary supplements for Omega 3 oils, such as flax seeds, seal oil, and some fish oils, etc. The reason for this is that many industrialised human communities consume foods that are deficient in essential fatty acids. However, some ancient human communities had the same problem, and that is why it is important for archaeologists to have a clear understanding of the basic issues involved in this subject.

Diets deficient in EFA lead to dermatitis, slowing of growth rate, and many other symptoms (asthma, diabetes, multiple sclerosis, etc.). Human brain is highly enriched in derivatives of linolenic and α linoleic acids, and recent research provides a clear link between violence and anti-social behaviour and EFA (Gesch *et al*. 2002). That is, increasing the amount of EFA in the diet has been shown to reduce such behaviour. Whether a shortage of EFA in some pre-European groups might be implicated in internecine conflicts is an interesting hypothesis. There is some evidence that the need for EFA may rise along with the amount of saturated fatty acids[3] in diet.

The minimum daily requirement is probably about 1g/day EFA (Davidson *et al*. 1972: 76); however, since this is also determined by the amount of saturated fatty acids in diet, this figure can be well above this value for many communities, and 3–6g/day may be a more typical requirement. My research on available sources of EFA for pre-European Pacific Island and New Zealand communities suggests that these higher 'optimum' levels might have been quite difficult to achieve. Table 8.3 provides the amounts of each of the three essential fatty acids in some of the foods available to these communities, together with the amount of each food which would be needed to yield 1g of the three fatty acids combined.

Unfortunately, values published by the United States Department of Agriculture National Nutrient Database and by the New Zealand Institute for Crop and Food do not have species names; there is no information on the diet of the specimens being analysed; and in some cases the individuals may be domestic animals fed on pellets. Despite these shortcomings, there are a lot of surprises in this Table, with considerable implications for the present discussion. Taking into account that these figures are *minimum* values, and normal needs may be three to six times these values, it is clear that obtaining sufficient essential fatty acids was not easy for pre-European Māori.

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[3] Saturated fatty acids do not contain any double bonds (e.g. stearic acid 18:0). Mono-unsaturated fatty acids contain one double bond (e.g. oleic acid 18:1), and poly-unsaturated fatty acids contain more than one double bond (e.g. linoleic acid 18:2).

TABLE 8.3
Essential Fatty Acids in some Common Foods
Derived from USDA 2005, Quigley *et al*. 1995, and my own research

The first four columns are g/100g. The final column is the *minimum* amount of the raw food required per day for a total intake of 1g of EFA. Unless otherwise stated, the values are all for whole specimens raw. Species names for the foods listed appear in Appendix 2.

Species/Food	**18:2**	**18:3**	**20:4**	**Total**	**Daily Amount Needed g**
Human fat	15.120	0.290	0.440	15.850	6.3
Duck fat	12.000	1.000	0.000	13.000	7.7
Pork back fat	9.500	0.740	0.110	10.350	9.7
Weka fat	2.770	0.950	0.590	4.310	23.2
Karaka berries§	3.520	0.260	0.060	3.840	26.0
Kiwi fat	2.570	0.320	0.000	2.890	34.6
Muttonbird fat	1.710	0.410	0.260	2.380	42.0
Bearded seal oil	0.630	1.000	0.000	1.630	61.3
Weka	1.040	0.320	0.210	1.570	63.7
Eel long finned†	0.500	0.300	0.600	1.400	71.4
Albatross fat	0.770	0.320	0.280	1.370	73.0
Muttonbird	0.710	0.150	0.120	0.980	102.0
Kiwi	0.680	0.070	0.020	0.770	129.9
Eel long finned	0.210	0.250	0.120	0.580	172.4
Eel short finned	0.330	0.000	0.120	0.450	222.2
Coconut cream	0.379	0.000	0.000	0.379	263.9
Coconut flesh	0.366	0.000	0.000	0.366	273.2
Albatross	0.120	0.020	0.060	0.200	500.0
Pūkeko	0.140	0.020	0.030	0.190	526.3
Green mussel	0.050	0.030	0.070	0.150	666.7
Kahawai	0.140	0.000	0.000	0.140	714.3
Kūmara	0.111	0.020	0.000	0.131	763.4
Snapper	0.040	0.010	0.070	0.120	833.3
Green turtle	0.033	0.017	0.052	0.102	980.4
Pāua	0.010	0.010	0.080	0.100	1,000.0
Barracouta	0.060	0.000	0.030	0.090	1,111.1
Taro (*Colocasia*)	0.058	0.025	0.000	0.083	1,204.8
Kina roe	0.080	0.000	0.000	0.080	1,250.0
Skipjack tuna	0.016	0.000	0.026	0.042	2,381.0
Tarakihi	0.010	0.001	0.030	0.041	2,439.0
Kelp (*Laminaria*)¶	0.020	0.004	0.012	0.036	2,777.8
Tree fern	0.014	0.018	0.000	0.032	3,125.0
Groper	0.030	0.000	0.000	0.030	3,333.3
Cockles	0.010	0.000	0.000	0.010	10,000.0
School shark	0.010	0.000	0.000	0.010	10,000.0
Blue cod	0.001	0.000	0.000	0.001	100,000.0
Crayfish	0.000	0.000	0.000	0.001	100,000.0
Flounder	0.001	0.000	0.000	0.001	100,000.0
Greenbone	0.001	0.000	0.000	0.001	100,000.0

† My specimen AL455 had an ungutted weight of 7,127 g, and a length of 1,208 mm

¶ This seaweed has a notable amount of carbohydrate, 9.57 g/100 g.

§ This specimen had 12.0 g fat, 20.3 g protein, and 45.2 g starch per 100 g dry weight.

In the case of common fish species, at least 1 kg/day would have to be eaten to supply the necessary EFA. For the common cockle, the figure is at least 10 kg/day. Especially bountiful sources of EFA are duck fat (8 g/day), weka fat (23 g/day), and kiwi fat (35 g/day), and of special interest are the karaka berries (26 g/day). Seal oil and eel fat are also very good sources of EFA. However, top of the list is human fat with only 6 g/day required, very close to pig. Perhaps this is the reason why there are many 19th century references to humans as ‘long pig’ by Māori (Orsman 1997: 454), who were once cannibals and may have been referring to the similar flavour. The very high values for duck, weka and kiwi are interesting. The network of artificial canals made in pre-European times near the mouth of Wairau River involved removing 60,000 cubic yards of soil, and is believed to have been especially useful for capturing paradise and grey duck and other wildfowl (Mitchell and Mitchell 2004: 81–83).

Caloric Energy — Mainly from Carbohydrate

The last main requirement (other than minerals, vitamins and water) is a source of caloric energy. Most human communities throughout the world obtain this from foods rich in carbohydrate, such as starchy foods. This type of food is particularly good for providing energy (4 kcal/g), which is one reason why it is so common in human diets; the other is that it is a convenient form of food for long term storage. By far the greatest source of energy, however, is from fat (9 kcal/g).

TABLE 8.4
Nutritional Value of some Dried Foods
Calculated from Vlieg (1988: 47)

Energy is kCal/100g. Other values are Percent caloric energy, Species names for the foods listed appear in Appendix 2.

Species	**Energy**	**Protein**	**Oil**	**Carbohydrate**	**Fat+Carb**
Kina	493	45.9	51.6	2.5	54.1
Green mussel	419	59.4	23.6	17.0	40.6
Tuatua	398	60.0	17.8	22.3	40.0
Scallop	395	73.2	13.9	12.8	26.8
Cockle	355	75.8	18.7	5.5	24.2
Pipi	316	79.8	15.3	4.9	20.2
Horse mussel	386	80.8	6.1	13.1	19.2
Bluff Oyster	413	82.7	16.5	0.9	17.3
Paddle crab	386	84.1	11.0	4.9	15.9
Pāua	394	86.8	9.4	3.8	13.2
Crayfish	389	89.8	7.4	2.9	10.2

In the wider Pacific region, root and tree crop vegetables such as taro, sweet potato (kūmara), yam, and breadfruit provide carbohydrate. In New Zealand, the only significant carbohydrate-rich plant foods available in any quantity during prehistoric times were kūmara, taro, fern root, and a product made from tī, the cabbage tree, *Cordyline australis*. Cultivation of kūmara and taro was reasonably successful in the far north of New Zealand, but only marginal at the latitude of Cook Strait and in a few patches in the northern parts of the South Island. In the Chatham Islands, there was a dearth of carbohydrate-bearing plants, which posed serious dietary problems for the Moriori people who lived there, though probably no more so than for people in the Murihiku area south of Banks Peninsula in the South Island of mainland New Zealand.

One source of carbohydrate, not normally considered in New Zealand, is a species of shellfish known as tuatua (*Paphies subtriangulata*). The soluble carbohydrate in this species is 6.2 g/100 g wet weight, providing a fair amount of the total caloric energy of 110 kcal/100 g wet weight (Leach *et al*. 2001a: 11). This caloric value is higher than most of the common species of fish and shellfish in New Zealand, and yet its role in diet is not normally considered very important. Its real value lies not in the amount of energy it could provide, but in the fact that 40% by wet weight is not from protein, but from carbohydrate and lipids. At the time of European contact Māori were observed drying shellfish for later consumption. This has another effect which could easily be overlooked — it concentrates the food energy by removing the water as is evident in Table 8.4, which provides the energy for some common shellfish and other foods. Drying tuatua increases the good value nearly four times.

Caloric Energy Mainly from Meat — The Danger of too much from Protein

There is a common misconception that starchy carbohydrate foods are essential in human diet in large amounts, but this is not strictly so. It is true, however, that the human brain does have a basic requirement for carbohydrate in the form of glucose or glycogen which cannot be synthesised in the body from the break-down products of lipids. Although carbohydrates are virtually absent in animal protein products, one exception is liver, which contains an animal carbohydrate known as glycogen. Liver could therefore be a satisfactory source of the carbohydrate required for normal brain functions as an alternative to starchy food when this is not readily available. There is a danger associated with eating too much liver of sea mammals in particular, since this contains high natural levels of toxic substances, such as methyl mercury. Meat itself typically contains about 10 g of glucose in the form of glycogen per 2,500 kcal, and the adult brain is estimated to require about 100 g of glucose or its equivalent per day. Consequently, adequate levels of blood glucose can be obtained by synthesis from amino acids released during digestion of protein. This requires the human involved to consume more protein for this purpose (Draper 1977: 311).

This is an important matter, because some populations did not have access to starchy foods in any abundance, and in these cases fat was a suitable alternative source of this energy. This is especially true of southern New Zealand and Chatham Islands. In these regions, the best source of non-protein caloric energy was fat from sea mammals. Access to sources of protein can be considered essentially uniform from one end of the country to another. Abundant fish and shellfish were available in all coastal areas, and the small population of pre-European Māori (at most 100,000 people) harvesting these resources had only a minute effect on the immense size of this protein source. Thus characterised, there was a substantial change in access to different sources of caloric energy from north to south in New Zealand, schematically illustrated in Figure 8.2 (see Davidson and Leach 2001: 119, Davidson and Leach 2002: 269).

We can see then that it is possible to maintain a healthy individual on a diet consisting of animal products alone (entirely protein and fat). As Stefansson points out:

> You could, so far as we know, live 3 score years and 10 on geese, for they have enough fat to counterbalance the lean. You could live equally long on rabbits if supplemented with bacon. On rabbit alone you would be ill in a few days. It is probably true that if one man has nothing but water and another has rabbit and water, they are likely to die in about the same length of time, from 3 to 8 weeks. The one who has just water dies of outright starvation; the other from diarrhoea and kidney afflictions (Stefannson 1956: 282).

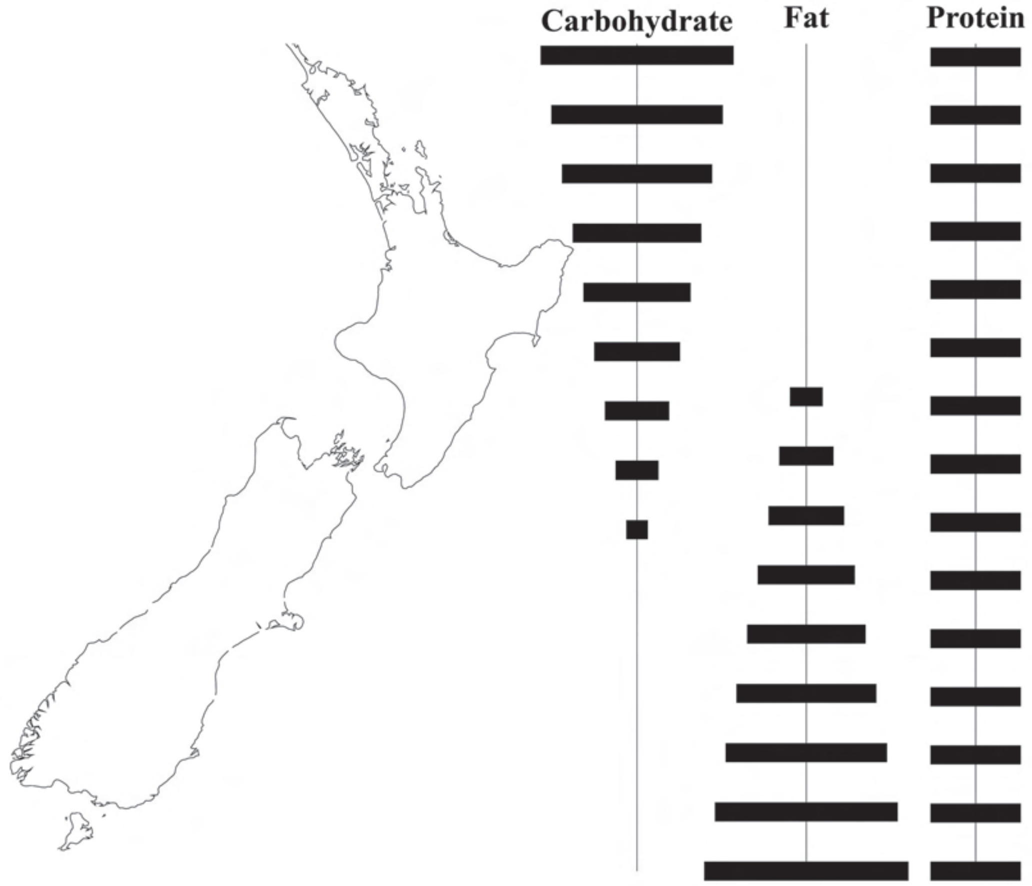

Figure 8.2: North to south clines in the availability of cultivated starchy foods and fat-rich sea mammals in New Zealand. Access to protein is effectively constant throughout. The main source of non-protein caloric energy shifts from carbohydrate to fat from north to south (from Davidson and Leach 2001: 119).

This is the substance of a famous experiment in which two arctic explorers, Stefansson and Andersen, ate entirely animal food (lean meat and fat) for just over 12 months in New York with no adverse effects such as scurvy (Stefansson 1957: 223; Draper 1977: 310; Speth 1990: 149)[4]. Clarence Lieb, the medical director of this experiment reported that: “the meat was usually boiled or stewed, the inside being left rare. Raw bone marrow was eaten as dessert” (Lieb 1929: 22). This experiment shadowed the diet of many Inuit (formerly known as Eskimo), which is almost entirely devoid of plant foods. Stefansson effectively solved a mystery about Inuit diet, which had led some people to think that they had a modified metabolism compared with other humans. Draper points out:

> While the primitive Eskimo was beset by serious nutritional crises, these problems arose not from deficiencies in the quality of his native diet but from periodic breakdowns in his food supply as a result of natural forces. He required no knowledge of nutritional principles in

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[4] Stefansson averaged about 2,650 kcal per day with 550 coming from protein (21%) and 2,100 from fat (79%). Anderson averaged 2,620 kcal with 510 from protein and 2,110 from fat (Stefansson 1957: xv). He points out, however (ibid.: xvi), that there has been a consistent and serious error in reporting this experiment. The much quoted daily diet of 1⅓ pound of lean meat and 1/2 lb fat is incorrect. The diet was of pemmican where a 1 lb cake was made from desiccating 3 lb of lean beef meat, mixed with 1/2 of fat rendered from beef suet. That is, the equivalent of 1,360 g of lean fresh meat and 227 g of fat.

> order to be well nourished. He ate a balanced diet for one simple reason: there was little else to eat (Draper 1977: 315).

This comment seems just as pertinent to the pre-European southern Māori and Moriori as it is to Inuit. The importance in New Zealand of seasonal changes in food abundance has been well documented by Helen Leach (Leach 1969), and periodic near-starvation is attested by Harris lines in human long-bones (Sutton 1975, 1979b). Problems of nutritional inadequacy may have been more significant in the central area of New Zealand in the intermediate crossover between reliance on carbohydrates and fats (Fig. 8.2).

The level of non-protein caloric energy (either from carbohydrate or fat) in human diet is important. If it is high with respect to need, then the protein ingested is spared from being broken down to meet the energy requirements, and the individual stores the excess energy as fat. If it is low with respect to need, then the energy requirements must be met by breaking down the ingested protein. This is a very wasteful metabolic process, and it is possible to starve, regardless of how much protein food one consumes. This is the essence of the problem referred to above, called ‘rabbit starvation’ (Stefansson 1957: 234; Speth and Spielmann 1983: 3).

Protein requirements depend upon the level of energy intake and upon the quality of protein ingested, with low energy diets generally requiring more protein in order to maintain nitrogen equilibrium and thus preserve tissue protein (Munro 1985: 163). Conversely, if a high-protein diet is consumed, energy requirements may have to be raised by up to 30%, because the body’s metabolic rate must increase in order to process the digested protein (Speth and Spielmann 1983: 5–6; Noli and Avery 1988: 396). It has been found that there is an upper limit to the total amount of protein which can be consumed on a regular basis. This limit is reached when approximately 50% of total calories are derived from protein, but most peoples limit their intake of protein to around 10–15% of energy needs (Noli and Avery 1988: 396). In fact, the ingestion of levels of protein as low as 23% of energy intake, over 10 days, has been observed to cause azotaemia (excess nitrogen) and a rise in plasma ammonia concentration which can be lethal (Noli and Avery 1988: 397).

The protein content of some traditional Inuit diets has been estimated to be up to 45% of total calories, with a similar proportion of energy needs derived from fats (Speth 1990: 155). Draper (1980: 259) cites values compiled in 1972 by Bang, Dyerberg and Hjorne for the percentage sources of calories in diets at the historic coastal Inuit settlement of Igdlorssuit in northwest Greenland. These were 26.2%, 37.1% and 36.7% for protein, fat and carbohydrate respectively, showing a strong influence of introduced European foods. This can be compared with records from northwest Greenland made in 1914 which indicated that at that time protein provided 44% of diet calories, fat 47% and carbohydrate 8%. The latter figures reflect a diet with a fat content which could potentially lead to ketonuria, or the accumulation of acidic ketone bodies in the bloodstream from the metabolism of fat, leading to serious illness and death (Anderson 1981c: 152; Denniston 1972). It has been suggested that ketonuria can be avoided in high fat diets if carbohydrates comprise at least 15% of the daily diet (Anderson 1981c: 153; Davidson *et al.* 1972: 214–216). As we will see below, however, this view is not correct. Humans can maintain a perfectly healthy diet consisting entirely of meat and fat, with no other source of carbohydrate than the glycogen obtained from protein. This was demonstrated by Stefansson and Andersen in the experiment cited earlier. Moreover:

> Multiple studies have shown that animal foods almost always result in a higher ratio of energy capture to expenditure than do plant-based foods… Consequently, the solution preferred by most world-wide hunter-gatherers to circumvent excess dietary protein would

> likely have been a relative increase in total dietary fat from animal foods (Cordain *et al*. 2000: 689).

The question of what is an acceptable daily protein intake is complicated by age, health, sex, and other aspects of the diet. A number of authorities suggest that the low end of the scale is about 50 g per day for a 70 kg adult male; however, daily protein intakes varying between 10 and 40 g have been reported for populations in Papua New Guinea, although the reliability of these values has been questioned (Robson and Wadsworth 1977: 191). It is possible that low levels of protein intake may be acceptable for a period of time. To some extent the human body may be able to adjust to lower protein intakes by reducing protein breakdown (Young *et al*. 1985: 199), but ultimately a long-term very low protein diet leads to stunting and nutritional dwarfism (Golden 1985: 174).

It is equally important to note that there is an upper limit to how much protein the human body can cope with. According to Speth, an extreme upper limit that can be consumed safely on a sustained basis is approximately 300 g per day. This figure represents a protein intake of roughly 50% of total daily caloric intake under normal, non-stressful conditions (Speth 1990: 155). A more realistic maximum daily protein intake may represent 20–30% of daily caloric intake, and would be in the region of 120–180 g of protein per day. Draper (1977: 311) has reported a protein intake of 200 g per day for pre-modern Arctic Inuit, an intake which represented 32% of their daily caloric intake.

Total Energy Requirements

Recommended energy requirements for human populations also vary according to sex, body weight and activity levels. The South Pacific Commission (Anon. 1983: 32) recommends an energy intake of 3,000 kcal/day for a 65 kg moderately active adult man, while a daily intake of 2,500 kcal is recommended by Wilson (1975) for Asian males. The World Health Organisation's daily average energy requirements for a 70 kg individual range from 2,150 kcal for a woman with a low activity level to 3,850 kcal for a man with a high level of activity (Anon. 1983: Tables 42 and 45). For moderate activity levels, the suggested daily intakes are 2,750 kcal for women and 3,150 kcal for men (ibid.). These values can be compared with estimated values of energy intakes of actual populations. Hasunen and Pekkarinen studied the diets of two Finnish Lapp populations and reported mean daily energy intakes in one population of 3,800 kcal for males and 2,620 kcal for females. This diet was reported as being nutritionally "generally adequate", whereas the second group, which had daily energy intakes as low as 1,653 kcal for females, had a nutritionally inadequate diet (Draper 1980). Robson and Wadsworth (1977) cite estimates of the daily energy intake in July for the !Kung of 2,140 kcal and 2,260 kcal respectively. These figures are low and it has been suggested that at the end of the dry season individuals living on 2,260 kcal a day would probably be in negative energy balance (ibid.: 189). Even lower daily energy intakes of 1,300-2,400 kcal are reported for Papua New Guinea, but these values may not be entirely reliable because of lack of knowledge about actual food intakes (Robson and Wadsworth 1977: 191). Clearly it is possible for people to exist on a fairly broad range of caloric intakes, but it is not yet clear whether health can be maintained if the imbalance between recommended daily intakes and actual intakes continues over long periods of time, to the extent that changes in body weight and composition result (Anon. 1983: 13). The consequences of reduced energy intake will also depend upon the level of pre-existing energy reserves, combined with environmental conditions (Beaton 1985: 228).

The definition of what is an acceptable range of energy intake is thus not straightforward, considering the number of factors, both environmental and physiological, which can influence the long-term maintenance of good health in the face of variable energy intakes. It should also be recognised that in prehistoric times dietary quality and variety may have been limited, particularly in the more temperate areas of Polynesia, so that a diet considered nutritionally inadequate today may have been adequate for at least short-term survival in prehistory. However, a range of 1,800–3,700 kcal/day is a reasonable choice.

Summary of the Basic Requirements of Human Diet

The most basic requirements of human diet are the following:

1: Eight to eleven essential amino acids in correct proportions, amounting to about 6.3 g/day
2: Two to three essential fatty acids, amounting to 1–6 g/day
3: Protein amounting to 25–200 g/day
4: Less than the upper limit of about 44% of caloric energy from protein, and preferably less than 30%
5: A source of non-protein caloric energy, either carbohydrate or fat or both, to make up a total of 1,800–3,700 kcal/day
6: Minerals, vitamins and water

These requirements provide a basis for all further considerations about diet in this chapter.

NUTRITIONAL ASPECTS OF FISH AS FOOD

Most Europeans think about fish food in the form of fillets, rather than as whole fish. This distinction is important, because in the Pacific Islands most fish are eaten as whole fish, not as pieces. It is true that some large fish, sharks for example, are carved up in special ways and different body parts may be given to people of different social rank. However, this is the exception, not the rule, and normally fish are cooked whole and eaten whole. One can get a lot more meat off a fish if it is eaten whole. This can be seen in Figure 8.3, which shows the distribution of protein in different parts of common New Zealand fishes. The amount of food varies in different body parts, but is surprisingly high in the head and frame[5] in some species. For example, in the case of red cod, the amount of usable protein is fairly evenly spread between head, frame and fillet with 27.5, 23.7, and 25.6% respectively. Notice that the head actually contains more protein food than the fillet! In the Pacific region generally, the head is the most esteemed part of the fish and is preferentially given to higher status individuals. There are several reasons for this, but more of that shortly.

Eating the whole fish, rather than portions of it, has another unexpected aspect: a small fish makes a perfectly adequate meal. Many fish which Europeans might consider too small to eat by themselves make a satisfactory meal for a Pacific Islander, augmented of course by other foods. We have seen in Chapter 7 that very small fish were captured by some of the earliest pre-European people in New Zealand. This is a tradition which fits comfortably with the culinary habits of Pacific Islanders. The fact that fish sizes appear to have increased over archaeological time in some instances has a number of related causes, but is bound to have affected social aspects of food presentation.

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[5] The term frame is used for what remains of the body after fillets have been removed.

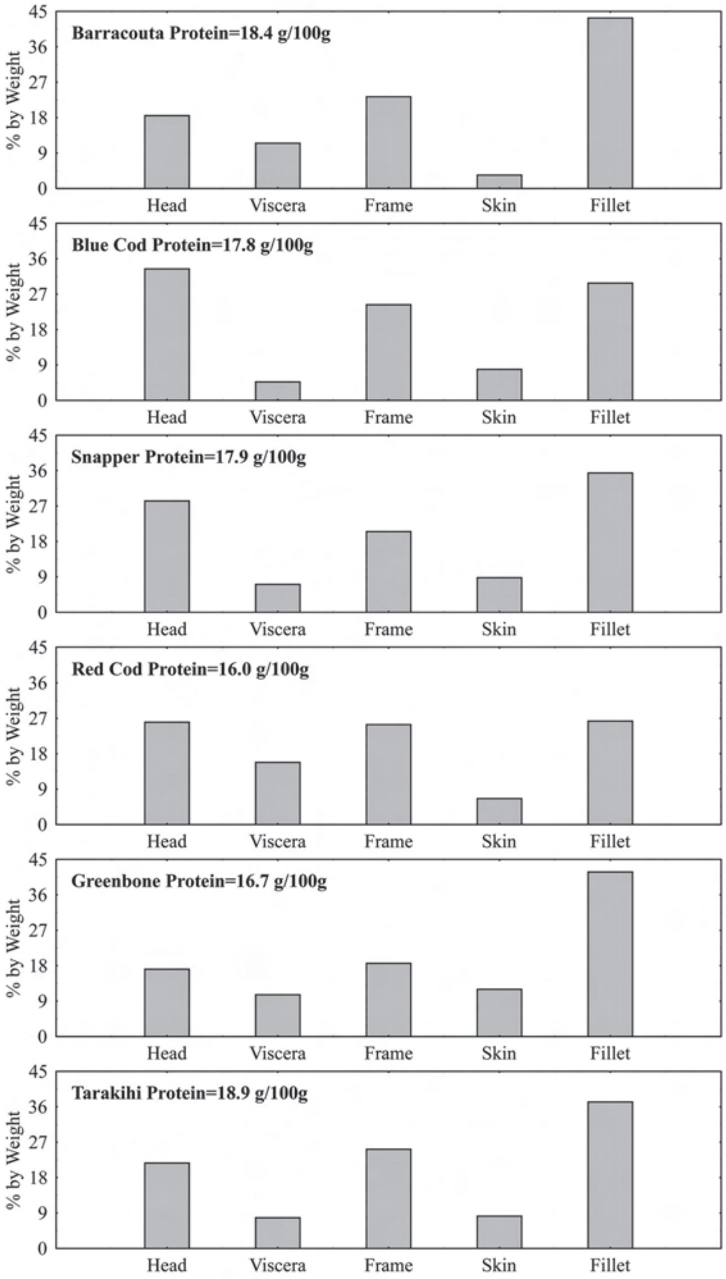

Figure 8.3: The percent distribution of protein in different body parts of common New Zealand fishes (from Vlieg 1988: 19). The cited values of protein in g/100 are for whole fish (after Vlieg 1988: 23).

In Figure 8.3 it is not only red cod which shows itself to have abundant food in the head portion. Blue cod has considerably more protein in the head than the main fillet area, and snapper heads also contain a large measure of the available food. It is interesting too that the viscera contain significant food. Peter Buck made the following observation of people in the Bay of Plenty (Buck 1926: 620):

> The entrails of the *kehe* [marblefish] become very fat at the right season, and are better esteemed by the local people than the flesh of the fish. Hence, in the saying below, used as an invitation to a visitor, they make a display of hospitality and at the same time reserve the tit-bits for themselves :—

Hoatu ki te kainga,
Kotaku ika ki a koe,
Ko te ngakau ki au.
Go on to my home;
My fish will be for you
And the entrails for me.

What exactly is meant by fat in this passage is not clear. Marblefish are very oily in general and because they are vegetarian, their guts are full of seaweed. After only a short time out of the water, the gut becomes markedly distended as it swells with the fermenting of its contents. If it is inadvertently opened up, it releases a most powerful stench. Distended bellies could be what is meant by 'fat' in this passage. Personally, I find it hard to imagine anyone eating marblefish flesh, let alone its guts, which shows that food tastes and habits are largely determined by human culture.

Some values of protein yield for whole fish are provided in Figure 8.4. Assuming that a daily requirement is about 150 g of protein, as discussed earlier, and all of this came from fish, one can easily calculate the size of fish required to provide this amount of protein and the amount of energy which this amount of food would yield. A few of the common fishes are:

Fish and legal size	Fork length mm	Weight g	Energy kcal
Barracouta (nil)	541	815	872
Blue cod (330 mm)	383	840	672
Snapper (270 mm)	349	835	768
Greenbone (350 mm)	404	895	716

Values are also given for the current legal minimum size for northern regions in New Zealand (there is no limit for barracouta). It can be seen from these few examples that modest-sized specimens of the common New Zealand fish provide an excellent source of protein. In practice, fish would not be the only source of protein available to pre-European people, and these daily values can therefore be scaled down by a commensurate amount. If protein was ingested at a rate of 50 g/day from fish alone, for example, the weight of barracouta required per day would be only 272 g, providing 291 kcal energy.

Experimenting with calculations like this serves the useful purpose of helping to identify the range of choices which had to be made by pre-European people. For example, in the South Island, where starchy foods were in short supply, it would be very difficult to obtain the daily energy requirement of say 2,000 kcal and avoid protein poisoning, unless a substantial amount of fat was available to build up the energy values. This could not come from barracouta.

The relative amounts of protein, oil and energy in the common New Zealand fishes are plotted out in Figure 8.4. Unfortunately, there are no published values for the common spotty, or any other labrids. As we have seen in Chapters 4 and 7, these were very important fish in pre-European New Zealand. As far as protein is concerned, the different species in Figure 8.4 have very similar amounts per unit weight. However, the relative amount of oil in the different species varies markedly. Tarakihi has far greater oil than other species; six times that of red cod for example. As sources of energy, tarakihi and barracouta are very similar, and other species are a little lower. Bottom of the scale is red cod. This corresponds well with the widespread modern prejudice about red cod to the effect that even a very large fish can have practically no meat, and is hardly worth filleting. Of course, a lot more food can be obtained if the Polynesian custom is followed of eating the whole fish, especially the head. The whole fish values are those appearing in Figure 8.4.

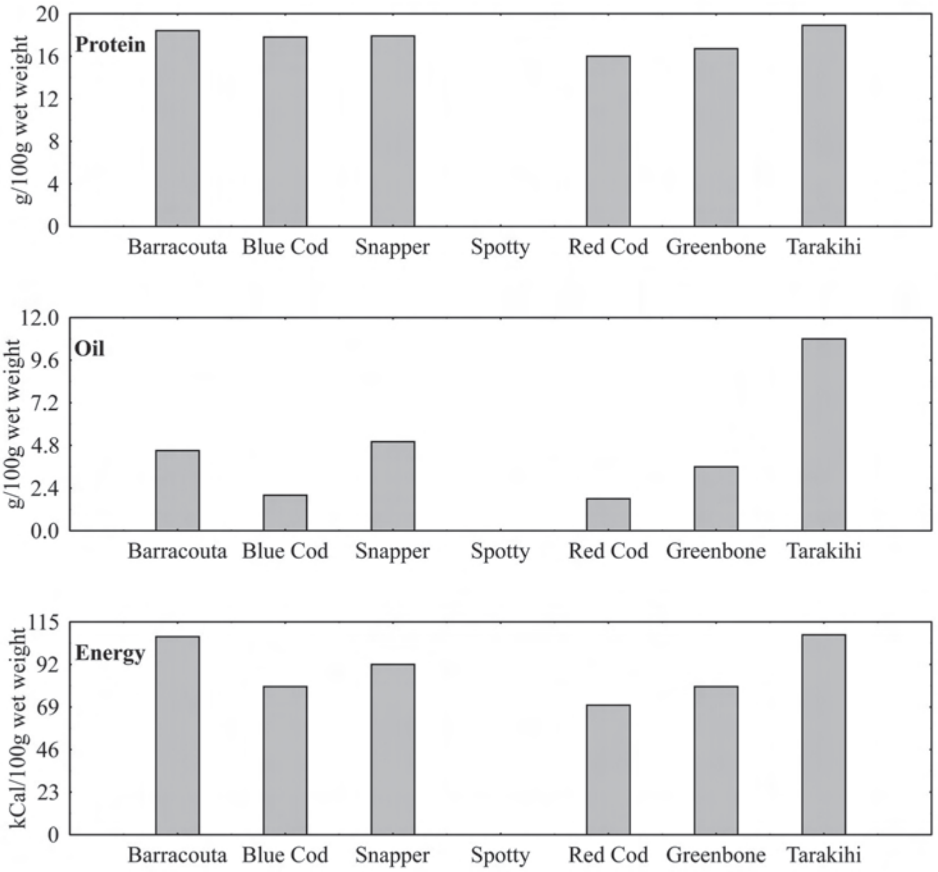

Figure 8.4: The amount of protein, oil and energy which can be derived from common New Zealand fishes (from Vlieg 1988: 23 ff., 48). Unfortunately, no figures are available for spotty or other labrids.

I have alluded several times to the difficulty which southern Māori and Moriori in the Chatham Islands experienced over the general absence of plant foods containing starchy material. This lack of a ready supply of carbohydrate for caloric energy meant that special efforts had to be made to find significant quantities of fat or oil as the only feasible alternative source of food energy. The quest for fat must have been a major preoccupation of these people, and marine mammals would have been one of the most important of the possible sources. The role of marine mammals in pre-European New Zealand has been thoroughly investigated by Smith (1975, 1976, 1977, 1985, 1989, 2005), who suggests that up to about 50% of the blubber of any animal caught would have been eaten. This is similar to the experiences of Inuit in the arctic, as Stefansson found:

> when traveling over the sea ice and living exclusively on seals that when the fat of animals secured had been put to all its uses he still had to throw away about a third (Stefansson 1957: 233).

A number of species of seals and small whales frequented New Zealand shores. Of these, the occasional mass strandings of pilot whales had a special importance, and great feasts would, no doubt, have ensued.

In the Chatham Islands, the Moriori people considered pilot whales a delicacy and a high status food. Women were not permitted to eat the flesh, and it was referred to as *kai ariki*, or the food of chiefs (Baucke 1928: 365). Baucke records strandings of pilot whales ranging from 5 to 140 individuals, but much larger numbers are also recorded — for example, 310 individuals in 1987 (Brabyn 1991: Plate 1). Unfortunately there are no direct records of whether Moriori ate the liver of pilot whales or not, but there are many references to the intestines of other large animals, including humans and sharks, being an important delicacy throughout Polynesia (Buck 1930: 125; Shand 1896: 74, 75, 76, 80, 1897: 145, 1911). Baucke describes the butchering of pilot whales thus:

> ... that human scavenger, *tchakat Mai-hor-r*, who speedily hacked, with flint saws, the stranded creature into junks, and, after baking in stone ovens, buried the flesh in earthen pits till it defiled the atmosphere where it lay, and not till then considered ripe and edible!
> …The flesh, stripped, bone-white, each carried his portion home to be cured for future — mostly festal — use. It was for these great occasions that firewood (ring barked to dry) was reserved: to heat the baking stones in the usual oven; but first the flesh was roughly roasted on the outside in an open fire. The oven was left two days — in fact, till cold. The meat was stacked in a fern-leaf lined pit and covered with earth, to be opened later to regale visitors or for other festive haps. I saw one opened! Whew! Let the stench and revolting appearance of that blue-mould-bearded mass of corruption be imagined! To educe its fullest gourmet flavor it was re-heated. Women were not permitted to taste this *k'ye arik'* (royal food). Even here the patron's name preceded the first delicious bite (Baucke 1928: 365).

His reference to a patron concerns the naming of each animal as being associated with an ancestral Moriori personage. There is no shortage of protein-bearing foods in the Chatham Islands; fish abound in profusion, even today. The Moriori, in giving such attention to pilot whales, were focused, in my opinion, on acquiring fat to combat starvation from lack of non-protein sources of caloric energy. Later we will see the full extent of this reliance. Archaeological evidence from the Chatham Islands shows that seals were also very important in the economy there (Smith 1976, 1977).

Most species of shark are rich in oil and there are many early historical accounts of Māori feasting on sharks, again, in my opinion, to fill up with non-protein caloric energy. Colenso, in 1841–1842, recorded the following:

> The natives of this place [Tamatarau in Northland], and in fact the whole neighbourhood, stunk insufferably from shark oil, and the effluvia arising from thousands of the *Squalus* genus, which were hung up to dry in the sun in all directions. This bay being shallow and sandy, is a favourite resort of several species of *Squalus* in the summer season; at which time the natives congregate together, and take them in great numbers (Colenso 1959: 49).

St John describes a mid-19th century village near Matata in the Bay of Plenty where "dried eels, fried in shark oil, followed by a second course of rotted maize, seemed to be the delicacies of the season" (St John 1959: 556). Another early historic reference to sharks as a highly desirable source of food, probably for their oil, is provided by Polack, travelling in the vicinity of Maunganui Bluff, Northland. The incident is worth recounting:

> On approaching towards the mountain, my olfactory nerves had been for some time discomposed; I now found the cause to proceed from the dead body of a shark, which had been cast on the beach full a month previously; and stormy tides had washed it high and dry on the beach. This offensive object was in the last stage of putridity and decomposition; and on Támároa [a Māori companion] approaching it, myriads of gad-flies issued from the body, which was about seven feet in length. My companion eyed it much, I rather thought wistfully, and observed, that the mango, or shark, was a rich treat to the New Zealanders.

> I assented, when it was to be had in a fresh state, but not in the disgusting condition of the fish before us (Polack 1838: 101–102).

After Polack had reached the bluff (which he calls a mountain), he turned and travelled more than seven miles back to Tangiari. When he arose next morning at 5 am, he found it difficult to raise his Māori companions from sleep, and some Māori women laughingly told him why:

> ...the boys had been absent all night, after I had retired to rest, and had hastened to the sea-shore, regardless of the distance, to devour the putrid shark; and, having filled themselves to repletion, they had slept a short time near the scene of their barbarous tastes, and had returned to Tangiari an hour before daybreak (ibid.: 107).

The use of shark oil is mentioned in a number of accounts of 19th century Māori life, and introduced European foods were quickly seized upon and incorporated into various concoctions, of which the following may not have been an exceptional example:

> a piece of hollowed wood being the vessel in which the ingredients were mixed: — The stem of the before-mentioned parasitical plant, Tawara, scraped and beat to a pulp; a few peaches and onions, chopped with a hatchet; a few cooked potatoes and kumera (the fruit of the Kohutuhutu, *Fuchsia excorticata*); the brains of a pig; a little lard or train-oil[6]; the juice of the Tupakihi (*Coriaria sarmentosa*), a berry similar in taste to that of the elder, whose leaves, branches and seed, are highly poisonous; and a little sugar, if they possess it; — these, all mixed together, are pressed to a pulp with the hands, which are often introduced into the mouth of the cook, who in this way manages to satisfy his own appetite, in tasting his dish before it is served up (Yate 1835: 111).

The combination of pig brains (? cooked), whale oil and peaches in this recipe may sound like an unlikely combination, but would be thoroughly nutritious for people often short of energy-rich non-protein foods.

In my experience, the strong desire for fat is widespread in the Pacific islands, and in some places can only be described as 'fat craving'. This provides a useful clue as to what it must have been like in early New Zealand, particularly in southern areas. In the highlands of New Britain where there are very few coconuts, which are a significant source of plant oil for coastal people, a great deal of human energy is devoted to hunting wild pigs as an important source of fat. Almost all the songs in the men's house at night are about endless adventures chasing pigs through the bush, although few songs seem to be about actually capturing them. Domesticated pigs in lowland coastal areas and in small islands of the Pacific are fed up so that they possess a very thick layer of subcutaneous fat before they are killed. During special feasts, high status people, such as European visitors, are afforded the honour of having a senior male seated opposite them to prepare individual tit-bits of the best food, which is passed on by hand to the celebrated guest. The greatest honour is bestowed when a chunk of fat pork is prepared, first by removing the meat, which is eaten by the senior male seated opposite, and then passing the huge slab of fat to the guest. Europeans may be astonished when confronted with such a custom, but in the context of an economy low in readily available carbohydrates and lipids, it is not at all surprising. When pigs are killed in Pacific islands, mesenteric fat is carefully gathered and pushed through a small hole into a coconut shell, later to

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[6] Train oil was any oil derived from whale blubber and used as lamp fuel and in soap manufacture from the 16th to 19th centuries.

be roasted or steamed in an earth oven, as a rare delicacy. In pre-European New Zealand there were no pigs, and the desire for fat must have been very pronounced.

There is ample evidence of this in early historical accounts relating to Māori. For example, the surgeon David Samwell on board the *Discovery* 13 February 1777 wrote in his journal:

> There were two or three Men on shore [Ship Cove, Queen Charlotte Sound] employed in melting down the Blubber that we got at Kerguelin's Land, & so fond were the New Zealand Ladies of this delicate food that they never refused to grant the last favour[7] for a few Spoonfuls of this stinking Oil; of this & all other kind of grease the New Zealanders both Men & women are very fond, & it must be confessed that in regard to their eating they are without exception the nastiest people under the Sun, hardly any thing coming amiss to them (Samwell 1967: 995–996).

This incident must have made quite an impression on the crew, and another rendition of the same event is provided in James Burney's Journal 24 February 1777:

> The New Zealanders are evidently ravenous & greedy—nothing comes amiss; but no victuals are so highly relished by them as the rank seal blubber we brought from Kurguelens Land, and which we boiled down here. So fond were they of this delicious food that some of our people who attended the boiling have for the skimming of the kettle procured very substantial favours (Burney 1914: 199).

The surgeon William Anderson also commented on the Māori desire for fat 25 February 1777:

> They also us'd to devour with the greatest eagerness large quantitys of stinking train oil and blubber of seals which we were melting at the tent and had kept near two months; and on board the Ships they were not contented with emptying the lamps but absolutely swallow'd the cotton and stinking wick with equal voracity (Anderson 1967: 812).

There cannot be a more graphic description of the desperate state of malnutrition of the New Zealand Māori at this time. In a land of super-abundance of fish and shellfish, how could people be so starving for oil as these passages show? From the foregoing description of basic nutritional requirements of humans, the answer must be obvious. These people had inadequate access to non-protein caloric energy. In short, they were suffering from 'rabbit starvation'. How widespread this was in New Zealand during this period is unclear, but historical observations from further north in New Zealand suggest it was not confined to Cook Strait.

Returning to the subject of nutrients in New Zealand fishes, the distribution of oil in the different body parts of some common New Zealand fishes is indicated in Figure 8.5. This shows that oil is reasonably well spread through the body, but with some exceptions. Blue cod has by far the greatest amount on oil in the head area, making this a particularly delectable treat for anyone short of food energy. It is also noteworthy that 63% of the oil in red cod is to be found in the guts. As mentioned previously, even the largest red cod can produce a disappointingly small fillet, and the European penchant for discarding everything except the fillet is clearly extremely wasteful. Red cod are often pulled up on a baited line with their bellies distended with 'whale feed' crustaceans, and this would be an added bonus for people eating the guts.

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[7] a polite expression for sexual favours.

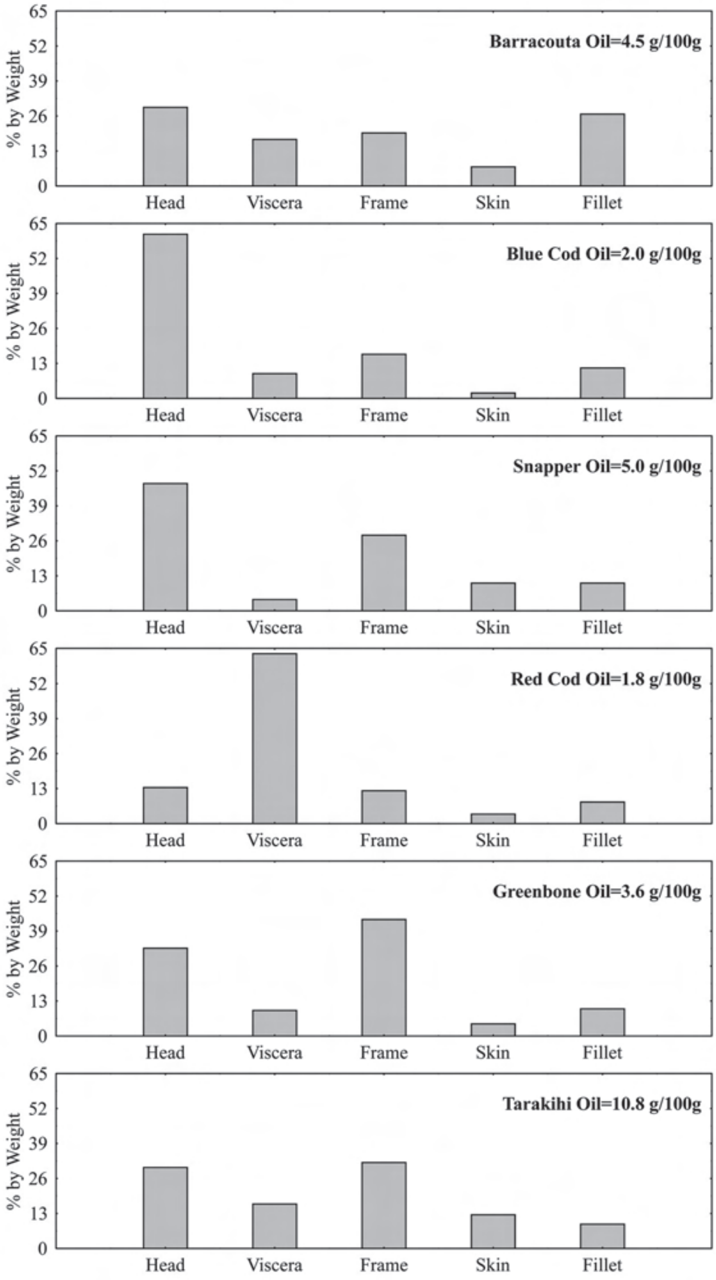

Figure 8.5: The percent distribution of oil in different body parts of common New Zealand fishes (from Vlieg 1988: 39 ff.). The cited values of protein in g/100 are for whole fish (after Vlieg 1988: 23 ff.).

Without doubt, the type of New Zealand fish that has the greatest amount of energy are the two species of freshwater eel (*Anguilla dieffenbachii*, the long-finned eel, and *Anguilla australis*, the short finned eel). Only passing reference has been made so far to eels in this book, the reason being that eels did not feature in the economy of pre-European Māori to any great extent. However, as also pointed out earlier, they were extremely important food items to many Māori groups during the early historic era, and the change of behaviour towards eels appears to have its roots in the late prehistoric/early protohistoric period. My working hypothesis for this change is that it is related to the onset of the Little Ice Age when conditions became very difficult for kūmara horticulture, especially in the Cook Strait region, and people turned to fat-rich foods as an alternative to carbohydrate as a suitable non-protein source of caloric energy. It is therefore useful to provide some nutritional information about eels at this point.

In total food value, eels average over 180 kcal/100g wet weight, which is nearly twice what can be expected from freshly harvested kūmara or fern root. The highest values for other fish species in New Zealand (Fig. 8.4) are for barracouta (107 kcal/100g) and tarakihi (108 kcal/100g)

The lipid profile of New Zealand fresh water eels resembles marine rather than fresh water fishes, in that the long chain fatty acids are rich in omega 3 forms, especially C20:5, and C22:6 (Eicosapentaenoic and Docosahexaenoic acids, EPA and DHA). This should not be confused with essential fatty acids. As shown above, eels have about 1.4 g EFA per 100g, and to obtain the daily requirement from this source, a modest 71 g of whole eel would be needed.

Because of the high proportion of body fat compared to protein in eels (Shorland 1948: 164 estimated 30% by weight), it would be possible to live on this source of food alone, in much the same way that Stefansson and Anderson did in their experiment cited earlier. This is illustrated on the left of Figure 8.6 where the proportion of caloric energy from eel protein is plotted against the percent of body weight that is fat (dotted line). This shows the boundary between an acceptable and a dangerous amount of food energy deriving from protein at about 30% of daily energy requirements. Above the dashed horizontal line it would be dangerous, and below it would be acceptable. The intercept of the two lines corresponds to 17.5% by weight of fat.

Not all eels would fulfil this necessary criterion, balancing protein and fat values, because the relative amount of fat in eels increases in a linear manner with increasing length of the fish. This is shown on the right hand side of Figure 8.6. For example, an eel which is 30 cm long has about 7% by weight of fat, and one which is 65 cm long has more than 30% by weight of fat. The critical figure of 17.5% by weight of fat is achieved by an eel with a length of about 45 cm. Below this length one could not live on eels alone. But above this length it would be possible to do so. Eels have all the essential fatty acids that are required; they have all the protein required; and they have the sufficient caloric energy deriving from something other than protein. New Zealand freshwater

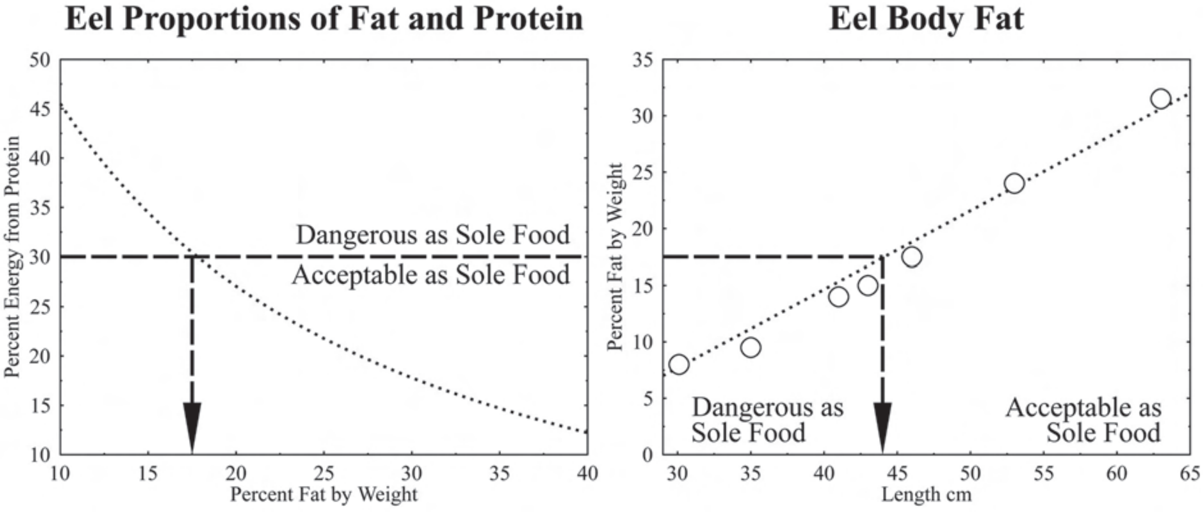

Figure 8.6: For humans with restricted access to carbohydrate food, eels would be a perfect survival food. Above 45 cm in length the energy deriving from protein and fat is in a suitable nutritional balance.

eels therefore can be seen as perfectly balanced food, assuming one can obtain the necessary vitamins and minerals as well.

At the beginning of this chapter three fatty acids were listed as essential to human metabolism; these were linoleic acid (18:2n-6), α-linolenic acid (18:3n-3) and arachidonic acid (20:4n-6). Some lines of evidence point to the idea that aquatic foods played an important part in the evolutionary development of the human brain, and that groups of people with a strong component of fish and shellfish in their diet have a distinct dietary advantage in this respect. The human brain is 60% lipid, mainly cholesterol and phosphoglycerides which are rich in 20:4n-6 and docosahexaenoic acid (22:6n-3) or DHA (Crawford 1992: 3). Most experts now agree that both n-6 and n-3 families of fatty acids are required in human diet, particularly for satisfactory brain growth. The human liver is poorly designed for synthesising these fatty acids, and there must therefore be a suitable source of food which can supply them. The best dietary sources of DHA are herbivore brains, fish and shell fish. Additional evidence of the importance of n-3 fatty acids (also called Omega 3) in human health comes from studies of Inuit and Japanese, who have lower death rates from cardiovascular disease (ibid.: 6).

An interesting nutritional study has been carried out of the people on Kitava Island in Papua New Guinea (Table 8.5). This is a small island in the Trobriands group, to the east of Kiriwina, the main island in the group. In this study, particular attention was paid to lipids in the diet and blood stream in an effort to understand the low incidence of heart disease. This low incidence is attributed to a high dietary ratio of n-3 to n-6 (Omega 3 and Omega 6) fatty acids, mainly due to consumption of fish foods (Lindeberg and Lundh 1993; Lindeberg and Vessby 1995; Lindeberg *et al*. 1994, 1996, 1997). The researchers found an n-3 to n-6 ratio of 0.11 compared with 0.05 for modern-day Swedish people. Another interesting aspect of their study was the finding that the general level of fat consumption was low at 21% of the caloric intake. Most of this fat was from coconut (34–39% by weight of mature kernel), more than 90% of which is in the form of saturated fatty acids, not the forms required for brain development.

TABLE 8.5
The Diet of the Kitava People, Trobriand Islands.
Daily median values for adults. Energy values are kcal/day, the rest are g/day
(After Lindeberg and Vessby 1995: 48)

Food	**Weight**	**Protein**	**Fat**	**Carbohydrate**	**Energy**
Yam, kūmara, taro	1,200	25	2	300	1,337
Fruit	400	3	<1	50	220
Coconut	110	4	43	7	445
Other vegetables	200	5	<1	14	86
Fish	85	17	4	0	106
Western foods	<1	0	<1	<1	5
Totals	**2,000**	**54**	**50**	**370**	**2,199**

European foods were still very uncommon on this island, so this study provides a most useful dietary baseline (Tables 8.5, 8.6) from the tropical Pacific region against which to view the diets which prevailed in pre-European New Zealand and the Chatham Islands. It also helps to reveal the extent of dietary adjustment that was required when Pacific islanders first reached these shores. In Table 8.6, comparative figures are also given for the Baegu people of Malaita in the Solomon Islands. These people live in the forested interior mountains and have a diet largely based on root crops, with hunting and fishing on a very small scale. From figures published by Ross (1976: 577) of average daily intake of protein, fats and carbohydrates, the relative amount of energy from these three sources can be calculated. These are provided for both male and female in Table 8.6. Although these people are seen to be extremely reliant on plant foods, consuming nearly 2 kg of food per person per day (ibid.: 576), their diet is surprisingly well balanced. Women have less access to higher status foods in this society, yet average out better for protein than men, although they are worse off for fats.

TABLE 8.6
Estimated Dietary Composition of Two Pacific Peoples,
Kitava in Trobriand Islands, and Baegu on Malaita.
Percent of Total Energy. RDA=Recommended Daily Allowances
(After Lindeberg and Vessby 1995: 48; Ross 1976: 579)

Component	**Kitava**	**Baegu Males**	**Baegu Females**	**RDA**
Protein	10	10.8	11.1	10–15
Saturated Fats	17	-	-	<10
Mono-unsaturated Fats	2	-	-	>10
Poly-unsaturated Fats	2	-	-	5–10
Total Fat	**21**	**18.3**	**13.7**	**≤30**
Carbohydrate	69	70.9	75.2	55–60
Total	**100**	**100.0**	**100.0**	**-**

In both cases, however, the percent energy from fat is quite low. This can be compared with very useful dietary information for Tokelauans in Tokelau collected four times over a period from 1966 to 1982, and for Tokelauans living in New Zealand 1974–1975 (Wessen *et al*. 1992: 292). The average percentage of energy deriving from protein, fat and carbohydrate are:

Population	**Protein**	**Fat**	**Carbohydrate**	**Total**
Tokelauans on Tokelau	12.3%	49.6%	38.1%	**100**
Tokelauans in New Zealand	14.9%	41.1%	44.0%	**100**

Unfortunately, there is no dietary information of this kind for traditional Māori society in any part of New Zealand, and it is now more than a century too late to record it. However, we can arrive at estimates for pre-European times from two primary sources of information: firstly, midden deposits containing faunal remains, and secondly from isotope analysis of minute samples of the residues of human tissue, such as collagen in bone.

MARINE FOODS IN PRE-EUROPEAN MĀORI DIET

This volume has mainly focused on fish remains in archaeological sites, and has largely ignored other foods harvested from the marine environment in New Zealand. When it comes to examining dietary questions, other marine foods need to be considered and, of course, plant sources of food as well. The latter pose a special problem in New Zealand archaeology because normally their quantitative role is archaeologically invisible.

Evidence from Midden Bones

The first serious attempt to evaluate the quantitative role of protein in ancient diet in New Zealand was by Shawcross, in a series of publications in which he worked out relative abundance of various species using MNI, and carried out experimental and literature research to assess the usable meat weight, caloric value and vitamin content of the different components. This research has already been briefly described and is now revisited in more detail.

The primary data which Shawcross used from the middens at Galatea Bay and Houhora were animal abundance values (MNI) of fish, shellfish, moa, dogs, sea mammals, etc. He estimated the average usable meat for each species, and was then able to combine this with MNI values to estimate the contribution of meat from the different types of animals represented in the sites. This was a useful attempt to provide, for the first time. a quantitative perspective on what the meat part of early Māori diet must have been like (Shawcross 1967a, 1972).

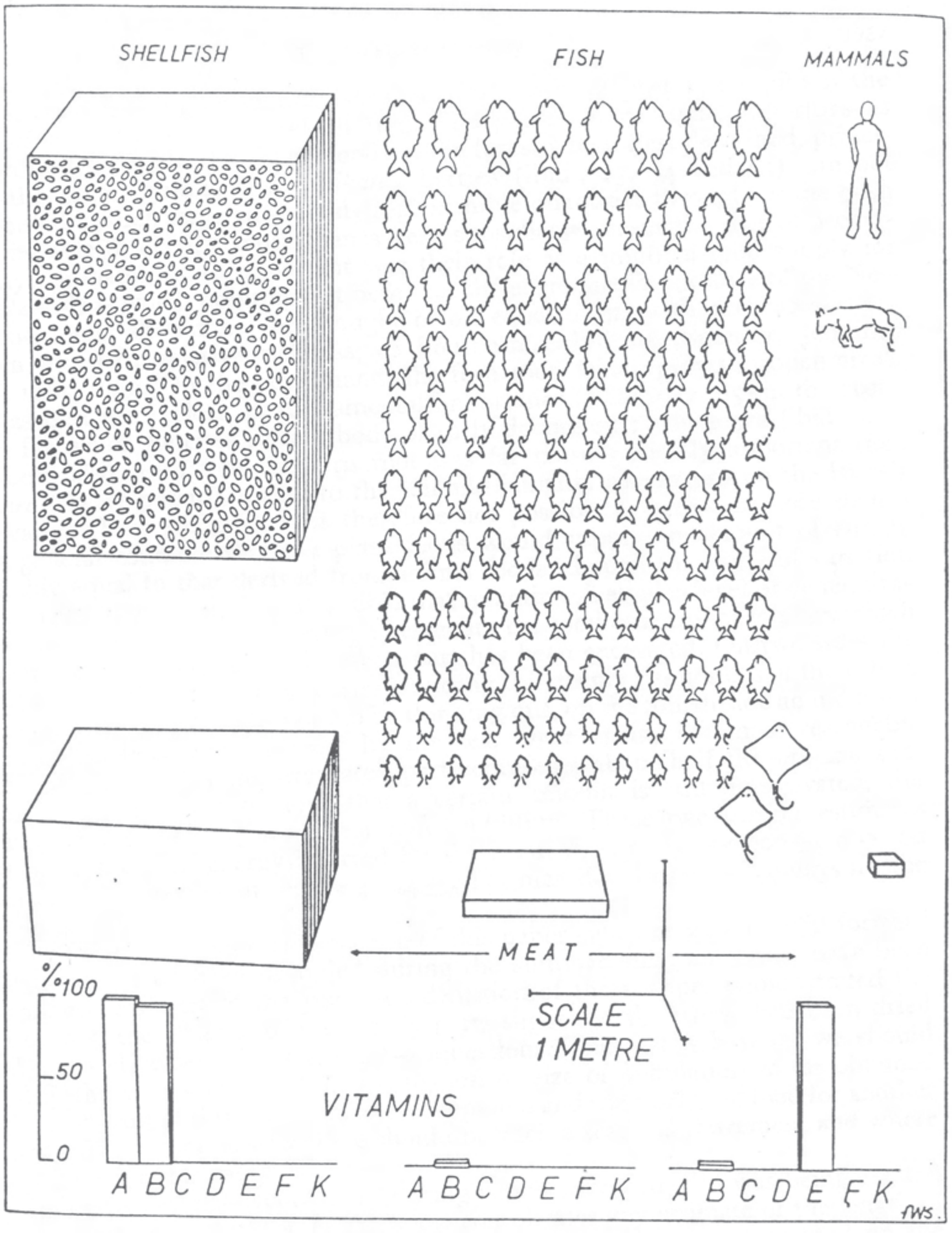

Figure 8.7: Proportions of different foods expressed as relative meat weights at the site of Galatea Bay, Ponui Island, Hauraki Gulf (from Shawcross 1967a: 127). Courtesy of Wilfred Shawcross and The Prehistoric Society.

The picture that emerges for the Galatea Bay site is shown in Figure 8.7. What this dramatically illustrates is the immense importance of shellfish as food at this site. Shawcross also assessed systematic errors in arriving at estimates of relative meat weight and possible length of stay for small social groups of various kinds. This work therefore marked an important advance in New Zealand archaeology, not only for its novel insight into palaeo-economics, but also for the introduction of discipline in the use of metrical data in archaeology. Such things were unheard of before this. With the increasingly widespread use of statistical techniques since Shawcross published this research, one might think that his approach of evaluating all possible systematic errors at each step has been overshadowed, but this is not so. In one area alone has this approach shown itself to be fully recognised, namely in the evaluation of radiocarbon dates. No longer do archaeologists

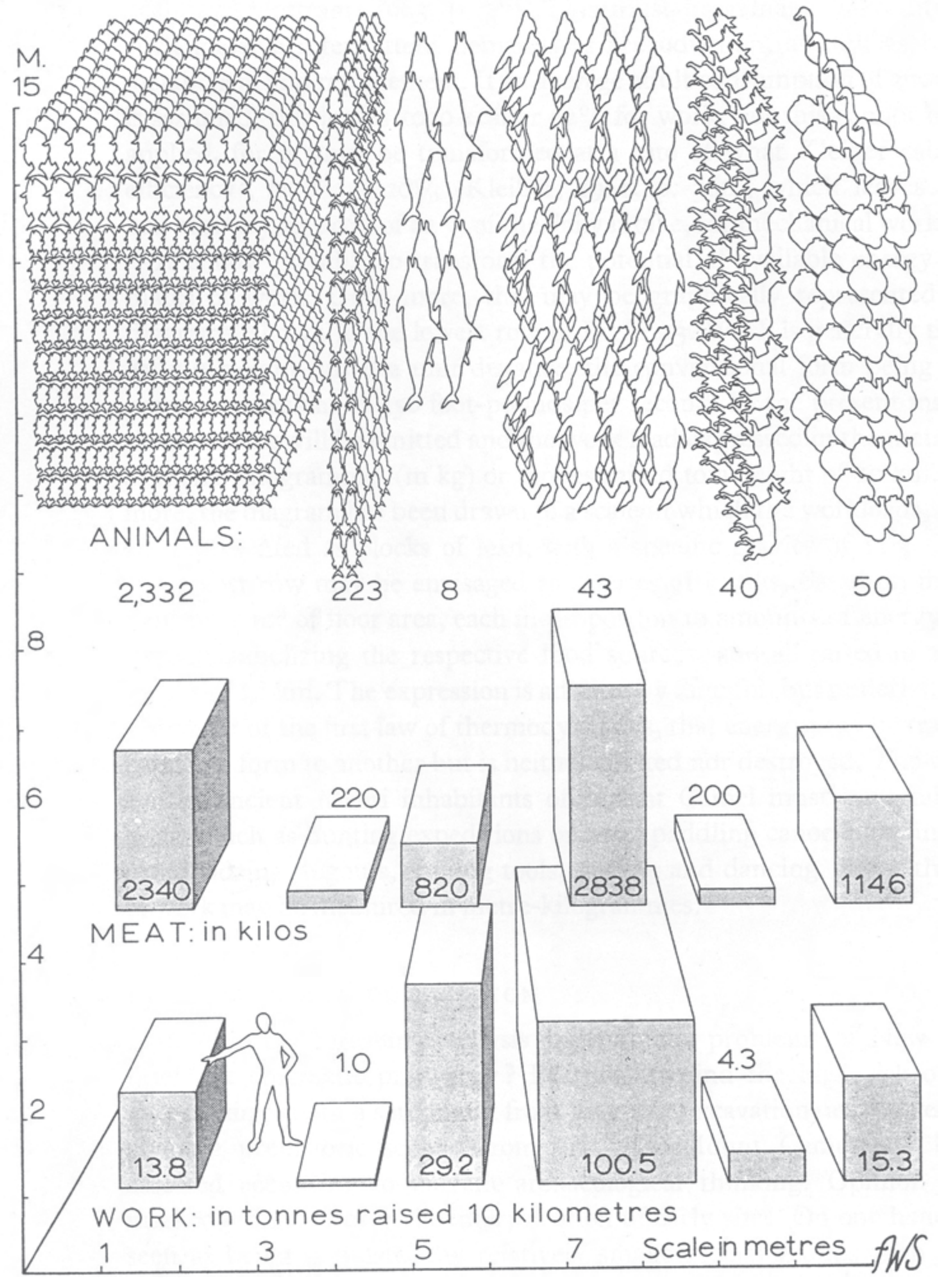

Figure 8.8: Proportions of different foods expressed as relative meat weights at the site of Houhora, near Mount Camel, Northland (from Shawcross 1972: 613). Courtesy of Wilfred Shawcross and Taylor & Francis (Methuen).

merely notice the purely statistical error associated with a radiocarbon date; they also take great notice of other sources of systematic error, such as inbuilt age, δ^{13}C corrections, ΔR assumptions, secular calibration, and so on. However, Shawcross's method of adding errors at each step of economic calculations, to yield a final realistic error at the end, appears to have been largely ignored. Shawcross's method follows standard procedures used in all branches of science (with the apparent exception of archaeology), and would be common knowledge amongst secondary school pupils carrying out a simple experiment in physics[8], when errors are estimated and combined at each step in the experiment (Daish and Fender 1956: 21–23, 306 ff.). Shawcross reached the dramatic conclusion that a small family group of Māori could sustain themselves on the resources in the Galatea Bay site for 692 days ± 699 days! (Shawcross 1967a: 128). This shocking result, with its enormous systematic error, has not had the effect of deterring later archaeologists from calculating meat weights from archaeological sites, but I know of no other published account where the accompanying systematic errors have been evaluated with such candour. On the contrary, it is the custom with economic calculations of the kind Shawcross was making about meat weights simply to ignore the effect of error accumulation through each step.

The second major study carried out by Shawcross was of a much more complex site at Houhora in Northland (Shawcross 1972). Although shellfish were present in abundance in the site, as a latex pull once displayed in the Auckland Museum showed, only five small samples were analysed (Roe 1967; Furey 2002: 119–120). Far greater attention was given to the large amounts of fish, dolphins, seals, dogs, moa, and smaller birds of various kinds. The numerous moa bones in this site conveyed an impression that these birds were the most important aspect of the subsistence economy; however, Shawcross's study showed, for the first time in New Zealand, how misleading such impressions can be, and that fish and sea mammals were actually more important (Fig. 8.8). Although Shawcross's methods have been refined over the years, his basic quantitative information on relative species abundance is still usable, and can be compared with that from other sites excavated in the last 30 years.

Trying to assess the role of marine foods in diet on a New Zealand-wide basis is not an easy task. The kind of information generated by Shawcross's research is unfortunately not common. One very simple approach is to document the amount of fish recovered from excavations in sites throughout New Zealand (Fig. 8.9). This is a very rough and ready indication of how important fish was to various pre-European communities scattered from the far north to the far south. Such a picture ignores the fact that some of the excavations involved very small areas of large sites, and others large areas of very small sites. However, even such a simple graph does show that with the exception of Houhora, sites with an MNI of more than about 1,000 fish have only been found south of Banks Peninsula. This includes several sites in the Chatham Islands. It is interesting that when the same data are plotted using a logarithmic vertical axis, the latitudinal differentiation disappears. This suggests that there are a few key sites in the South Island which stand out far above the rest as having large amounts of fish, and which may not be typical of the more general pattern. Whether this means that these sites were 'central-places' of special sociological importance to more disparate community settlements is unknown, but is a possibility.

One of these sites, located at the mouth of the Shag River in Otago, has long been known as an important site with abundant moa bones and numerous artefacts. This wealth had the unfortunate effect of attracting many curio hunters over the years and a great deal of uncontrolled excavation has therefore occurred at this site. Anderson and colleagues tried to salvage something from the site

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[8] When adding or subtracting two values together, the final error is the sum of the two separate errors. When multiplying or dividing two values, the final percentage error is the sum of the two separate percentage errors.

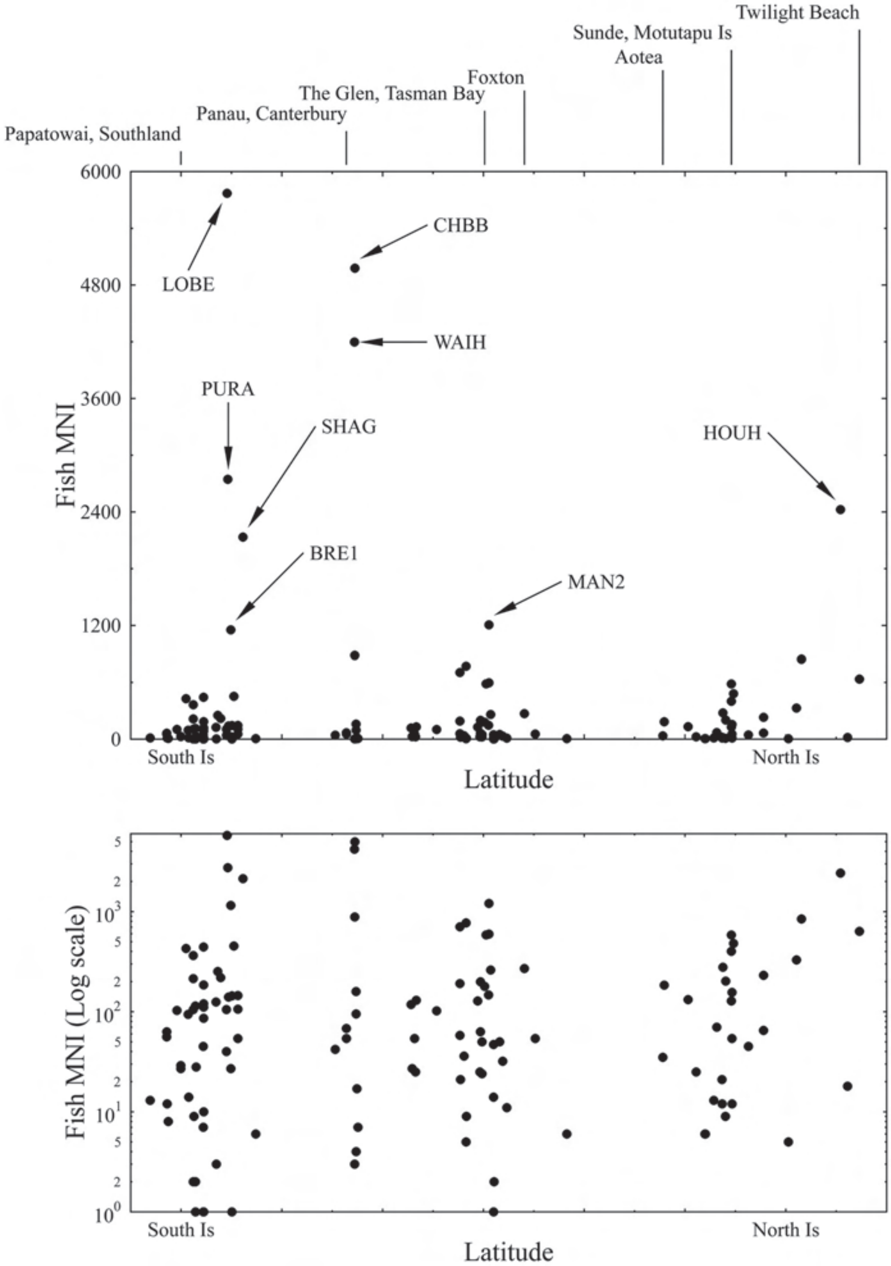

Figure 8.9: The abundance of fish in 126 archaeological sites in New Zealand organised by increasing latitude. With one exception (Houhora), sites with very large amounts of fish are only known south of Banks Peninsula. When plotted with a logarithmic vertical axis (below), any difference between North and South Island sites disappears. Full names of sites are given in Appendix 1.

using modern techniques (Anderson *et al.* (eds) 1996). This has resulted in high quality economic information of the same general character as Shawcross's, which can be used to assess the relative role of meat foods, at least, in ancient New Zealand diet. One should not underestimate the background research required to do this. It has taken a great deal of work over many years to establish the usable portions of the butchered carcasses of different species of sea mammals, birds, and moa. The effect of this is that the raw MNI data produced by Shawcross and others, including myself, can be re-evaluated and more meaningful comparisons drawn between different sites throughout New Zealand.

For example, a simple list of the main meat components in the Shag River site has been drawn up in which very simple guidelines are applied for usable meat for major groups of animals (Anderson *et al*. 1996c: 279):

MNI	g/individual	Type of Animal
70	55,420	Moa
76	9,240	Dog
510	740	Small birds
55	140	Rat
75,279	2.3	Shellfish
1,442	1,120	Fish
57	30,810	Fur seal
30	85,540	Other sea mammals

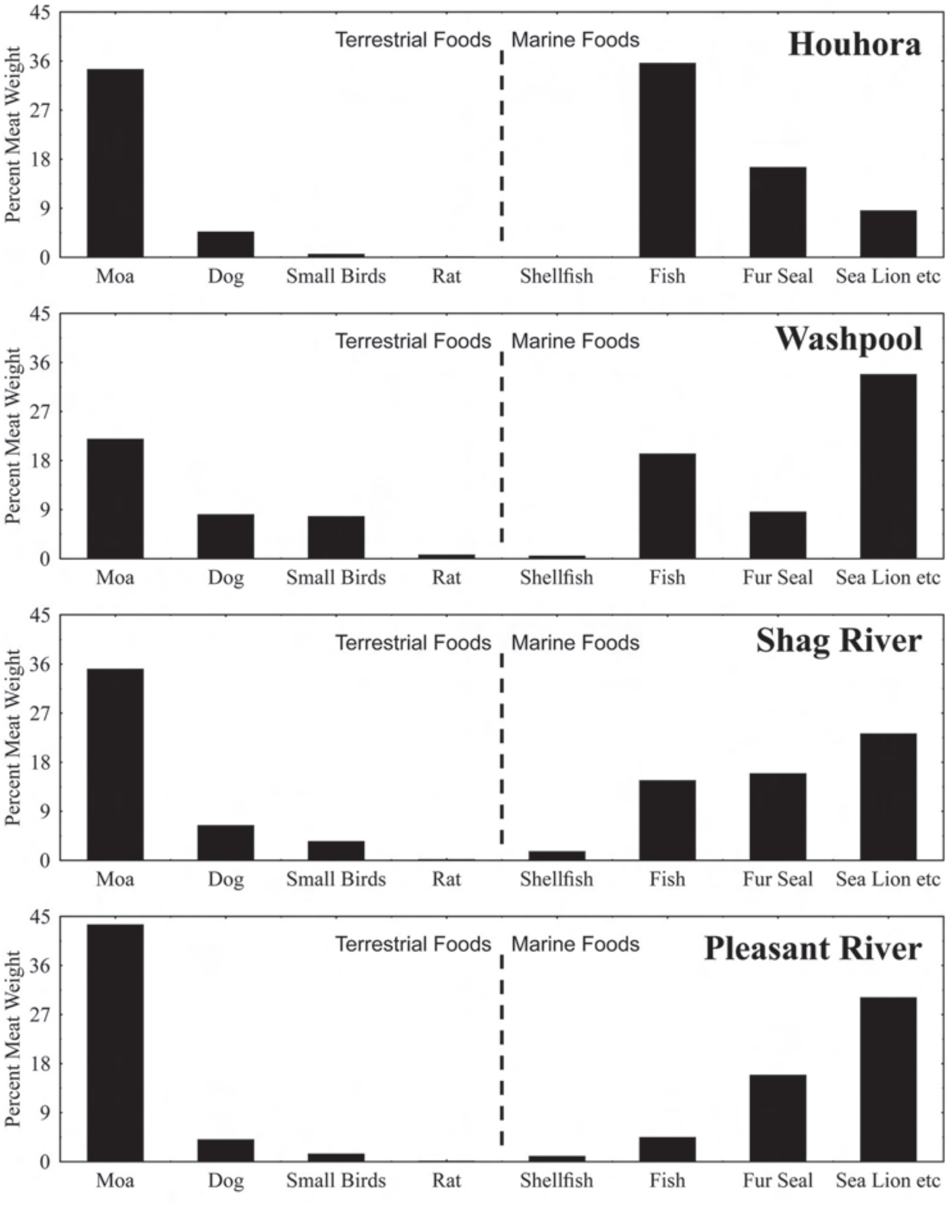

Figure 8.10: Relative meat weights of terrestrial and marine foods in some key sites in New Zealand from analysis of animal remains in archaeological sites.

The central column can be used to recalculate Shawcross's assessment of Houhora (Fig. 8.10). This is particularly interesting, because it shows that sea mammals were nowhere near as important as Shawcross thought. Also, moa assume far greater importance relative to fish than originally suggested. One could start splitting hairs here and explore the question that different species are involved at the two sites, but equally one could argue that it is useful to use the same general assumptions when trying to compare sites in this way. One can go to a great deal of trouble to work out the age of each individual fish or moa and assess season of death and 'condition factor', and so on, and still not necessarily get any closer to the correct ballpark. There is strength in providing similar rules for different sites. When analysing trends within any one site, however, it may be desirable to apply metrical values appropriate to the animals available very locally to it.

Figure 8.10 presents the relative meat weights for marine and terrestrial animals at several key sites, two in the North Island and two in the South Island, using the g/individual values cited above. Several interesting things are revealed. Moa clearly increase in importance the further one moves southwards. The Washpool site, situated on the northern shores of Cook Strait, is located in an area where there were no naturally occurring moa during the period of human habitation, and the moa remains were derived from elsewhere as trade commodities. Nevertheless, they still figure in the economy. Fish are very abundant in the far North and steadily decrease in importance the further south one goes. Sea mammals were important at all these sites, and shellfish played only a minor economic role. Incidentally, these four sites are all relatively early in the prehistoric sequence in New Zealand, and the patterns are likely to be quite different for late sites.

Although such a graph may be useful in helping us to appreciate the relative importance of terrestrial and marine meat in diet, it is only a small step towards understanding the dietary importance of these foods. We could convert these relative meat weight values to those appropriate to protein, carbohydrate and fat, which would begin to come a little closer to the kind of nutritional information a dietitian would understand. This would show that carbohydrate was practically nil in these diets, since meat foods have practically no carbohydrate! Moreover, it would not show the contribution of protein from plant foods. Just such a study has recently been published by Smith (2004). This is a masterly attempt to explore the quantitative role of marine foods in 49 faunal assemblages from one end of New Zealand to another. He calculated the total usable meat weights for each species using average values per individual for fish, shellfish, sea mammals, terrestrial mammals and birds, including moa. For each of these he also used average values of protein, fat and carbohydrate, so that estimates can be made of the total contribution of each to the diet of people responsible for these faunal assemblages. This permitted him to plot each archaeological assemblage using these all-important nutritional components (Fig. 8.11).

This study is the culmination of an enormous amount of research carried out over many years. Smith shows that fish were the leading source of meat and protein in all assemblages studied, and were greatest in the northern part of New Zealand and lowest in the south. He also found evidence of increasing importance of fish in central and southern New Zealand over time.

As Smith was careful to point out, "the major concern of this paper is with the relative importance of fish in relation to other *animal* foods in the diet of prehistoric New Zealanders" (Smith 2004: 6), and he is fully aware of the problems of attempting an assessment of prehistoric nutrition using animal evidence alone. To achieve a fully rounded picture of prehistoric diet we need to adopt a different approach whereby all the major nutritional components can be identified quantitatively. Until fairly recently such an approach seemed impossible because the extent of plant foods in diet was archaeologically invisible. We know that plant foods were part of ancient New Zealand diet because we see kūmara storage pits on the landscape, garden plots neatly laid out with stone wall

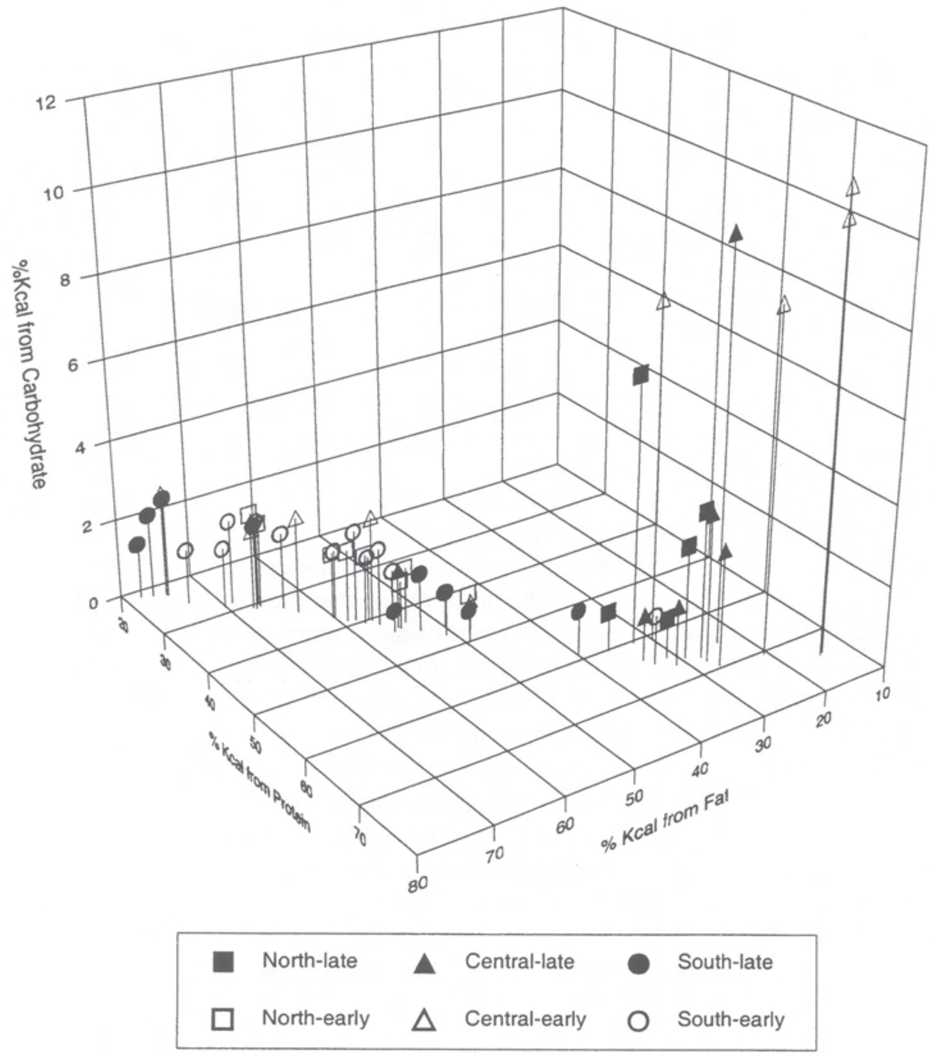

Figure 8.11: Proportions of energy from protein, fat and carbohydrate using meat weight data alone for marine and terrestrial animals in 49 archaeological assemblages throughout New Zealand (from Smith 2004: 24).

boundaries, human remains with translocated teeth as a result of stripping fern-root, and occasionally even carbonised kūmara tubers. However, the recognition of these signs is only the first tottering step towards defining the quantitative role of plants.

The Use of Isotope Analysis

The possibility of defining the quantitative role of different types of foods comes about because the chemistry of different foods is not the same. When we ingest food we pick up defining markers of those foods, which can later be identified in human tissue samples. To give a simple example — methyl mercury is a toxic compound to be avoided if at all possible. If eaten with food, it has a very long half-life in human tissue, and therefore we can take a hair sample from an individual, or a blood sample, or indeed a small fragment of bone or tooth long after the person has died, and determine how much of the toxic food had been eaten by the person. The same underlying ideas provide the basis for identifying the role of non-toxic foods, which have more subtle but equally permanent markers. Figure 8.12 shows the basis for this, using isotopes of carbon, nitrogen and sulphur. In the top part of the graph, the carbon and nitrogen isotope values for land-based carnivores and herbivores are plotted. It can be seen that there is not very much overlap. If you had,

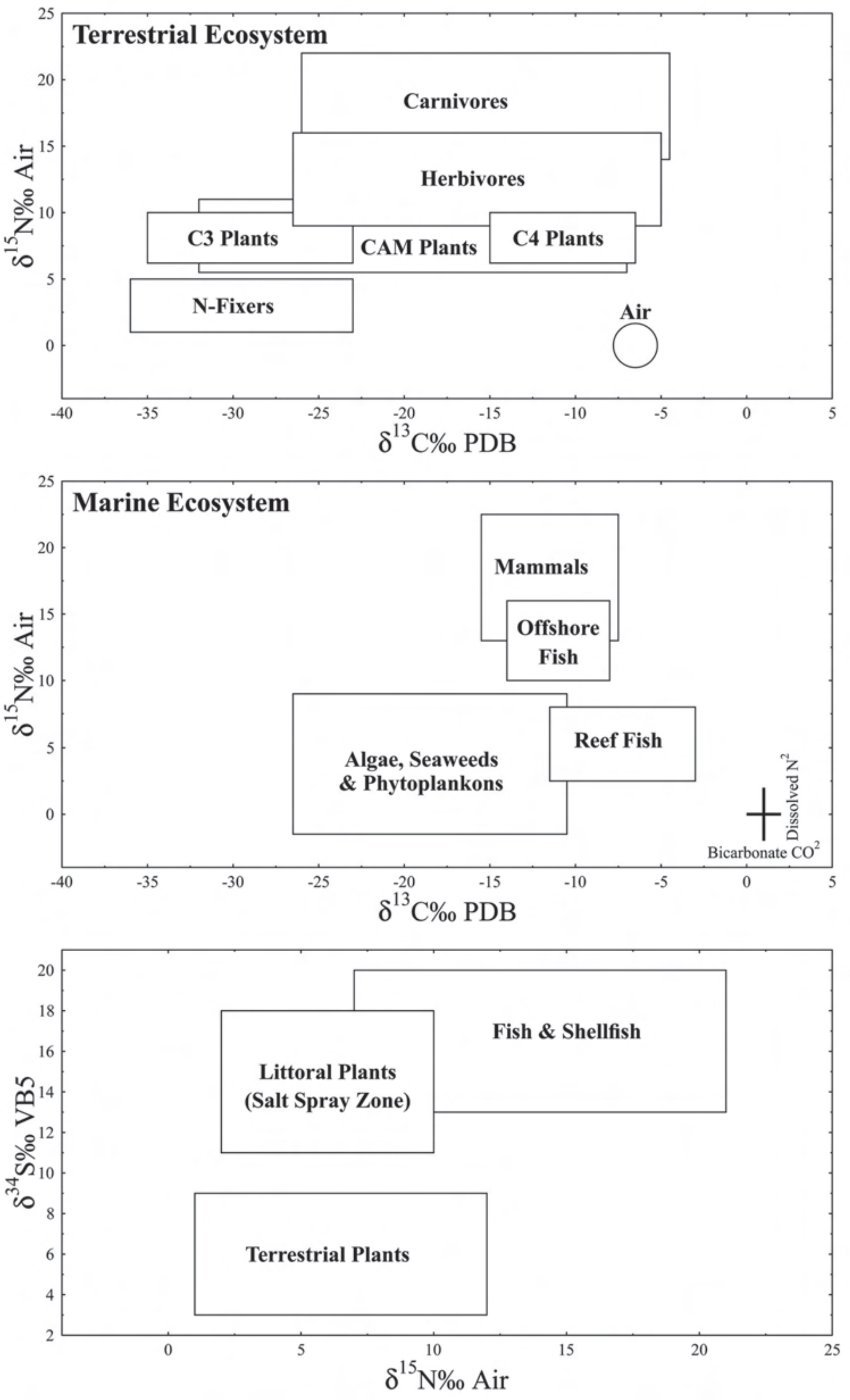

Figure 8.12: Isotope fractionation in the plant and animal kingdoms (after de France *et al*. 1996: 299, and the author's research).

say, a hair sample and you knew it was from a land-based animal, you could carry out an analysis of the carbon and nitrogen isotopes in it and from this information make a pretty reliable identification of whether the animal was a carnivore or a herbivore. The unique isotope signature of one animal is passed on to another animal which eats it. So, if a human ate only terrestrial carnivores, it would be possible to establish this from a tissue sample from the human.

As might be expected, the real situation is a great deal more complex than these simple examples. In the central part of the graph, animals and plants from the marine environment are plotted. From this it can be seen that the nitrogen isotope helps to differentiate between marine mammals, oceanic fish, and those fish which live close to land in the reef area.

It is of great importance to note that if the middle and top graphs are superimposed, the C3 plants and Nitrogen fixing plants are in an area which cannot be confused with anything else except marine algae and seaweeds. This means that if a tissue sample from a human has an isotope signature in this region of the graph, one can be certain that C3 plants were a major component of the diet of the person concerned.

What are these C3 plants? It has been found that plants photosynthesise energy from the sun by one of two quite different biochemical pathways. One leads to a δ^{13}C value in the plant tissue of about −26‰, and the other of about −11.5‰; these are the C3 and C4 plants respectively. The C4 plants are the odd ones out, and are mainly grasses. Some of these grasses are edible and the important one in the Pacific region is sugar cane. Anyone eating a lot of sugar cane would obtain a characteristic δ^{13}C value, which an archaeologist could later determine from a sample of human bone or other tissue. The intermediate CAM (crassulasian acid metabolism) plants are succulents which are able to switch from C3 to C4 depending on environmental circumstances. These plants are seldom if ever eaten. The majority of the plants we are concerned with here, including kūmara and bracken fern, are C3 plants.

When these isotope ratios began to be studied using ancient human tissues, such as a fragment of skin, hair or the organic part of bone (collagen), the main aim was to identify the differential roles of terrestrial and marine foods on the one hand, and plant and animal foods on the other. This research has been moderately successful but, as can be seen when the top two graphs are superimposed, there is a lot of overlap between different categories and therefore ambiguity in working backwards from a tissue sample to the original mixture of different foods in diet. Moreover, in a paper by Schwarcz (1991), it was argued that there is a strict theoretical limit to the number of sources of food that could be reconstructed from a fixed number of isotope ratios (effects). He stated this relationship simply as follows:

> Using analyses of a given number, N, of isotope elements (C, N, H, O, etc.) it is possible in principle to estimate the proportions of N+1 dietary compositions of known, well defined isotopic composition. For maximum effectiveness, any isotopic palaeodiet study should be preceded by an archaeological, archaeo-botanical and -zoological study to define the lists of foods that were actually consumed (Schwarcz 1991: 273).

This strict theoretical limitation only applies in the case of what Minagawa has called the ‘analytic feeding model’ where an exact algebraic solution is sought (Minagawa 1992: 146–147). Schwarcz’s requirement is unnecessarily harsh, and Minagawa suggests that it is possible to reconstruct more than N+1 dietary constituents from N isotopes, if one takes a somewhat more relaxed approach to the matter, and sacrifices exact solutions in favour of probable ones. This seems a perfectly reasonable suggestion, given the sources of variation in this field. Moreover, this model also permits us to integrate isotope research with faunal analysis as the following makes clear:

> Another useful suggestion has been made to expand the information base by incorporating the results from classical midden analysis into the interpretation of isotope signatures (Minagawa and Akazawa 1989: 10–11, 1992). This concept is a little like the 'box or slot' model, and consists of placing a series of Boolean filters along the path to dietary interpretation. It could also incorporate the filtering out of unlikely possibilities based upon ecological or geographic factors. For example, if one was investigating the diet of a group of people on an island where no C4 plants are found, then the part of the algorithm which calculates the contribution of C4 plants from a collagen $\delta^{13}C$ value can be ignored. This suggests adopting a more flexible approach when interpreting cause from effect in this field, and using a mixture of common sense Boolean logic as well as arithmetic and/or multivariate modelling (Leach *et al*. 2003: 64);

This procedure of integrating the results of faunal analysis within the isotope simulation algorithm was detailed in the description of the first step of the stochastic model: "Read all the assumptions being used for a particular problem. This consists of the values presented in either Table 2 or Table 3 plus the mean isotope signature for the group of people being studied, together with any known food proportions, established from archaeological studies" (Leach *et al*. 1996c: 26). The ability to blend the results of faunal analysis with isotope analysis of human tissues does not seem to have been fully understood, as is clear in Smith's following statement:

> However, it has never escaped the major limitation imposed by its inability to document the role of plant foods because of their virtual absence from the archaeological record. Valuable information about the dietary role of plant foods can be gained through stable isotope analysis of human tissues (e.g. Leach *et al*. 2000c; Davidson and Leach 2001), but there is as yet no clear method for integrating such data with that of faunal analyses" (Smith 2004: 6) [emphasis mine]

On the contrary, where good quality information exists on the relative abundance of different items of fauna, this may readily be incorporated into the isotope simulation analysis, as the foregoing has made clear.

This field of research has taken a significant step forward recently with the use of a third isotope, ^{34}S, which differentiates much more clearly between sea foods and land foods (bottom of Fig. 8.12). This greatly helps to solve ambiguities which arise when using only ^{13}C and ^{15}N. However, in some littoral plants where there is a lot of salt-water spray, a mixed $\delta^{34}S$ can result. My own research has revealed this with some coconuts and root crops growing on soils close to the sea on Pacific Islands. Despite this minor set-back, ^{34}S has added a very important new dimension to dietary studies using isotope markers. Bone protein contains two amino acids, methionine and cysteine, which have sulphur in their molecules. Unfortunately, cysteine breaks down very quickly and disappears, but there is usually sufficient methionine to carry out isotope analysis. Typically, there is between 0.75 and 0.79 Molar percent methionine amongst the amino acids in archaeological samples.

Some isotope results for New Zealand and Chatham Islands tissue samples are shown in Figure 8.13. Although there are complications, basically the isotope values on the left hand side of each graph result from diets which are terrestrial in origin, while those on the right hand side result from diets which are more derived from the sea. Bearing this simple criterion in mind, it will be noticed that the analyses of individuals are reasonably consistent. The European person on the far left (a

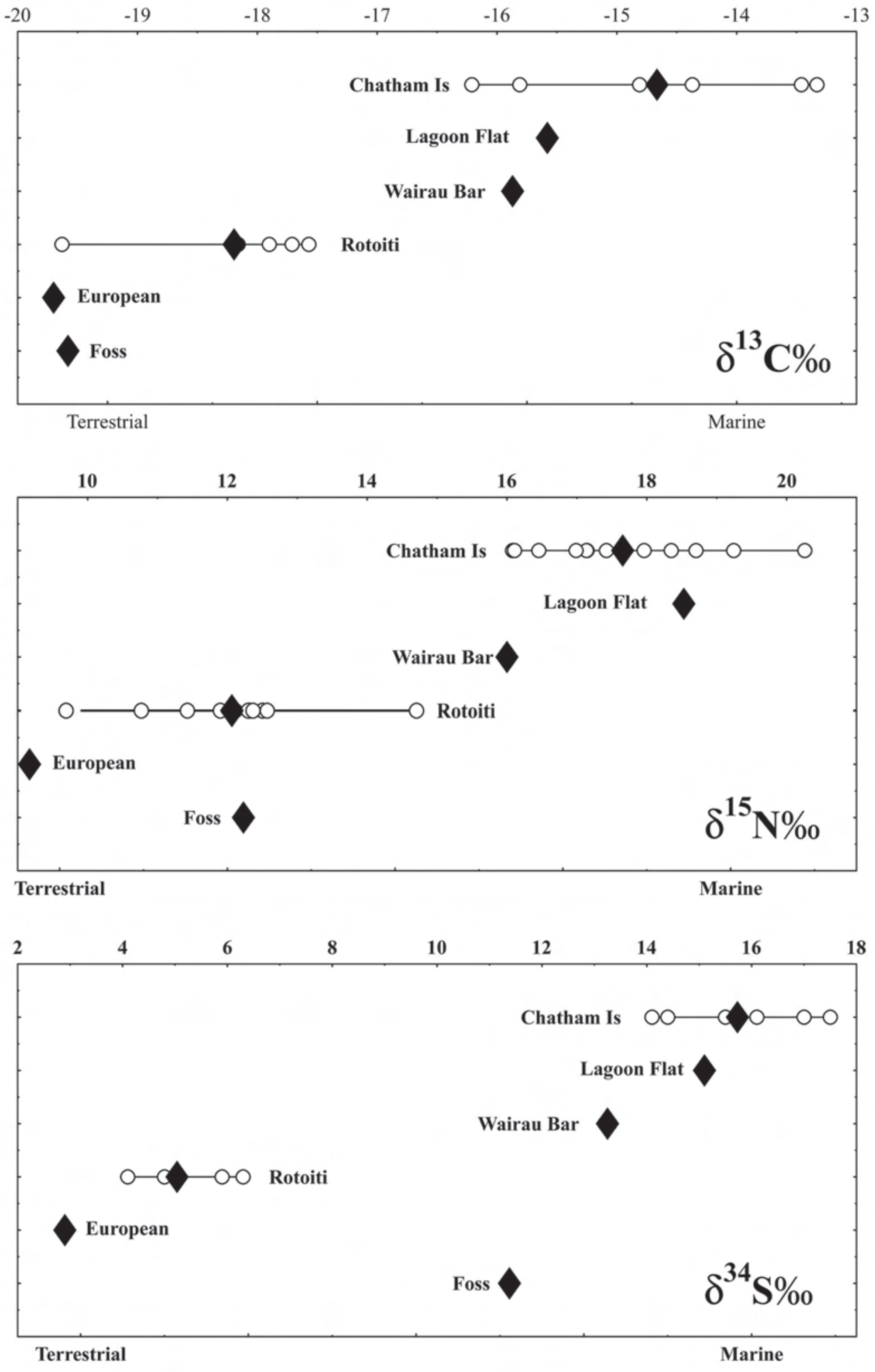

Figure 8.13: Isotope results from some New Zealand and Chatham Islands bone collagen samples.

person who lived in the South Island and died in the 19th century) has a very terrestrial signature in all three isotopes; whereas the Moriori of the Chatham Islands are right over on the right hand side of the graph, indicating a strong reliance on marine foods. People from Rotoiti, near Rotorua in the inland North Island, are shown to have a strong terrestrial diet, as might be expected from their location. The values marked 'Foss' on these graphs are from the bone removed during my total knee replacement. This shows a basically terrestrial diet, but confirms a modest contribution of marine foods.

These bald isotope values for particular prehistoric groups, leading as they do to rough estimates of the amount of terrestrial versus marine food, do not take us much further ahead in the quest to understand the main ingredients in the original diet. We need now to use two sources of additional knowledge to provide the vehicle for a more detailed reconstruction. The first source consists of the accumulated knowledge of the isotope composition of the various foods which a particular prehistoric group could have eaten. For instance, if there is no sugar cane or similar C4 plants in the South Island of New Zealand, there is little point in permitting this possibility in our reconstruction. However, some South Island groups could have grown some kūmara, so we need to allow for the possibility that foods of this isotope composition could have been eaten. The second important source of information comes from the results of traditional midden analysis. For example, if we know from bone studies that the people at Shag River Mouth collected and ate southern fur seal and moa in a certain proportion, then we should make sure that our attempt to reconstruct the diet from the isotope values is constrained by this archaeological finding.

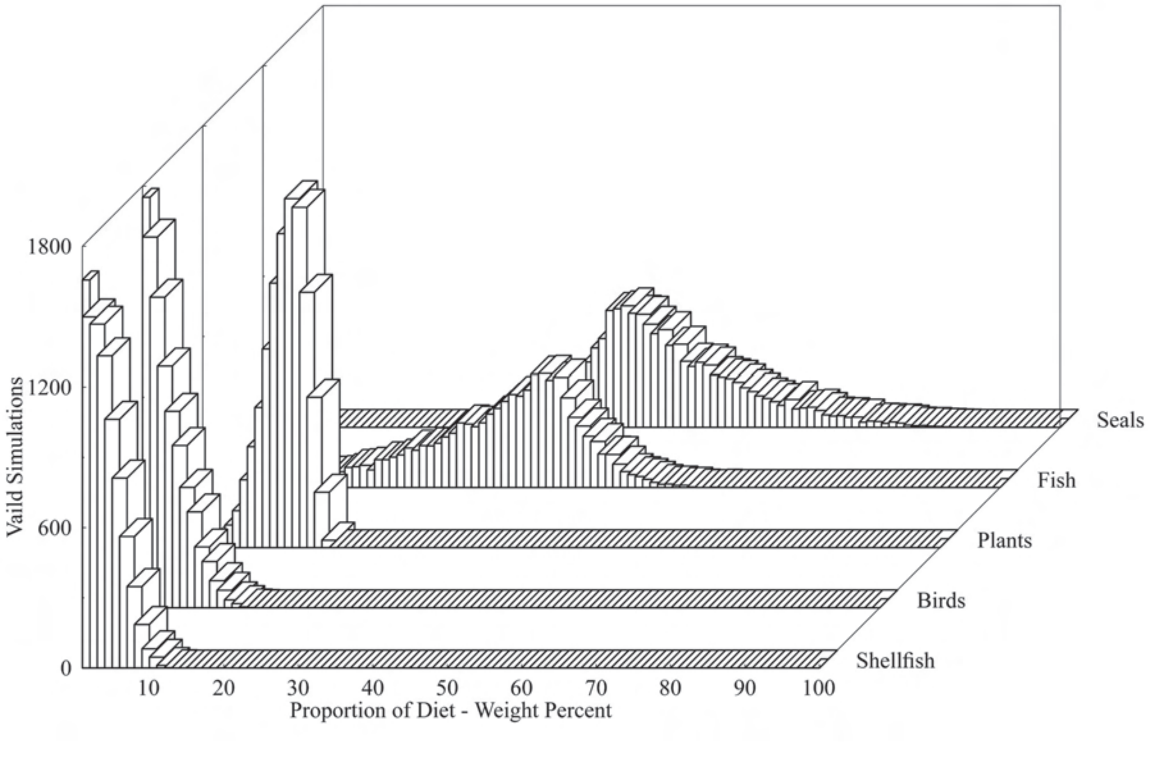

Figure 8.14: The diet of Moriori people of the Chatham Islands as reconstructed using isotope analysis and computer simulation (after Leach *et al*. 1996c: 32).

TABLE 8.7
Reconstructed Daily Diet for Moriori of the Chatham Islands. (after Leach *et al*. 2003: 71)

	Mean Weight %	**SD**	**Raw Food Weight g**
C3 Plants	13.5	2.0	159.7
Land Animals	2.8	2.1	33.1
Marine Shellfish	3.3	2.3	39.1
Marine Fish	31.8	11.1	376.2
Marine Mammals	48.6	10.7	574.9
Totals	**100**	**-**	**1183.0**

Weight (g/day)	**Protein**	**Fat**	**Carb**	**Total**
C3 Plants	3.5	9.6	47.9	61.0
Land Animals	7.4	9.6	0.0	17.0
Marine Shellfish	5.1	0.4	1.2	6.7
Marine Fish	74.2	7.5	0.0	81.7
Marine Mammals	80.5	126.5	11.5	218.5
Totals	**170.8**	**153.6**	**60.6**	**385.0**
Percent	**44.4**	**39.9**	**15.7**	**100.0**

Energy (kcal/day)	**Protein**	**Fat**	**Carb**	**Total**
C3 Plants	11.3	68.8	153.0	233.1
Land Animals	12.8	37.1	0.0	49.9
Marine Shellfish	19.4	3.4	4.5	27.2
Marine Fish	306.8	70.0	0.0	376.8
Marine Mammals	322.0	1138.4	46.0	1506.4
Totals	**672.2**	**1317.7**	**203.4**	**2193.4**
Percent	**30.6**	**60.1**	**9.3**	**100.0**

A computer simulation process has been developed to take into account all the sources of information and arrive at a 'best-fit' diet which satisfies the isotope values obtained for a particular prehistoric group (Minagawa 1992). Figure 8.14 is an example of the results of this simulation process for the prehistoric Moriori people of the Chatham Islands (see also Table 8.7). This mathematical simulation process is simple in its basic concept, yet somewhat complicated to implement. Careful examination of the full extent of the assumptions involved led to a list of 63 conditions which must be satisfied at all times (Leach *et al*. 1996c), ranging from an average value for $\delta^{13}C$ for C3 plants which could have been eaten, to fractionation effects in human metabolism when food with this $\delta^{13}C$ value is eaten. The basic requirements of human diet, outlined in the first part of this chapter, are fundamental to the simulation.

A typical example of the simulation working is as follows:

1: Generate a single meal consisting of the randomly chosen proportions of five basic foods (C3 plants, birds, shellfish, fish, marine mammals).
2: Does this satisfy all 63 primary assumptions?
If not go back to 1, otherwise continue.
3: Calculate the three isotope values which a person would have in their collagen if they ate such a meal. If it is significantly different from the isotope values we obtained from our analysis of the prehistoric group then go back to 1, otherwise continue.
4: If we get here, we have found a meal which satisfies all conditions, so keep a record of the meal composition, and go back to 1. Repeat until satisfactory statistical stability has been reached.

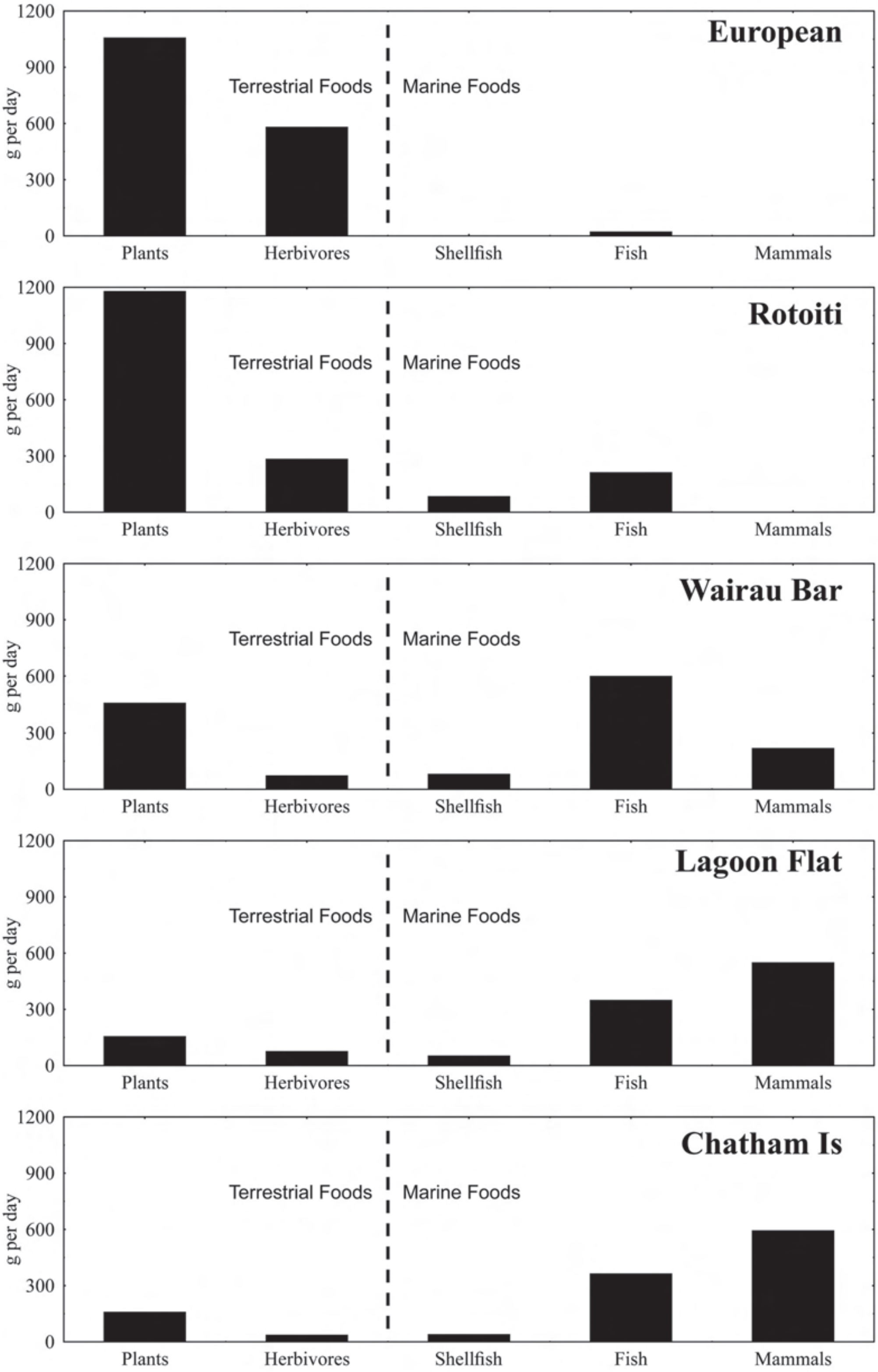

Figure 8.15: The major components in the diet of several New Zealand and Chatham Island individuals from stable isotope analysis of human bone collagen. The European is a 19th century South Islander.

After many millions of times round these loops from 1 to 4, we begin to build up a picture of all the possible meals which could have produced the kind of isotope signature we obtained in the original sample of human tissue. Such a picture is presented in Figure 8.14.

Once we have built up our reconstructed diet, we can also back-calculate the protein, fat and carbohydrate values from each of the original food sources. For the Chatham Islands example, this information is given in Table 8.7. Of special interest is the ‘bottom-line’ of the Table, that is, the relative sources of energy from protein, fat and carbohydrate. In the case of the Chatham Islands, the proportions are 30.6%, 60.1%, and 9.3%.

The same process can be carried out with additional isotope results of further individuals to build up a database of diets in time and space and start looking for patterns. Some further results are presented in Figure 8.15, which begins to show the extent of variation around New Zealand. The energy contributions from protein, fat and carbohydrate for these same groups of people are plotted out in Figure 8.16. In might be noticed that shellfish does not figure prominently in the reconstructed diets of any of these human groups in Figure 8.15. This is in close accord with the earlier crude estimates based entirely on meat weights from analysis of bones (Fig. 8.10).

Earlier in this chapter I paid considerable attention to the need to address the extent of errors in quantitative economic analysis, following the lead set by Shawcross 40 years ago. So the question arises—just how good is this isotope simulation method? Being a stochastic process it produces a range of ‘best fits’, and this range is readily observed in Figure 8.14. Quantifying this range involves keeping track of statistical variation during the simulation process, and typical values are provided in Table 8.7 as standard deviations of the mean weight percentages. Although these values appear rather large, they are probably realistic.

At last we can begin to see the true role of fish and other marine foods in the diet of groups from different parts of New Zealand and the Chatham Islands. It has come about by blending results from traditional midden analysis (identifying, counting, and measuring fish bones, and reconstructing catches and relative species abundance) with those from isotope analyses on tiny scraps of human tissue. Both sources of information are required for such a conclusion.

This kind of research is in its infancy in New Zealand, so at this stage very few analyses have been carried out. The analysis of human tissues, such as scraps of bone from archaeological sites, is not always possible, with descendants or those holding *mana whenua* (authority over the land) insisting that such remains are re-buried unstudied. It is hoped that this vital research can be continued under suitable controls. Despite the small number of results so far, we can already see that there is very great variation from one part of the country to another, and there are some surprises too.

The European person in this study is estimated to have eaten just over 1 kg of starchy foods each day (probably bread and potato), and nearly 600 g of land herbivore meat (probably sheep). There are very small signs of marine food, judged to have been fish, averaging about 600 g per month (Fig. 8.15).

The average diet at Rotoiti, in the interior of the North Island, is more like that of the European person than those any of the other groups, which would be expected, given the location. However, some sea food is present in the diet. Starchy plant food is assessed as just on 1200 g per day, probably a mixture of kūmara and fern root. Some 280 g per day is from a terrestrial animal source, such as forest birds, rats, freshwater crayfish, etc. It is interesting that sea foods have contributed as much as 82 g of shellfish and 200 g of fish per day on average. This is a surprisingly high amount, but must provide evidence either that sea foods were being brought inland through a flourishing trade system, or that the people spent some time on the coast as well as inland.

It is interesting to compare the diet of this inland New Zealand group with those of the Kitava people in the Trobriands and the Baegu people of Malaita. All three groups gained a similar amount of energy from fat sources (about 18–21%), the Rotoiti people were better off as far as energy from protein sources was concerned (16% compared with 10–11% for the Pacific groups), and the Pacific Islanders had a somewhat greater share of energy from carbohydrate sources (69–75%), compared with the Rotoiti people (67%). Despite the similarities, the Rotoiti people were able to gain access to rather more sea foods than their Pacific Island cousins. Their diet was also within recommended daily allowances for protein and fat, but slightly above that recommended for carbohydrates. Basically, we are dealing here with a horticultural society with a pretty well balanced diet. The general character of this diet does not represent a marked adjustment from that of a Pacific Island community, at least of the types compared.

Any similarity with the tropical Pacific ends at this point. The diets of the other three communities illustrated in Figures 8.15 and 8.16 are quite different. Archaeological excavations in the Chatham Islands have revealed sites containing not only very large amounts of fish remains (Fig. 8.9), but

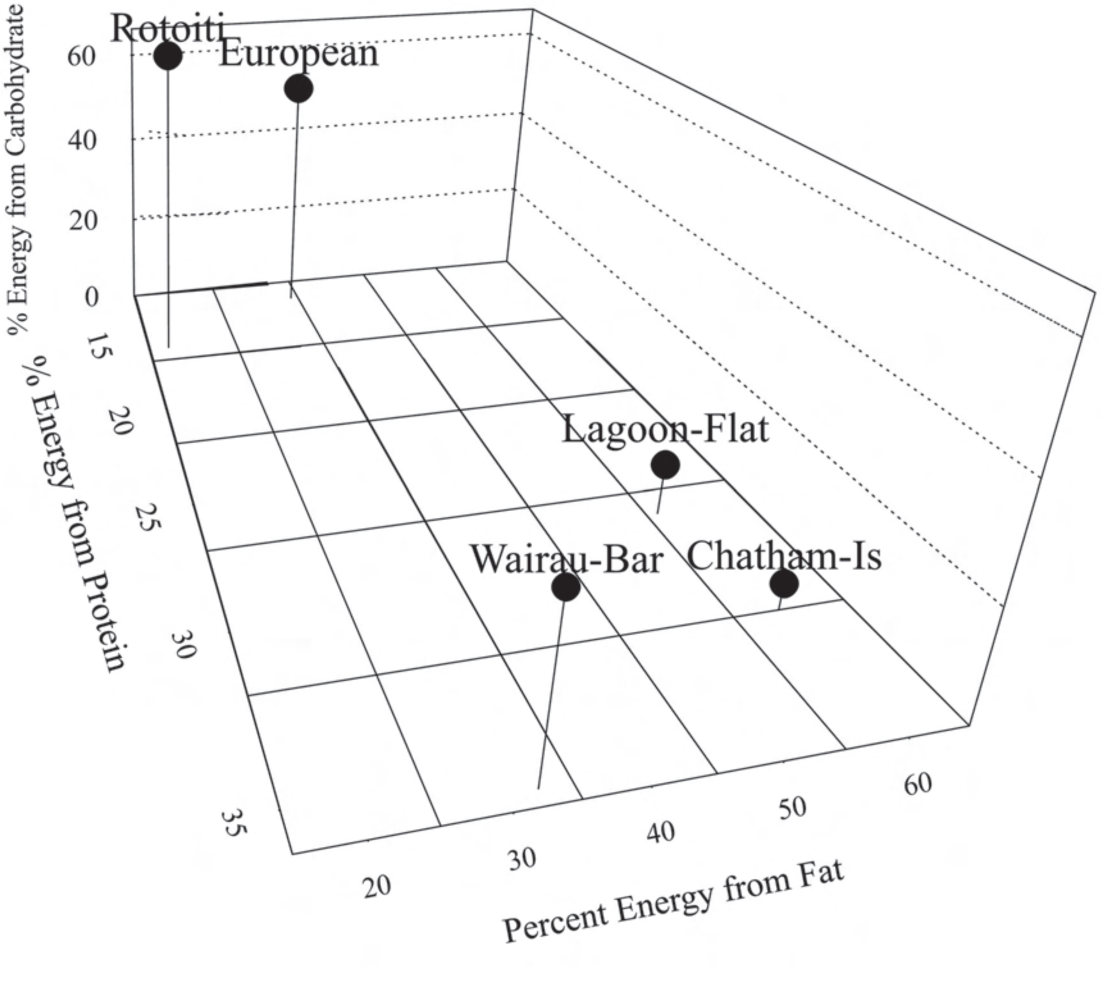

Figure 8.16: The percent of caloric energy deriving from protein, fat and carbohydrate foods for several New Zealand and Chatham Island individuals. From Leach *et al*. 2003: 72.

also large amounts of sea mammals. This is evident in the dietary reconstruction shown in Figure 8.15. Plant foods form a very low proportion of this diet. Of some surprise is the finding that the Lagoon Flat individual had a very similar diet to the Chatham Islands people. The Lagoon Flat site is a ‘moa-hunting’ site about 500 years old (Davidson 1984: 252), but these people must have had much easier access to sea mammals than moa, because food from these animals far exceeds the contribution from land herbivores.

The result from Wairau Bar is also very interesting. This tissue fragment was from Burial 42A, which is not one of the typical early Moa-hunter burials. Unfortunately, the age is not known directly, but the absence of wealthy grave goods probably indicates a somewhat later period. The reconstructed diet suggests that this individual, like the Lagoon Flat person, did not consume a significant amount of moa flesh. Some sea mammals were eaten, but fish represents by far the greatest component in the diet by weight. It is also notable that food from plants was of greater significance to this individual than at Lagoon Flat.

In all the reconstructions presented in Figure 8.15, shellfish contribute only a minor portion of the overall diet. It would be interesting to see whether this was so for communities in the Auckland region or the Bay of Plenty, where sites with very large amounts of shellfish remains are found. The contribution of fish to these diets was significant at Wairau Bar, Lagoon Flat and in the Chatham Islands, but the results clearly show that marine mammals were a prominent item. The main issue here is that marine mammals provided access to fat, of paramount importance as a source of caloric energy in areas where carbohydrate-rich plants were in short supply. The diagrammatic representation of these diets in Figure 8.16 is the really important one, showing the balance between the three major foodstuffs required for healthy life.

Only one study has been undertaken so far of a Pacific Island community from an archaeological site, which we can compare with these New Zealand results. This is from Watom, north-west New Britain, where human bone tissues could be analysed, and where faunal analyses have been undertaken. The relative amounts of the major food types are shown in Figure 8.17. Pigs and wallaby were clearly important here, as well as fish; but plant foods are not as important as they are for the Rotoiti people.

In Table 8.6 the recommended daily allowances for protein, fat and carbohydrate were given as a percentage of the total energy requirements. These were:

Protein	10–15 %
Total Fat	≤30 %
Carbohydrate	55–60 %

These can be compared with the reconstruction presented in Figure 8.16 and Table 8.8. What this shows is that with the exception of the Rotoiti people in the North Island, the pre-European Māori and Moriori had diets well outside recommended margins of safety. The Lagoon Flat and Chatham Island results are closely aligned with those of Arctic Inuit in that carbohydrate foods have been almost totally replaced as a source of food energy by fat, in this case from the blubber reserves of marine mammals. As pointed out above, these recommended daily allowances are only a guideline; not only do Inuit lead a perfectly normal life with their extreme diet, but the myth that they have a modified metabolic system to cope with such a diet was dispelled when two Europeans, Stefansson and Andersen, were able to survive in perfect heath for a long period on meat, fat and water. We must conclude, therefore, that the unusual diet evident at both Lagoon Flat and in the Chatham Islander would have been satisfactory too.

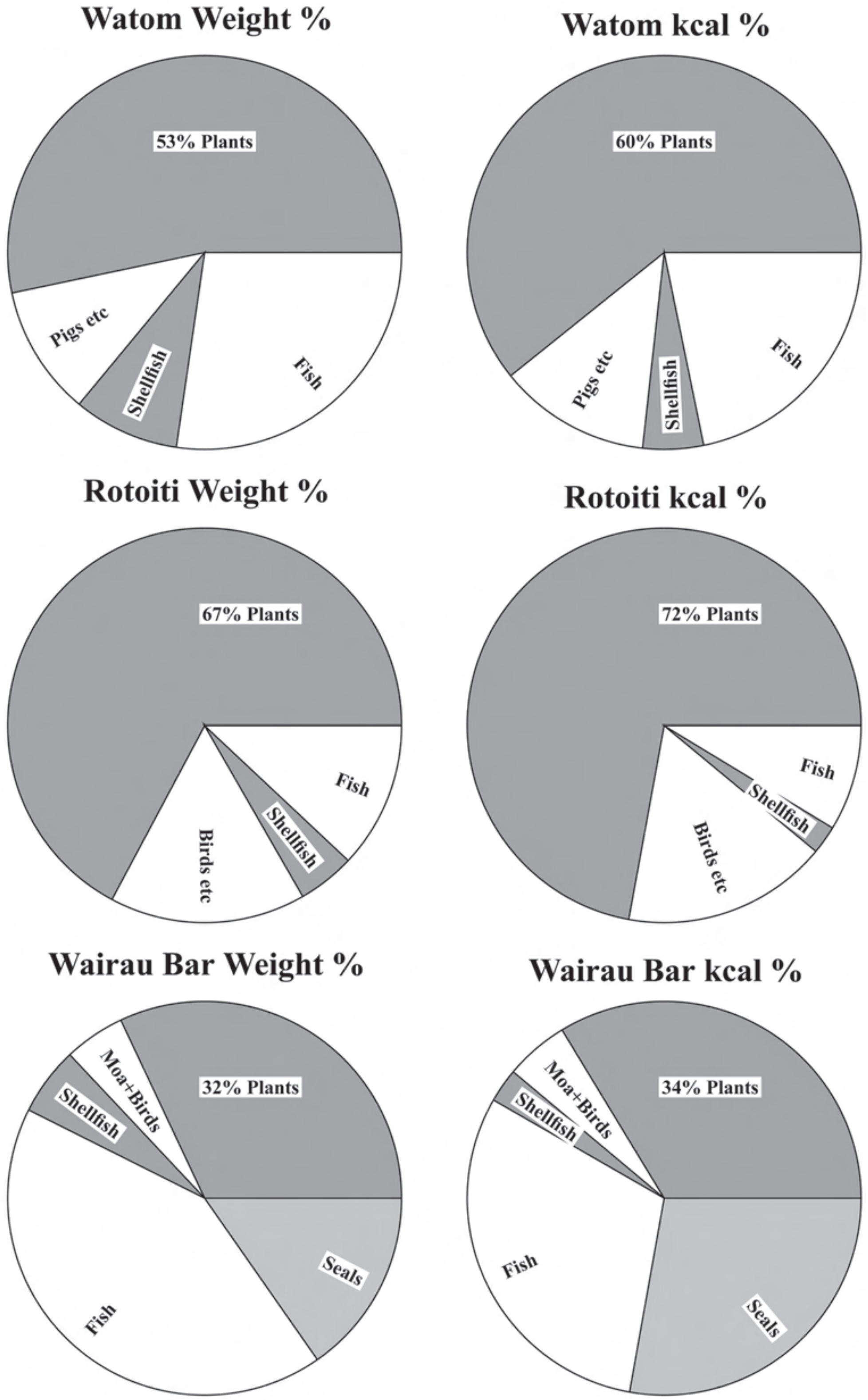

Figure 8.17: The relative abundance of the main food types at Watom compared to two New Zealand groups (based on Leach *et al*. 2000c: 154 and Leach *et al*. 2003).

TABLE 8.8
The Main Dietary Constituents in Select Prehistoric Groups
Percent of mean daily energy consumed (from Leach *et al*. 2003: 72)

Group	**Protein**	**Fat**	**Carbohydrate**	**Total**	**Total kcal/day**
European	10.5	31.0	58.5	100	2447
Rotoiti	18.3	16.2	65.6	100	2409
Wairau Bar	36.6	31.8	31.6	100	1977
Lagoon Flat	30.5	60.3	9.2	100	2141
Chatham Is	30.6	60.1	9.3	100	2193

It is less certain whether the Wairau Bar individual, with by far the highest value of protein in this series, had a satisfactory diet. Unfortunately, little else is known about this individual. Houghton, who made a study of the Wairau Bar burials, did not find any Harris lines in the long bones (Houghton 1975: 234), but burial 42 was not included in his research.

CONCLUSIONS

Several lines of evidence point to the conclusion that fish and other marine foods played a dominant role in the diet and economy of many Māori and probably all Moriori people. Not only was this source of food important for protein and essential fatty acids, but for some communities it provided the only means of acquiring enough caloric energy, since carbohydrate foods could not be procured in sufficient quantity. If it were not for the presence of sea mammals on the coastal areas of the South Island and in the Chatham Islands it is very doubtful whether these areas could have been permanently inhabited during the prehistoric period.

It is very likely that the whole of the central New Zealand area from south of Hawke’s Bay to Banks Peninsula was a difficult area economically, in that starchy root crops like taro and kūmara were at the best of times hard to grow and in some years may have been largely unproductive. No amount of fish and shellfish could make up the difference, since increasing protein consumption would eventually lead to starvation, as more and more of the ingested food would need to be broken down for caloric energy. The critical factor in a successful economy in a landmass like New Zealand and the nearby Chatham Islands is certainly not access to protein — the sea abounds in readily available protein-rich foods — but access to fat or carbohydrate. With the exception of the sub-tropical far north of New Zealand, where kūmara and taro crops were guaranteed, successful permanent habitation depended in the end on a reliable source of fat. Sea mammals offered the security of this essential commodity in some areas. Another important source is freshwater eel. Eels contain abundant fat reserves, and are easily taken in abundance in streams and lakes throughout New Zealand, but were apparently ignored until close to the end of the prehistoric period.

In broad quantitative terms, the amount of food energy deriving from the marine environment varied from about 11% for the inland people at Rotoiti to more than 61% on the coast at Wairau Bar (Fig. 8.17). This is a very large range, but is probably a fair reflection of the magnitude of environmental change throughout New Zealand. No single economic system was possible in such a land, ranging from sub-tropical in the far north to sub-antarctic in the far south. Pre-European Māori found ways to live the length and breath of New Zealand by adopting different economic strategies which would permit a satisfactory diet and long term survival.

CHAPTER 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 Maoris 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 Maoris as a rahui or breeding grounds.
>
> Today, as a Maori, I am ashamed to talk about out kai-moana, 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 Maori 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 and 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 and 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 (H.M. Leach and 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 and 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 (ibid.: 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 $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ 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 Moriori 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% ± 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 (ibid.)
53.6%	Early Kokohuia, Hokianga (Leach *et al*. 1997a: 109)
48.1%	Late Kokohuia, Hokianga (ibid.)

A figure of 48% ± 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 ± 0.03 * 0.218 ± 0.008 = 0.1046 ± 0.0104, or **10.5 ± 1.0%** (The procedure for combining errors is described in Chapter 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 ± 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 and 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 ± 12 and 3,252 ± 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 ± 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 ± 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 ± 3,000 Persons
Step 2: Average Energy Intake per day = 2,150 ± 215 kcal per person
Step 3: Mean Snapper in diet = 10.5 ± 1.0 % of caloric intake
Step 4: Energy per g for snapper = 0.92 ± 0.092 kcal
Step 5: Snapper Mean Ungutted Weight = 2,807 ± 280 g
Step 6: Proportion of snapper eaten = 70 ± 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%
Final Estimate of Northland Harvest = 1,919 ± 1,612 Tonne

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 and 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 therefore 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

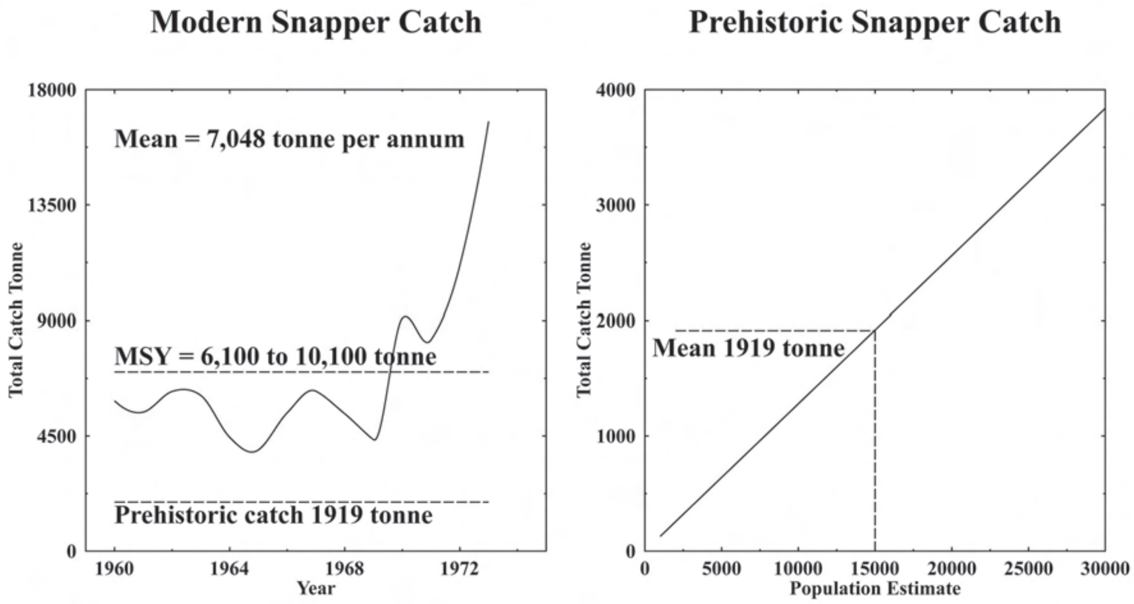

Figure 9.1: The pre-European Māori annual catch of snapper in Northland was far below the lowest recorded commercial catches in the same area, and well below the sustainable yield. This shows that their effect on this fishery was negligible. NB: the two vertical axes are different scales (see text).

These figures are plotted alongside the estimated pre-European catch for Northland in Figure 9.1 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 overexploited by the Maori" (Flannery 1994: 244) is also manifestly incorrect as shown in Chapter 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.

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' (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 9.1.

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 9.1, 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 9.1. 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".

TABLE 9.1
Examples of different causes and their possible effects

Causal Agent	Effect on Environment
Natural Environmental Change	
• Firing of coastal forest	• 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.
• Tsunami	• Stripping of inshore marine communities, and fairly rapid recovery to pre-existing conditions.
• Increase/Decrease Surface Sea Temperature	• 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.
• Tectonic Change	• Rapid change in local biological communities, followed by recovery over a longer period.
Human Activities	
For all fish species	
• Non-selective	• If harvesting is heavy and sustained, overall biomass will decline, but age structures and relative species abundance may change little.
• Select some, reject others	• Biomass of some species will decline, and the biomass of some other species may increase as they expand into partly vacant niches.
For any one fish species	
• Non-selective by size	• If harvesting is heavy and sustained, the biomass of the species should decline, but age structure may change little.
•Select small specimens	• This will encourage higher survival rate for larger specimens, and the growth rate of the species may increase in response to this.
• Select large specimens	• This will lead to preferential survival of small specimens and might result in a lowering of growth rate.

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 and 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[1], 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 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 chapters in this book, and the pattern which emerges from this, surprisingly, shows increase in mean size over time, not the reverse.

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[1] Hence the expression that one could be a brilliant tactician, but a terrible strategist, by winning individual battles but losing the war.

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 9.2 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 Chapter 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 and Wing: 26). The concept of 'return for effort' therefore should not necessarily be only about weight of meat. As I hope that Chapter 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,

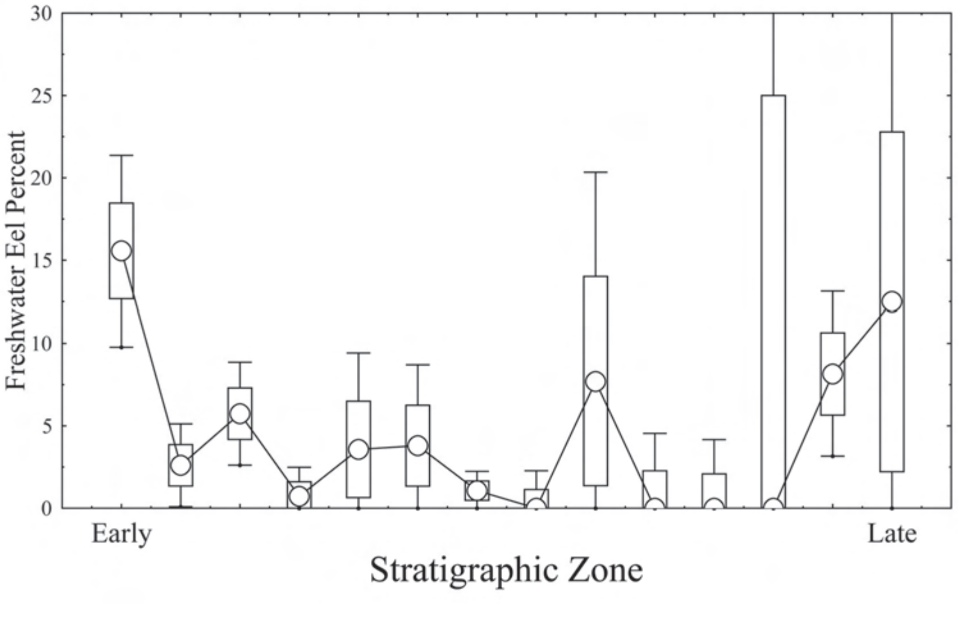

Figure 9.2: Freshwater eels were about 15% of the fish catch in the earliest times at Tangatatau on Mangaia, but declined in abundance later.

we found that over 80% of the ringed seals killed by polar bears were less than 2 years of age" (Stirling and McEwan 1975: 1022). Moreover, "After a polar bear kills a seal, it feeds predominantly on the blubber and often abandons the meat" (ibid.). 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 preference to fish, as was described in Chapter 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[2]. 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 (H. 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

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[2] Nett rate means after natural mortality is taken into account.

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 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 Chapter 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 prehistoric 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 book (fish), I begin with two good examples of prehistoric harvesting of marine invertebrates, and then return to fish.

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 and Anderson 1979b).

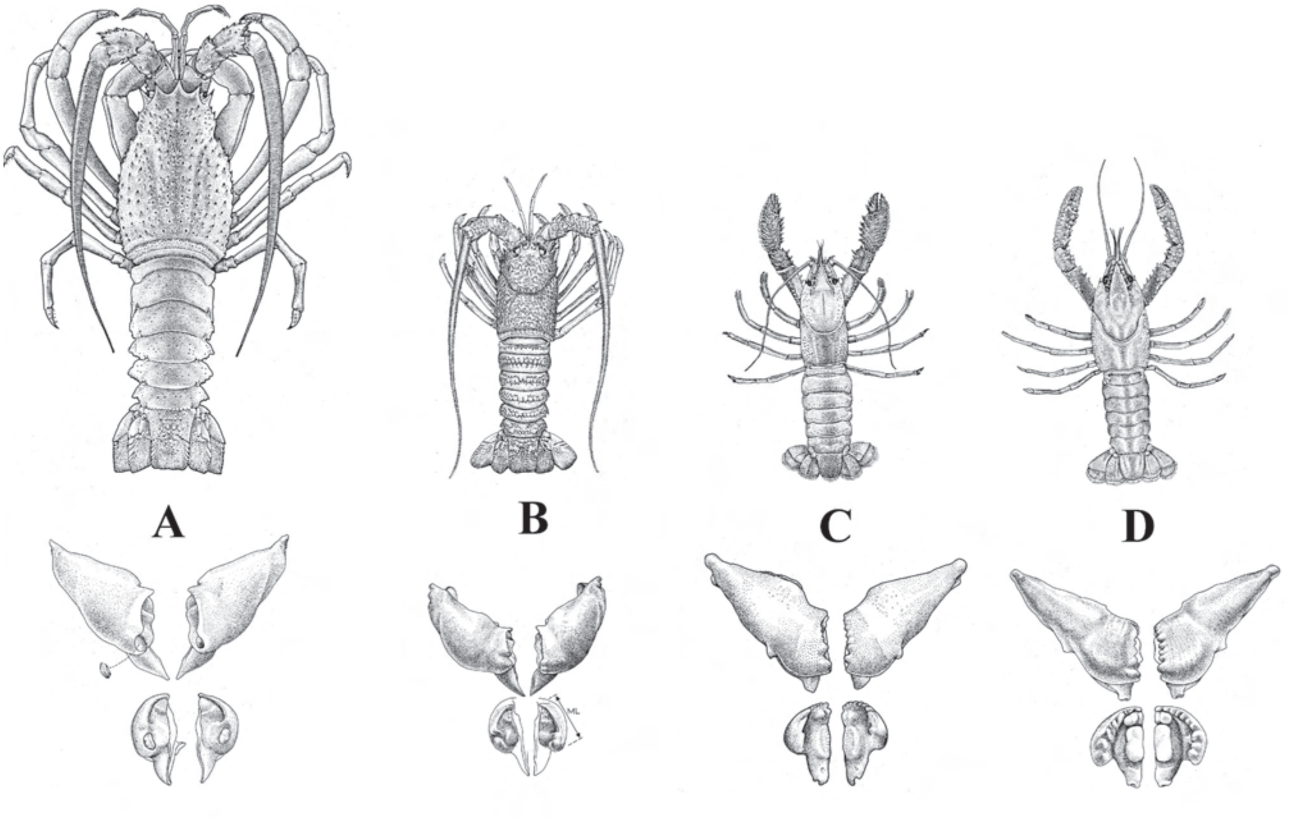

Figure 9.3: The four New Zealand species of crayfish. A: *Jasus edwardsii*, B: *Jasus verreauxi*, C: *Paranephrops planifrons*, D: *Paranephrops zealandicus*. A and B are marine, C and D are freshwater (not to scale). Illustrated below are their mandibles (adapted from Leach and Anderson 1979b: 146 ff.).

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 9.3), two marine and two freshwater. To date only *Jasus edwardsii* has been identified archaeologically, although the mandibles of other species are quite distinctive.

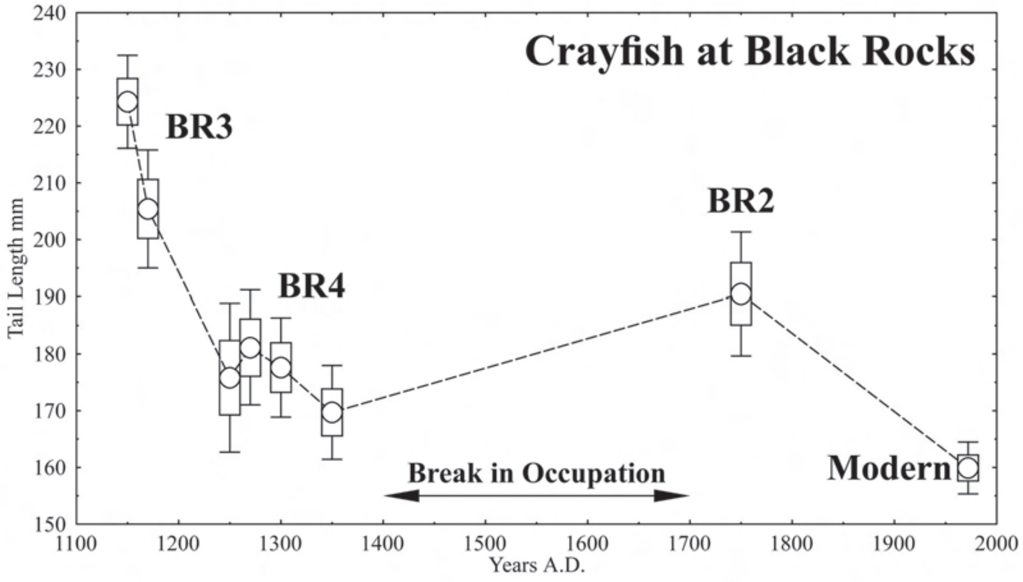

Figure 9.4: Changes in mean size of crayfish at Black Rocks, Palliser Bay, over archaeological time (adapted from Leach and Anderson 1979b: 160).

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 9.4.

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 Chapter 7. The main evidence of this at Black Rocks is from the landsnail 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 9.4.

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 9.4 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

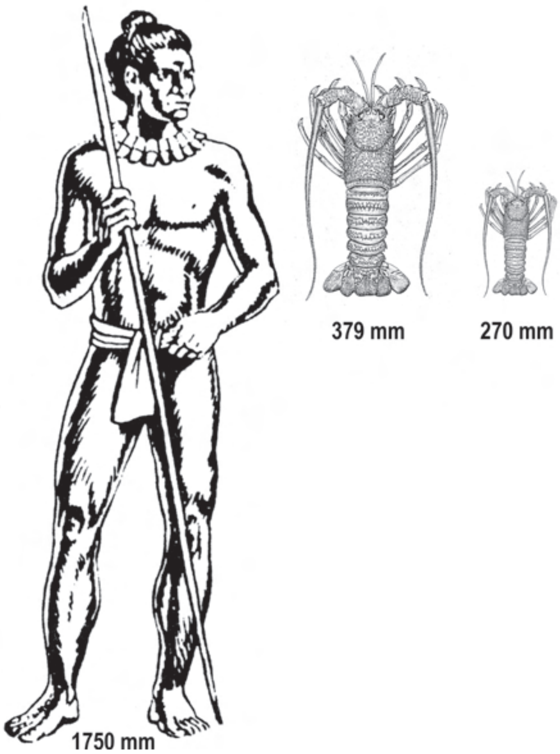

Figure 9.5: The average size of crayfish in the earliest archaeological site at Black Rocks compared with the average size in 1972. The three figures are drawn to the same scale. The drawing of the pre-European male is taken from Duff (1949: 24–25). See text.

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 (Fig. 9.5) 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 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 and 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.

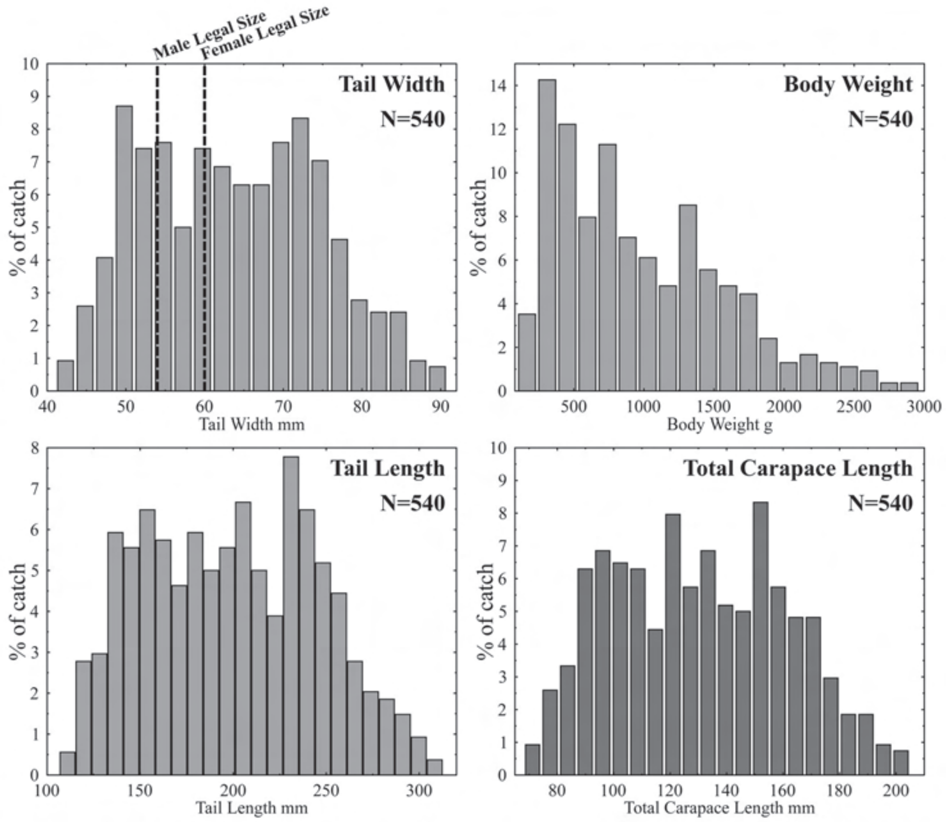

Figure 9.6: Size frequency diagrams of the crayfish catch from Black Rocks, all assemblages combined. From databases left by Leach and Anderson (1973). See text.

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 9.6 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 and 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 ($g1=0.14$), and slight -ve kurtosis ($g2=2.1$), both values are significant. Not a lot can be inferred from this, particularly as several assemblages from different time periods have been combined. This 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 and 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 density. 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 shellfish 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[3].

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 9.7 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.

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[3] These collections and the metrical databases are held in the Archaeozoology Laboratory, Museum of New Zealand, Te Papa Tongarewa.

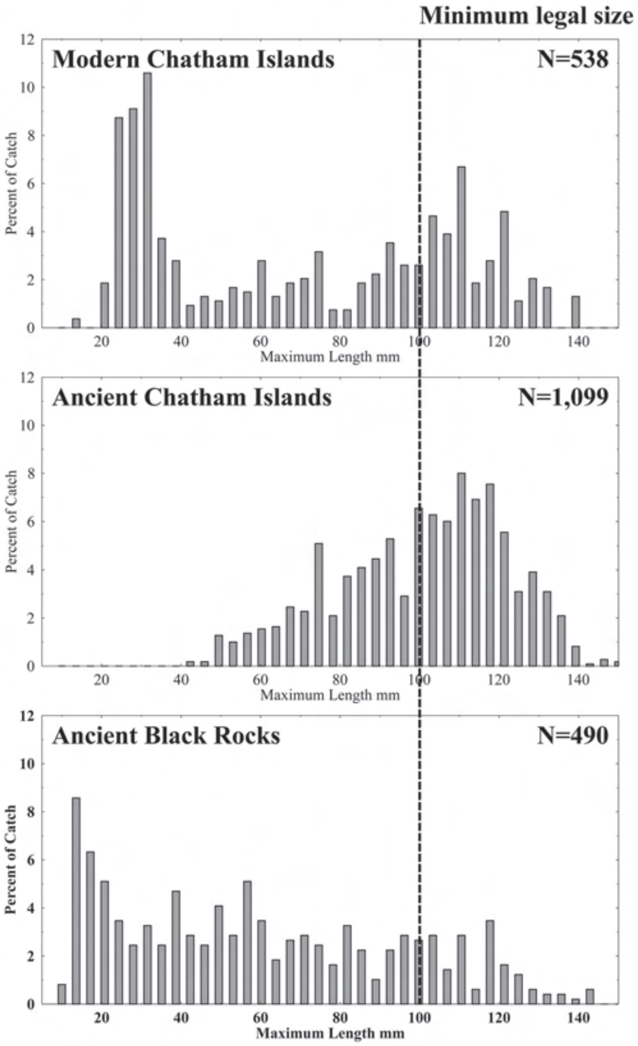

Figure 9.7: Pāua size in archaeological sites at Black Rocks and Chatham Islands compared with modern specimens. From databases left by Anderson (1973), and McIlwraith (1976).

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 (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 chapter, 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 Sustainable 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 Chapter 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 Chapter 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 Fig. 7.10; Mana Island Fig. 7.14; Foxton (Davidson *et al*. 2000b: 82); Kokohuia Fig. 7.16).

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 Chapter 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 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 9.8 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 assemblages is from Houhora, but unfortunately these 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 9.2).

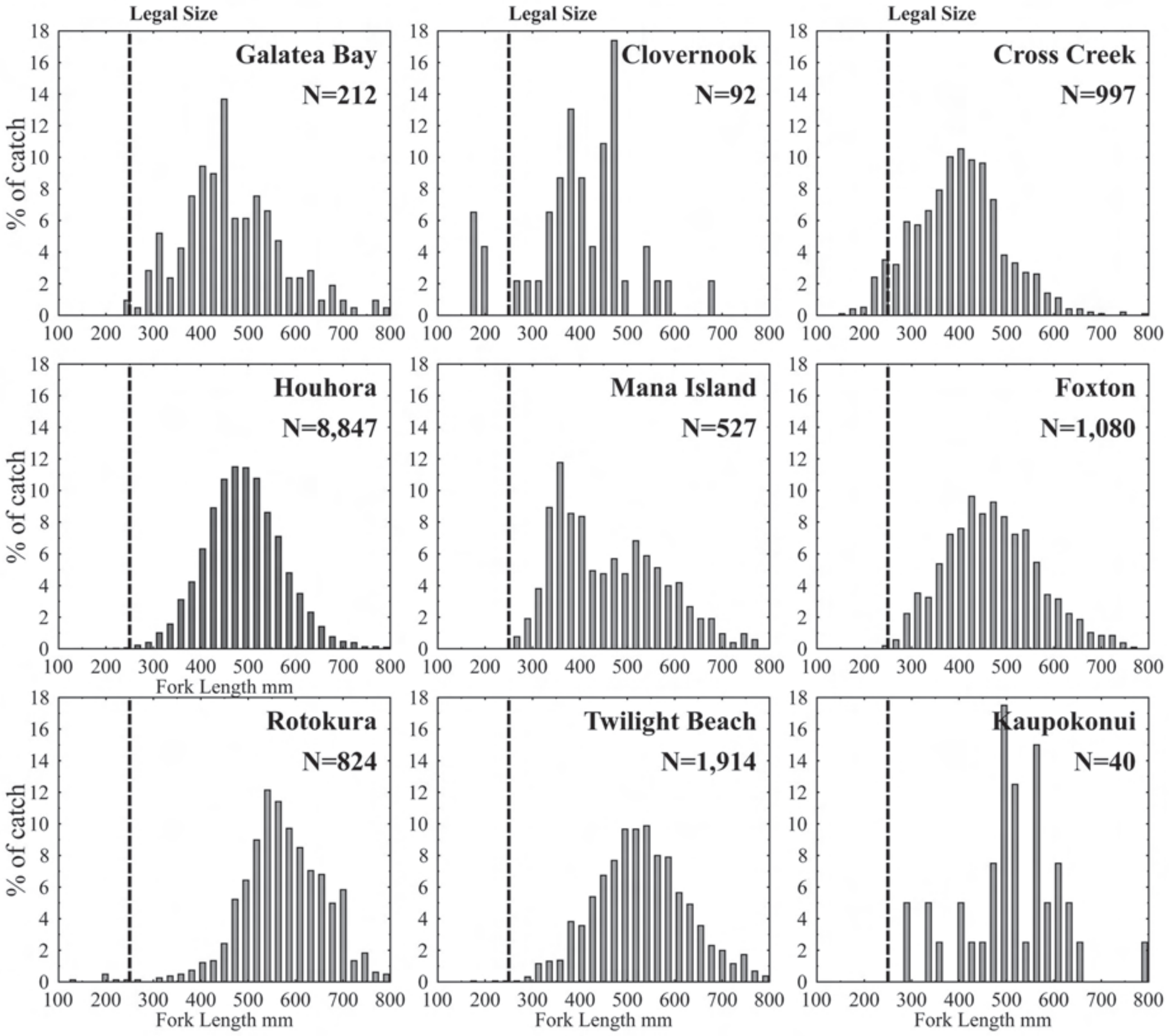

Figure 9.8: Size frequency diagrams of archaeological snapper catches. From data in the Archaeozoology Laboratory database at the Museum of New Zealand.

TABLE 9.2
Dispersion statistics for some archaeological snapper assemblages.
Source: Archaeozoology Laboratory database, Museum of New Zealand.

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.

There are probably two reasons why so few small snapper were being caught by pre-European Māori. Firstly, young snapper (two and three year 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 4½ 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 5½ inch (140 mm) mesh size (discussed in Chapter 5), and assuming this was a common size, it might account for the lack of small fish in the assemblages shown in Figure 9.8 (statistics appear in Table 9.2). 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 9.9.

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).

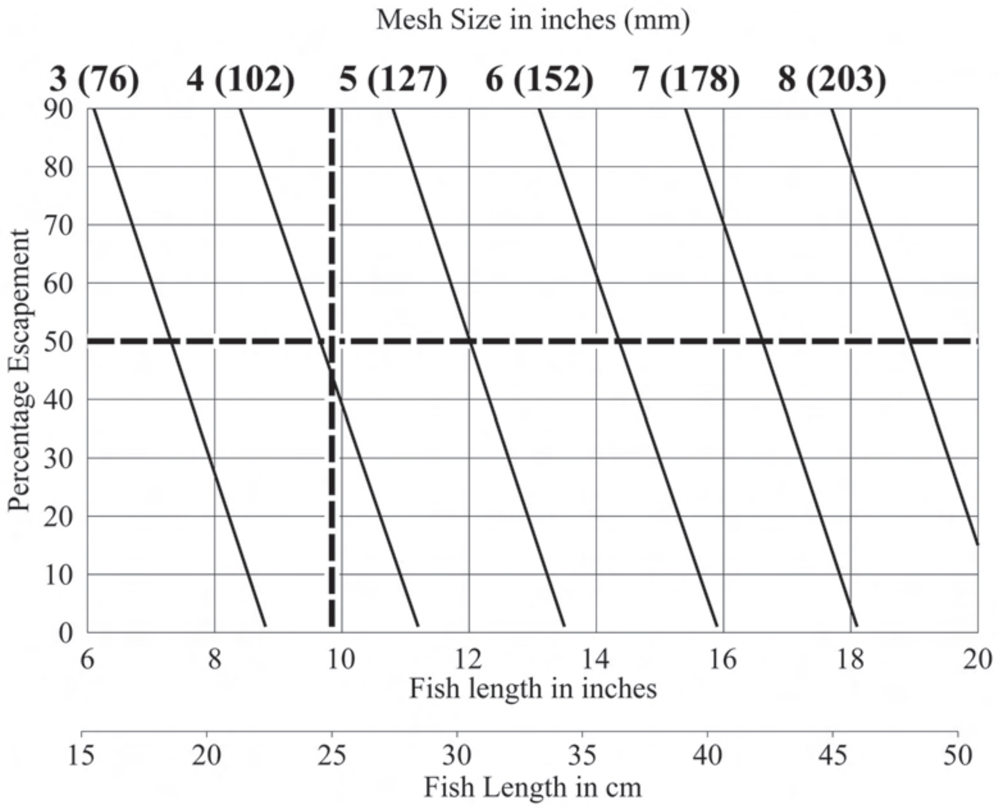

Figure 9.9: Relationship between mesh size, snapper length and escapement. Adapted from Cassie (1955: 73).

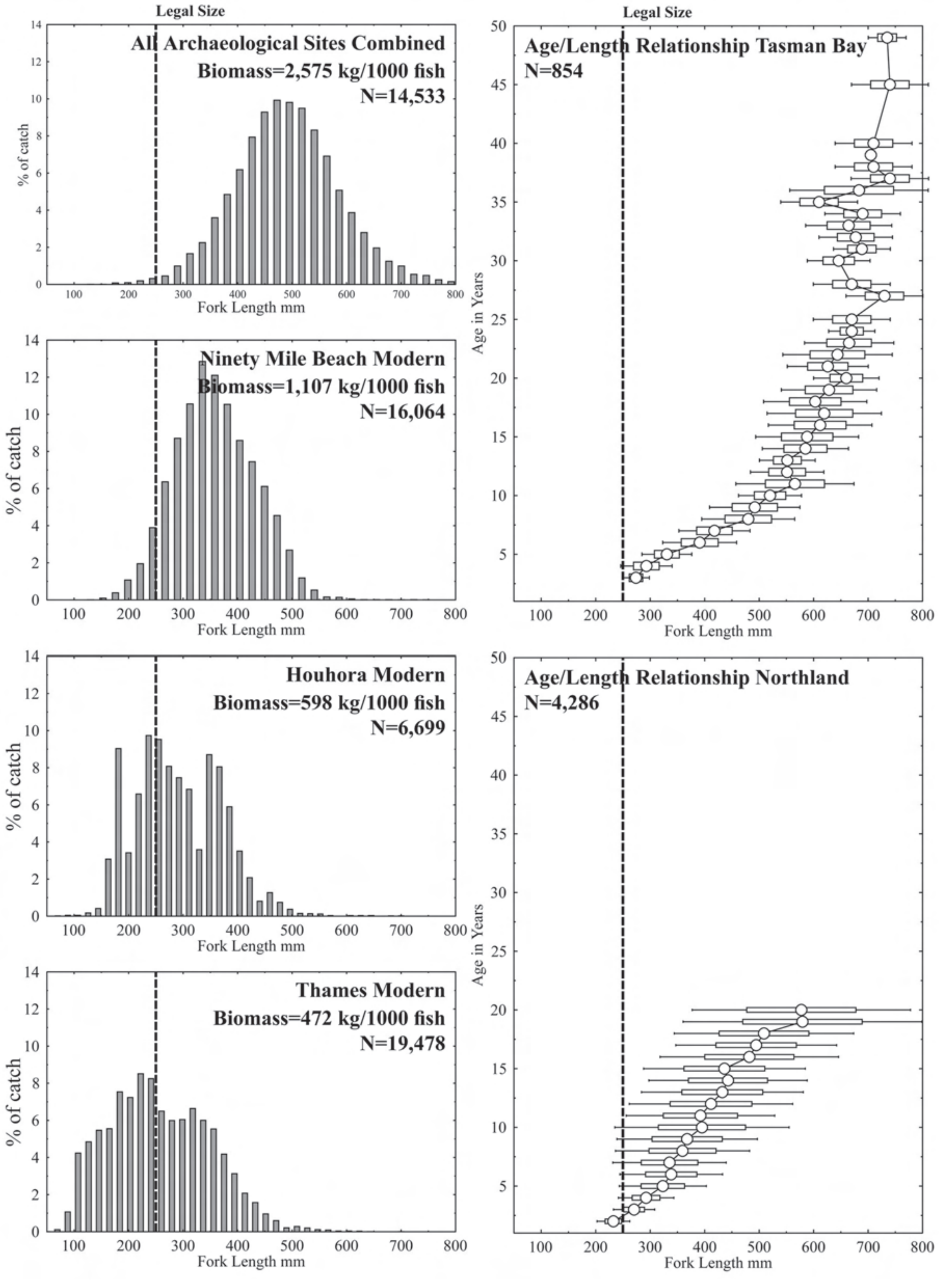

Figure 9.10: Size frequency diagrams of archaeological snapper catches compared to modern trawl data. From data in the Archaeozoology Laboratory database at the Museum of New Zealand, and modern data courtesy of Larry Paul.

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 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 9.8 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 9.10 where the catch data from the nine sites appearing in Figure 9.8 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 and Boocock (1995). On the right is plotted the relationship between age and fork length using data from Walsh and 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 (Table 9.2). 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 Chapter 7 (see discussion of Fig. 7.24, 7.25), but requires closer scrutiny now because it has a bearing on the harvesting strategy employed by the people concerned.

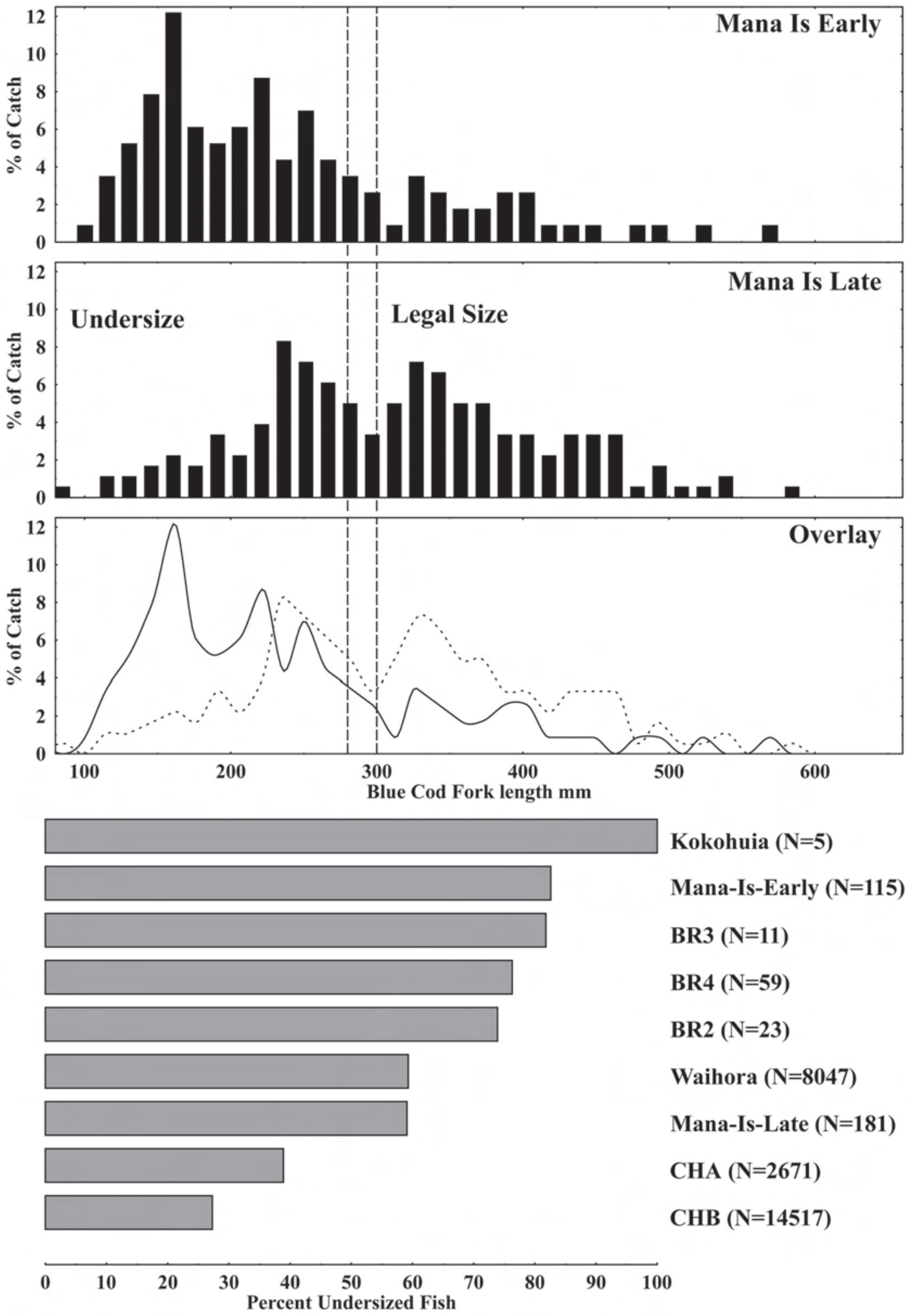

Figure 9.11: The blue cod catch at two time periods at Mana Island, showing a shift towards larger fish. Below: By today's standards, very small blue cod were being consistently taken for food in pre-European times.

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 9.11 shows the size frequency distribution for the two periods at Mana Islands and also the proportion of fish caught, which by today's standards are undersized, 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 and 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" (ibid.: 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" (ibid.: 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" (ibid.: 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 and 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.
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 and 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 (ibid.: 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 and 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 (ibid.: 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 (Fig. 5.7, Fig. 5.8).

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[4]. At best we can say that pre-European Māori consistently favoured small and very small fish, and blue cod (Fig. 7.24 and Fig 9.11) is a good example of this. In the case of strongly territorial species with relatively low biomass such a harvesting 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 7.6, Fig. 7.26, Fig. 7.27, Fig. 7.28). 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 Chapter 7 that spotty and scarlet wrasse may have decreased in abundance over time and banded wrasse increased (Leach *et al*. 1999a: 127; Leach and 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 7.28 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[5], 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

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

[5] Polynesians are astounded at the idea of 'catch and release', which is in vogue amongst fly fishermen.

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 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.

CONCLUSIONS

This chapter 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, 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.

CHAPTER 10: THE PRE-EUROPEAN MĀORI AS A FISHERMAN

INTRODUCTION

This volume has been concerned with the period of New Zealand's past before the arrival of Europeans; that is, before the advent of historical records. The subject matter therefore is not history but prehistory, and the primary source of knowledge for this is obtained by archaeological research. It has sometimes been said that when literate Europeans arrived in New Zealand, "prehistory was caught alive" (e.g., Golson 1959: 47). This is true of the wider Pacific area too, when European explorers first ventured there. The thousands of islands throughout the Pacific, including New Zealand, had been more or less isolated from the events which shaped Europe and Asia up until that time. These areas outside the Pacific had long ago been through the 'Neolithic revolution' when grain started to be harvested and selectively bred so that huge surpluses of carbohydrate foods could be easily stored. This set into motion a process of population growth, animal husbandry, specialised crafts, and ultimately led to city states — and, of great importance for historians, the invention of writing. But life in the Pacific region carried on as before, oblivious to these external events. Hence the expression *catching prehistory alive*. The first explorers were able to write down records about Polynesians and Māori which, although technically 'history', in another sense might also be called 'prehistory'. It forms the beginning of what we now call 'ethnographic records', descriptions of the way of life of people isolated to a greater or lesser degree from the march of history in Europe and Asia.

Not surprisingly, archaeologists working in New Zealand and the wider Pacific area have been inclined to use this wealth of fascinating ethnographic material to fill out the knowledge gained from archaeological excavations in their efforts to build a picture of prehistoric life over hundreds and in some cases thousands of years. Although this is perfectly natural, it does have its dangers. Archaeologists working in Europe are well used to writing prehistory from archaeological excavations alone without recourse to historical records. This has resulted in a strong self-contained discipline, where it is perfectly clear what the origin of knowledge is, and the step-by-step process of building a picture of life in remote times. Unfortunately, this is not always the case in New Zealand and the Pacific and, at worst, ethnographic records can become a silent tyrant in the hands of archaeologists, undermining the discipline of archaeology. In my opinion it is vitally important for archaeologists whose subject material is pre-European Māori or Polynesians to distinguish history and prehistory far more clearly than they have in the past. The period of time close to when prehistory was caught alive is sometimes called the 'proto-historic period', and it is perfectly legitimate to use ethnographic records judiciously alongside archaeological excavations in this case. On the whole, I think that this form of 'text-aided archaeology' should be confined to one or at most two standard errors of a radiocarbon date, say 50 to 100 years before the arrival of Captain Cook in 1769[1].

This volume has been about prehistory, not about history. When I wanted to describe what species of fish pre-European Māori caught, or the size of fish that were taken, or changes in fish catches through time, I did not explore historical records, I used knowledge directly gained from archaeological sites. If there are challenges to various conclusions I have reached, I hope that these will be based on purely archaeological data, not on historical records. This choice of building knowledge from the bottom up, from fish remains found in archaeological sites, is quite deliberate, and I recognise that it does have its limitations. However, at least it should be perfectly clear how

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[1] The earlier encounter by Tasman in A.D. 1642 was very brief and had nothing like the impact on Māori of Captain Cook's visits between A.D. 1769 and 1772. For this reason A.D. 1769 is chosen as the terminal date of the prehistoric period.

the conclusions have been reached. Another quite different volume could be written called ‘Fishing in Proto-Historic New Zealand’, and this would be a really useful work. In the course of carrying out research for contributions to the Waitangi Tribunal, I have become aware of the immense riches about Māori fishing in the 19th century, relatively untapped, that are contained in Māori Land Court documents. Combined with archaeological excavations of proto-historic sites, this could form a wonderful chronicle of fishing in early historic New Zealand.

This volume has traversed many aspects of pre-European Māori fishing. This short final chapter is not a summary of what has gone before; instead it offers a few final comments on issues that I think are especially important.

FISH WERE BOUNTIFUL IN PRE-EUROPEAN NEW ZEALAND

Archaeological evidence has provided many clues of the opulence of the New Zealand fishery in pre-European times. The average size of snapper in the far north during those distant times would have any modern fishermen gaping in astonishment. So too, crayfish in early Palliser Bay were simply enormous by today’s standards. Adding to this, the earliest historic records provide us with a unique perspective on the state of the New Zealand fishery at the close of the prehistoric era. An especially graphic description of the fishery in the Marlborough Sounds is worth citing.

When Cook visited Queen Charlotte Sound in January 1770, the crew used a seine net in Ship Cove and “made a few hawls and caught 300 pounds weight of different sorts of fish which were equally distributd to the Ships Compney” (Cook 1968: 235). Banks also comments on this incident, writing that they “caught more fish in the Seine than all our people could possible destroy” (Banks 1963 (I): 453). Beaglehole, in an editorial footnote to this statement, cites a list of more than a dozen kinds of fish noted by Parkinson in his journal (1972: 114) and gives possible identifications of these:

> squid, snapper, tarakihi, barracouta, gurnard, blue cod, horse mackerel, dogfish, soles and dabs, grey mullet, Drums[2], scarpee, elephant fish (Banks 1963 (I): 453).

There is no doubt that Queen Charlotte Sound at the close of the pre-European era was a magnificent fishing ground. Cook describes it thus: “The sea abounds with a variety of fish and in such plenty that without going out of the Cove where we lay [Ship Cove], we caught daly what with the Saine hook and line quite sufficient for all hands” (Cook 1968: 247). Anyone familiar with the modern-day Marlborough Sounds will be astonished at these descriptions of the fishery in 1770. It would be impossible to catch a dozen species of fish with a few hauls on a seine net in this area today, and certainly not in the quantity described. Although this comment was made specifically about Queen Charlotte Sound, the super abundance of fish was something which characterised all parts of New Zealand, as Banks makes clear in his summary observations about New Zealand:

> For this scarcity of animals on the land the Sea however makes abundant recompense. Every creek and corner produces abundance of fish not only wholesome but at least as well tasted as our fish in Europe: the ship seldom anchord in or indeed passd over (in light winds) any place whose bottom was such as fish resort to in general but as many were caught with hook

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[2] Beaglehole thought this might be a fish of the Sciaenidae family (croakers). This is a current family (Nelson 1994: 364), occurring in Australian waters (Roughley 1951: 70), but is not present in New Zealand. It is possible that this fish was either the marblefish or greenbone, which can also make a noise when landed.

> and line as the people could eat, especialy to the Southward, where when we lay at an anchor the boats by fishing with hook and line very near the rocks could take any quantity of fish; besides that the Seine seldom faild of success, insomuch that both the times that we anchord to the Southward of Cooks streights every Mess in the ship that had prudence enough salted as much fish as lasted them many weeks after they went to sea.
>
> For the Sorts, there are Macarel of several kinds, one precisely the same as our English ones and another much like our horse macarel, besides several more; these come in immense shoals and are taken by the natives in large Seines… (Banks 1963 (II): 6, see also Cook 1968: 276).

The modern-day inshore fishing environment is but a poor and pale reflection of what is being described here. The picture painted by Cook and Banks depicts a marine environment which was bountiful with fish after 800 years of Polynesian occupation. The same cannot be said after a mere 200 years of European occupation. Estimates of virgin and current biomass of snapper, for example, suggest that only about 10% of the original biomass remains (Table 4.2, page 77).

We can draw two conclusions from these descriptions by the first European explorers to experience the inshore fishery. Firstly, whatever impact pre-European Māori may have had on the fishery, this pales into insignificance when compared to the devastation that has occurred since the arrival of Europeans. Secondly, catching fish for food presented no real problem for Māori. This is not merely a matter of the available technology and skill which the Māori possessed, but signifies that a ready supply of protein for their diet was simply there for the taking without too much difficulty.

CONSERVATION STRATEGY

Much has been claimed about the pre-European Māori as both a conservationist and a destructive influence on the fauna and flora of New Zealand. Some have taken the view that the pre-European Māori were ‘Future Eaters’, depleting the resources for future generations. In some cases, such as that of the moa and other flightless birds, this characterisation is probably quite an appropriate one; however, in the case of the fishery, this volume lends little or no support to this view. Of course, we need to consider just how large the biomass was compared with the human population size in any region, and therefore the potential intensity of marine harvesting, before making claims as to whether pre-European Māori were mindful of possible adverse effects they might be having on the resources available to them. I think it has been fairly shown in this volume that any repercussions of human behaviour on the fishery that can be observed from archaeological data show little or no adverse effect. It has been shown, for example, that for a number of species, the mean size of fish increased rather than decreased over archaeological time and this means a clear increase in relative biomass. In only two cases can a size decrease over time be observed (barracouta and crayfish). In the case of barracouta this is more likely to have resulted from natural environmental changes in New Zealand, as this species has an enormous biomass. In the case of crayfish, however, early human communities in Palliser Bay did indeed reduce their size over time.

This does not necessarily mean that the pre-European Māori deliberately adopted a fishing strategy designed to increase the size of fish. A more plausible interpretation is that the people brought with them from Polynesia cultural attitudes towards harvesting the sea which inadvertently had this result: in particular, the pattern of keeping all fish that were actually caught, rather than discarding some as not worth eating (such as small ones), or discarding some on the grounds that they would either maintain or even improve the fishery in future (such as large mature fish with greater spawning capabilities). In this respect, we cannot now second guess what was in the minds of early fishermen in New Zealand, but we can certainly observe the results of their activities in archaeological sites and guide our interpretations with knowledge gained from ethnographic observations in near and remote parts of Polynesia. The taking of small fish is a widespread practice throughout the Pacific and is seen as perfectly appropriate behaviour; the fish are seen as entirely suitable as food. This cultural attitude is the one most likely to have arrived with immigrants to New Zealand some 800 years ago and, so far as we can tell, the one which prevailed until the arrival of Europeans. This is certainly not the commonly held ideology today, amongst either Māori or Europeans. I have no doubt that this largely reflects widespread publicity in newspapers and television about the supposed detrimental effects of taking small fish, rather than long established traditional belief and behavioural charters. This modern resource management strategy has certainly not been accompanied by any improvement in the inshore fishery during the historic period, and while fisheries scientists will claim many complex factors for its decline, we may perhaps in the end learn something useful from the way pre-European Māori, with their proclivity for small fish, harvested the sea.

OFFSHORE FISHING

One of the most surprising things to emerge from the archaeological study of fish remains in New Zealand is the complete absence of any indicators of fishing for species which inhabit the clear oceanic waters near the edge of the continental shelf and beyond. A number of such species are present in New Zealand waters, particularly in summer months, and would have been taken if pre-European Māori sought them. For example, along the west coast of the South Island and further north albacore are quite common. Skipjack tuna are also present in both eastern and western waters off the northern half of the North Island. Dolphinfish, although relatively rare, are present in oceanic waters from the Bay of Plenty northwards. Marlin, too, found primarily on the east coast of the North Island, straggle to Cook Strait in some years. Although all these fish were certainly known to the Māori and had names, if they were caught and eaten at all it must have been extremely rare because their bones have never been recovered in archaeological sites. This contrasts with a number of parts of the tropical Pacific. For example, the people at Mochong in the Mariana Islands systematically hunted and caught marlin and dolphinfish (Leach *et al*. 1988b) and, in the eastern Pacific, tuna of several species were being caught in substantial numbers in both the Society Islands (Leach *et al*. 1984; Davidson *et al*. 1998), and the Marquesas Islands (Leach *et al*. 1997c; Davidson *et al*. 2000a).

By contrast with these Pacific Islanders, the pre-European Māori were nowhere near as adventurous, harvesting fish almost exclusively from close inshore. In Appendix 3 I have attempted to arrive at a quantitative estimate of this. I distinguished between inshore and offshore as being either greater than 50 metres depth of water or more than 100 metres from the shore. The archaeological samples of fish remains were then cautiously apportioned to these two categories. More than 80% of all fish caught could be attributed to the inshore fishing environment.

There is little doubt that in places in the tropical Pacific where oceanic species were specific targets for fishing activities this was not by necessity for food. With some notable exceptions, such as Easter Island, fish are superabundant close inshore in the Pacific, just as they once were in New Zealand. Fishing in oceanic waters is distinctly dangerous and full of adventure and, as far as the food quest is concerned, is a far less reliable source. People who fish in these waters do not go there primarily for food, as there are already abundant supplies closer to home inshore. They go to sea precisely because of the danger and excitement associated with it. It presents an opportunity for men (not women) to escape from the humdrum routine of village life with wives and children demanding attention with domestic duties. In small islands with high population density people are constrained in various ways. Getting to sea away from these constraints was an impetus by itself and had its own reward; and if the fishermen arrived home with tuna this was even better.

By contrast, New Zealand has an enormous landmass. The pressures of high density living did not apply to anything like the same extent as in the tropical Pacific, and one of the motivating forces to go out to sea did not apply to the same extent. Men could satisfy their need for adventure in many other ways not available on small islands, such as exploring forested areas for new sources of useful stone, and taking part in trading expeditions to distant communities.

TECHNOLOGICAL ACHIEVEMENTS

There is abundant evidence from archaeological sites of a highly differentiated fishing technology, particularly with bone and shell hooks. This attests to a great deal of experimentation and a keen interest in the development of new forms. It does not necessarily mean that new forms were more effective than older ones. A casual visit to a modern fish tackle shop will convince anyone that form and functionality are not closely related. For each fish species there is a veritable plethora of fish hook or lure types. In pre-European New Zealand, when fish were so numerous one could catch them with the most rudimentary equipment, it is hard to attribute the obvious experimentation taking place to a desire for increased efficiency. It is much more likely that the stimulus for diversifying the range of fishing equipment was the need of individuals to express stylistic features rather than functional ones.

It must also be remembered that the moment iron was introduced by Europeans, the Māori abandoned shell and bone in favour of making their hooks from nails and other scraps of metal.

There are no indications that highly specialised fishing technologies were being developed during the prehistoric period in New Zealand. I have already mentioned the lack of fishing activities focused on the offshore oceanic waters, and to this can be added the lack of deep water fishing, such as for ruvettus. These fish are present in New Zealand waters, and were apparently discovered in the prehistoric period in other parts of the Pacific, but not in New Zealand. Similarly, the basis of specialised fishing techniques like ‘frightening lines’, which take advantage of the fact that some species are afraid to swim under thick hairy ropes, were not discovered by the Māori. Finally, there are no signs in New Zealand of the development of an aquaculture industry such as took place in Hawaii during the prehistoric period (Kirch 1985: 211–214).

As far as new fishing technologies and specialised knowledge are concerned, there are few signs of significant new achievements in prehistoric New Zealand.

This should not be seen as denigrating the pre-European Māori as fishermen. On the contrary, they were clearly very skilled and extremely knowledgeable about all aspects of their fishery[3]. However,

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[3] The choice of phrase ‘their fishery’ is deliberate, for this ownership is entrenched in the Treaty of Waitangi as the following excerpt from *Article the Second, Treaty of Waitangi, English version, 6 February 1840* shows: “Her Majesty the Queen of England confirms and guarantees to the Chiefs and Tribes of New Zealand and to the respective families and individuals thereof the full exclusive and undisturbed possession of their Lands and Estates Forests and Fisheries and other properties which they may collectively or individually possess so long as it is their wish and desire to retain the same in their possession” (Orange 1987: 258).

we must be careful to obtain a balanced perspective. Some groups of people in the Pacific hardly fished at all, particularly those on larger land masses, and many never ventured far out to sea in canoes for fish or any other reason. There is therefore nothing unusual in this somewhat mundane view, which I think is a closer reflection of reality.

Certainly, the first Europeans to New Zealand greatly admired the prowess and skill of Māori fishermen. They in turn were amused at the trifling efforts of the Europeans:

> … and after having a little laught at our seine, which was a common kings seine [i.e. the seine net commonly used in the navy], showed us one of theirs which was 5 fathoms deep and its length we could only guess, as it was not strechd out, but it could not from its bulk be less than 4 or 500 fathom. Fishing seems to be one of the cheif business of this part of the countrey; about all their towns are abundance of netts laid upon small heaps like hay cocks and thatchd over and almost every house you go into has netts in it making (Banks 1963 (I): 444).

This comment was made when Cook and Banks visited the Bay of Islands in December 1769.

PRE-EUROPEAN MĀORI DID NOT LIVE ON FISH ALONE

There are very important environmental changes from north to south in New Zealand. The marine fauna changes significantly over the length of the coastline, so that in the far north snapper is the dominant fish available to prehistoric communities, whereas in the far south blue cod and barracouta are the most common species. These changes are well reflected in the archaeological record. Over this same geographic range, access to carbohydrate foods changes from relatively abundant to almost non-existent.

With this perspective, it can be seen that in the far north both protein and carbohydrate foods were readily available and permitted a relatively large population to develop by the time of European contact. In the far south, the general lack of carbohydrate foods meant that access to fat was the single most important consideration for these people, and large populations were not possible.

Thus characterised, access to protein was not an issue in either the north or the south. There were plenty of fish available to anyone living near the coast, and in some places forest birds were also readily available to satisfy the need for protein. The really important problem was access to fat or carbohydrate in all parts of New Zealand.

In the central area of New Zealand, once again, plenty of protein was available, but carbohydrate foods were difficult to grow and access to sources of fat, such as seals, was relatively limited. Not surprisingly, the population in the central area appears to have been small at all periods.

CONCLUSIONS

The purpose of this volume was to provide a summary of current knowledge about the fishing activities of the pre-European Māori. Since the subject matter concerns the period before written records, the view is heavily biased towards the information gained from the archaeological record and pays only minor attention to other sources, such as oral history and tradition. This slant is quite deliberate, and reflects my opinion that wherever possible prehistory should be written using prehistoric evidence from the bottom up. Oral traditions are formulated and transmitted from one generation to another with purposes other than transmitting a simple chronicle of daily human activities. Archaeological evidence also has its own problems concerning biases of various kinds; towards certain durable forms, for example. However, archaeologists are keenly aware of these sorts of problems, and are constantly seeking new ways of improving the quality of knowledge gained from the ground and refining interpretations as a result.

In the last 200 years, the New Zealand Māori and Pacific islanders in general have variously been viewed by Europeans as ignorant and primitive people with only crude technology, representing a fossilised form of an earlier stage of human social and cultural evolution or, in a more romantic vision, as noble savages in harmony with nature. To some extent, this latter idealised view still prevails in some quarters. However, we now know from a great deal of archaeological evidence that pre-European life was definitely “nasty brutish and short” and, for the bulk of people, probably on a par with Medieval Europe in many respects.

I hope that this volume will serve to dispel romantic notions about the nature of pre-European fishing in New Zealand and reveal the Māori for what he really was—profoundly knowledgeable about the sea and its resources, and well able to harvest fish in a manner which conformed, in the main, to the customs of his ancestors in the tropical Pacific.

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APPENDIX 1:
NEW ZEALAND ARCHAEOLOGICAL SITES WITH RELIABLE INFORMATION ON FISH ABUNDANCE

The information below is a summary of MNI values for 126 archaeological sites in New Zealand. This constitutes the best currently available information. Although many identifications were originally made to species or genus level, they are grouped into families here. For this summary, the MNI values are combined for all stratigraphic provenances in each site. The matrix presented below has 126 rows (one for each site) and 36 columns (one for each fish family). The total MNI for all sites is 40,433. The matrix is preceded by a list summarising each site in the matrix and a second list summarising the fish families.

The approximate age of each site is indicated by a numeral from 1 to 3. These assessments follow the extensive discussion on dating in Leach and Boocock (1993). For sites not included in that volume, the age assessments provided by Anderson (1997) are followed. In a few sites, Mana North, Long Beach, Rotokura, there is significant chronological change, and the blanket age assessment reflects the bulk of the fish remains. The age categories are:

1 = **Early Prehistoric**. Before AD 1500, loosely corresponding to what is referred to as the Archaic Period, or New Zealand East Polynesian Culture.

2 = **Late Prehistoric**. After AD 1500 and before AD 1769, loosely corresponding to what is referred to as Classic Māori culture.

3 = **Protohistoric**. After AD 1769 and before AD 1840. Protohistoric Māori settlements

No	NZAA #	Abbrev	MNI	Site Name	Easting	Northing	Age
1	B44/41	BRE1	1153	Breaksea Sound 1,Discovery Cove,(BSS/1)	2032600	5498800	3
2	B43/7	BRE2	1	Breaksea Sound 2, Chatham Point 3, BSS/2	2032700	5501000	2
3	B45/1	CASC	125	Cascade Cove, Dusky Sound (CC/1)	2012200	5469400	2
4	B45/22	CHAL	45	Chalky Is, Chalky Inlet, Southport CH/1	2013900	5444100	1
5	B44/22	COOP	219	Coopers Island, Dusky Sound, (CI/1)	2027000	5478700	1
6	R10/38	DUND	54	Davidson Undefended Site, Motutapu Is	2682400	6493200	2
7	K30/2	FOXR	102	Fox River, Te Onumata, Potikohua River	2376000	5907200	2
8	S24/3	FOXT	270	Foxton	2700900	6081300	1
9	B45/23	GARD	1	Garden Island, Chalky Inlet, Southport	2014300	5444200	3
10	O27/13	GLEN	179	The Glen, Tasman Bay	2540300	6002400	1
11	T8/5	HARW	65	Harataonga Bay W Midden, Gt Barrier Is	2734100	6555800	1
12	T11/115	HOTW	278	Hot Water Beach, Coromandel Peninsula	2762100	6475200	1
13	O32/10	HUDS	27	Hudson's Site, Goose Bay, Kaikoura	2553300	5858700	2
14	Q27/30	IKAE	63	Te Ika a Maru, Eastern Flat	2649400	5994100	2
15	Q27/36	IKAF	199	Te Ika a Maru, Flat at Base of Pa	2649400	5994200	2
16	C240/21	KAHN	95	Kahiti North, Hansons Bay, Chatham Is	3291687	5747400	2
17	C240/20	KAHS	159	Kahiti South, Hansons Bay, Chatham Is	3291687	5747300	2
18	E48/30	KIRI	56	Te Kiri Kiri, Ruapuke Island, (KK/1)	2164800	5371500	3
19	E48/36	LEEI	8	Lee Island Site, on Ruapuke Island, LI/1	2169300	5374700	1
20	I44/23	LOBE	5770	Long Beach, Dunedin	2326900	5491400	2
21	B44/1	LONG	252	Long Island, Dusky Sound, (LI/1)	2013900	5472900	2
22	R10/31	LUND	12	Leahy Undefended Site, Motutapu Island	2682500	6493400	2
23	R27/41	MAKB	50	Makara Beach Midden	2653100	5997200	2
24	R27/42	MAKT	24	Makara Terrace Midden	2653000	5997200	2
25	B45/23	MILF	7	Milford	2014300	5444200	2
26	C240/277	NGAI	4	Te Ngaio, Petre Bay, Chatham Island	3271787	5747500	2
27	C240/273	OHIN	17	Ohinemamao, Petre Bay, Chatham Island	3273987	5749000	2
28	O32/8	OMIH	118	Omihi, Kaikoura	2552700	5856500	2
29	G47/50	PAPA	27	Papatowai, Catlins	2239800	5399600	1

30	E48/34	PARA	12	Parangiaio, Ruapuke Island, (PP/1)	2169100	5372500	1
31	R26/122	PARE	147	Paremata	2666700	6010200	2
32	C46/16	PCR1	114	Port Craig Cave, Foveaux Strait, (PC/1)	2074900	5428500	1
33	C46/17	PCR2	2	Port Craig Dry Rock Shelter 1, Foveaux	2074900	5428700	3
34	C46/18	PCR3	1	Port Craig Dry Rock Shelter 2, Foveaux	2074900	5428700	1
35	C46/19	PCR4	28	Port Craig Midden, Foveaux Strait, PC/4	2074200	5430000	1
36	O31/15	PEKP	54	Peketa Pa, Kaikoura	2558300	5863400	2
37	T9/139	PJAC	45	Port Jackson, Coromandel	2759400	6525800	1
38	C240/266	POKI	7	Pokiakio, Petre Bay, Chatham Islands	3277087	5751100	2
39	I43/22	ROSS	144	Ross's Rocks, Otago	2326100	5501100	1
40	C46/31	SAN1	214	Sandhill Point 1, Foveaux Strait, SHP/1	2072100	5424300	1
41	C46/31	SAN2	2	Sandhill Point 2, Foveaux Strait, SHP/2	2072100	5424300	1
42	C46/31	SAN3	364	Sandhill Point 3, Foveaux Strait, SHP/3	2072100	5424300	2
43	C46/31	SAN4	105	Sandhill Point 4, Foveaux Strait, SHP/4	2072100	5424300	1
44	B45/11	SOU1	443	Southport 1, Fiordland, (SP/1)	2014900	5444700	3
45	B45/14	SOU4	86	Southport 4, Cave Site, Fiordland, SP/4	2014800	5444900	1
46	B45/15	SOU5	120	Southport 5, Cave Site, Fiordland, SP/5	2014800	5444900	2
47	B45/16	SOU6	185	Southport 6, Fiordland, (SP/6)	2014800	5444900	3
48	B45/17	SOU7	111	Southport 7, Fiordland, (SP/7)	2014800	5444900	3
49	B45/18	SOU8	10	Southport 8, Fiordland, (SP/8)	2014900	5445100	2
50	B45/19	SOU9	1	Southport 9, Cave Site, Fiordland, SP/9	2014900	5445100	2
51	R10/26	STAT	156	Station Bay Pa, Motutapu Island	2682900	6493300	2
52	R10/25	SUND	128	Sunde Site, Motutapu Island	2679700	6492000	1
53	J44/77	TAIA	40	Taiaroa Head, Otago Peninsula	2333000	5490100	2
54	O31/5	TAKA	130	Takahanga Post Office Site Kaikoura	2566200	5866800	2
55	P26/217	TITC	14	Titirangi Cattleyards, Marlborough	2606200	6020100	1
56	P26/229	TITG	2	Goose Bay Midden, Titirangi, Marlborough	2606400	6021200	2
57	P26/218	TITP	1	Titirangi Pa, Marlborough Sounds	2606400	6020200	2
58	P26/208	TITS	47	Titirangi Sandhills, Marlborough Sounds	2605500	6020100	1
59	E47/13	TIWA	103	Tiwai Point, Bluff Harbour	2155400	5391900	1
60	N37/12	TUMB	42	Tumbledown Bay, Banks Peninsula	2491500	5706000	1
61	D46/38	WAKA	94	Wakapatu, Western Southland	2113200	5414100	1
62	S23/71	MANA	54	Parewanui Midden, Bulls, Manawatu	2700700	6102900	3
63	J43/2	SHAG	2134	Shag River Mouth	2339100	5522900	1
64	O6/317	KOKO	844	Kokohuia, Hokianga	2546200	6631100	1
65	U13/1101	MATA	132	Midden 8, Matakana Island	2777300	6406100	2
66	S28/49	WASH	771	Washpool Site, Palliser Bay	2694400	5965600	1
67	S28/54	MAK3	9	Makotukutuku M3 Fort Site, Palliser Bay	2696100	5966300	2
68	S28/48	MAK1	5	Makotukutuku M1 Camp Site, Palliser Bay	2694300	5965600	2
69	S28/104	BLR2	58	Black Rocks BR2 Pond Midden, Palliser	2696600	5953400	2
70	S28/104	BLR3	191	Black Rocks BR3 Black Midden, Palliser	2696600	5953400	1
71	S28/104	BLR4	705	Black Rocks BR4 Crescent Midden Palliser	2696600	5953400	1
72	S28/103	BLR5	21	Black Rocks Fan	2696400	5954500	1
73	R26/141	MAN1	596	Mana Island South Midden R26/141A	2659800	6011000	1
74	R26/141	MAN2	1206	Mana Island North Settlement R26/141	2659800	6011000	2
75	B46/12	ANDR	9	Andrewburn, Fiordland	2032200	5425700	2
76	I43/1	HURI	453	Huriawa Peninsula. Areas A,B,Salvage	2328200	5504900	2
77	E49/15	KELL	13	Kelly's Beach, Stewart Island	2143000	5338800	2
78	O31/30	OLDP	25	Old Pier Point Avoca, Kaikoura	2568100	5865300	1
79	I44/1	OMIM	27	Omimi, Otago	2324100	5498900	1
80	I44/5	OTOK	3	Otokia Mouth, Brighton Beach, Otago	2303300	5470100	1
81	H47/1	POUN	428	Pounawea, Otago	2256300	5409900	1
82	I44/21	PURA	2745	Purakanui Inlet, Otago	2325300	5492800	1
83	D46/35	RIVE	14	Riverton, Southland	2121400	5415300	1
84	O27/1	ROTO	585	Rotokura, Tasman Bay	2544400	6005300	1
85	J42/22	WAIA	6	Waianakarua Mouth, North Otago	2341600	5548300	1
86	T8/4	HARP	231	Harataonga Bay E. Midden, Gt Barrier Is	2734400	6555900	2
87	U12/5	SLIP	13	Slipper Island, Near Tairua Harbour	2771400	6457100	1
88	T11/62	TAIR	70	Tairua, Coromandel	2765000	6463000	1

89	T12/2	WHAN	6	Whangamata Wharf, Coromandel	2765800	6440500	1
90	T10/399	CROS	481	Cross Creek Site	2758700	6496300	1
91	C240/283	WAIH	4197	Waihora, Chatham Islands	3269687	5744100	2
92	C240/681	CHAA	884	CHA, Chatham Islands	3270187	5744700	2
93	C240/680	CHBB	4978	CHB, Chatham Islands	3270387	5745000	2
94	C240/689	CHCC	3	CHC, Chatham Islands	3269887	5744500	2
95	N36/72	PANA	68	Panau, Canterbury Peninsula	2512500	5728100	2
96	M2/162	TWIL	635	Twilight Beach, Northland	2482200	6746100	1
97	N3/582	AUPO	18	Aupouri Dune Middens 90 Mile Beach	2507400	6722600	2
98	N3/59	HOUH	2425	Houhora	2525300	6708500	1
99	O6/290	WAIP	329	Waipoua	2549300	6621200	2
100	Q7/58	NHBW	5	Northland Harbour Board Site, Whangarei	2631500	6605200	2
101	R10/25	SUN2	584	Sunde Site Oyster lens	2679700	6492000	1
102	R10/25	SUN3	401	Sunde Site soft shore midden	2679700	6492000	1
103	R11/898	WES1	21	Westfield N42/941	2674900	6473400	2
104	R11/142	HAML	12	Hamlins Hill N42/137	2673700	6473800	2
105	T11/242	HAHE	202	Hahei N44/215	2760700	6480800	2
106	T11/326	HARS	9	N44/97	2761100	6480300	1
107	T12/192	ORUR	6	Oruarangi N49/28	2739400	6439500	2
108	T13/13	RAUP	25	Raupa N53/37, T13/13	2745200	6422100	2
109	R15/10	AOTE	35	Aotea N64/25	2667400	6356000	2
110	V15/80	KOHI	184	Kohika N68/104	2842900	6358800	2
111	N26/18	AWAR	32	Awaroa N26/18	2511700	6038300	2
112	N26/214	BARB	261	N26/214	2510900	6014400	2
113	N26/16	BARK	50	Bark Bay	2514200	6032200	2
114	N25/50	TAUP	11	Taupo Point	2506100	6046400	2
115	N27/118	APPL	128	Appleby	2520100	5988600	1
116	O27/56	HAUL	25	Haulashore Island	2531600	5993000	2
117	G36/1	BRUC	54	Bruce Bay	2233200	5728200	1
118	W21/1	TIRO	6	Tiromoana N135/1	2852300	6165500	2
119	S28/68	PAR2	36	Pararaki Wall, Pararaki North N168-9/41	2694200	5961600	1
120	J43/4	PLE1	54	Pleasant River (Anthropology) S155/8	2332500	5512800	1
121	J43/4	PLE2	145	Pleasant River (Smith)	2332500	5512800	1
122	J43/4	TUMA	106	Tumai, Pleasant River Mouth South	2332500	5512800	1
123	I44/17	MAPO	140	Mapoutahi S164/13	2324400	5494300	2
124	J44/4	PUKE	105	Pukekura Pa, Taiaroa Head	2333100	5490100	2
125	G47/50	PAP2	29	Papatowai S184/5	2239800	5399600	1
126	E48/29	WES2	63	West Point WP/1, Ruapuke Island	2164300	5371700	2

Total MNI 40433

No	**Family**	**Common Name**	**MNI**
1	Anguillidae	Freshwater eels	131
2	Aplodactylidae	Marblefish	48
3	Arripidae	Kahawai	481
4	Carangidae	Trevally, etc.	603
5	Triglidae	Red gurnard	170
6	Sparidae	Snapper	6346
7	Congridae	Conger eel	192
8	Chondrichthyes/Elasmobranchs	Sharks, etc.	224
9	Ophidiidae	Ling	713
10	Scorpaenidae	Scarpee, etc.	542
11	Uranoscopidae	Giant stargazer	4
12	Latrididae	Blue moki, etc.	473
13	Leptoscopidae	Estuarine stargazer	9
14	Moridae	Red cod, etc.	3685
15	Balistidae	Leatherjacket	712
16	Cheilodactylidae	Tarakihi, etc.	990
17	Nototheniidae	Maori chief	316
18	Odacidae	Greenbone	2967
19	Mugiloididae	Blue cod	6664
20	Pleuronectidae	Flounder, etc.	27
21	Percichthyidae	Groper	238
22	Labridae	Spotty, etc.	4259
23	Gempylidae	Barracouta, etc.	10075
24	Scombridae	Blue mackerel, etc.	26
25	Kyphosidae	Parore, etc.	11
26	Centrolophidae	Blue warehou	22
27	Osteichthyes	Other bony fishes	141
28	Zeidae	John dory	29
29	Mugilidae	Yelloweyed mullet, etc.	192
30	Callorhinchidae	Elephantfish	21
31	Merlucciidae	Hoki	9
32	Squalidae	Spiny dogfish	39
33	Myliobatidae	Eagle ray	34
34	Dasyatidae	Sting ray	2
35	Diodontidae	Porcupinefish	3
36	Chimaeridae	Ghost shark	35
			Total MNI 40433

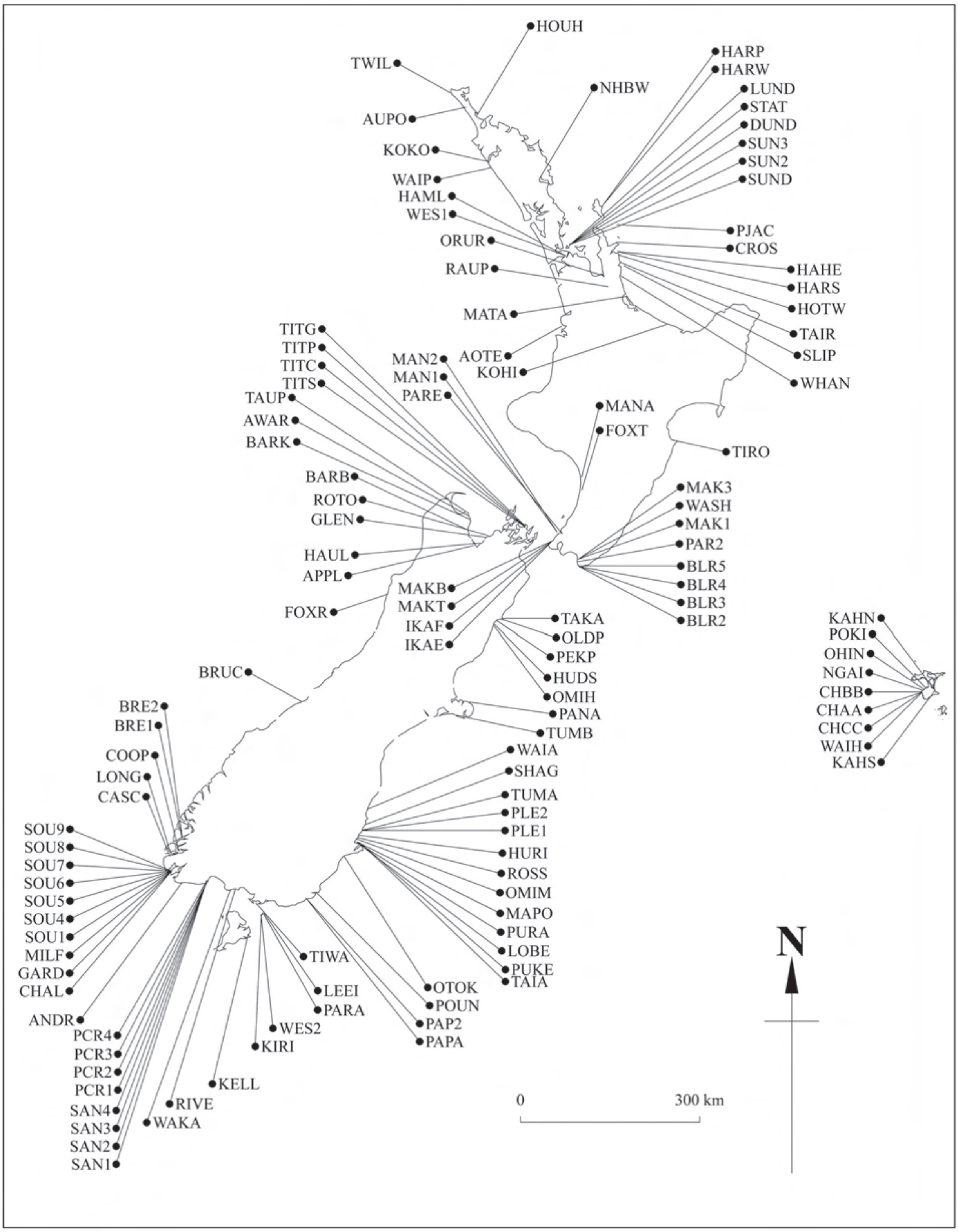

Figure A.1: Location of archaeological sites in New Zealand and Chatham Islands included in the database.

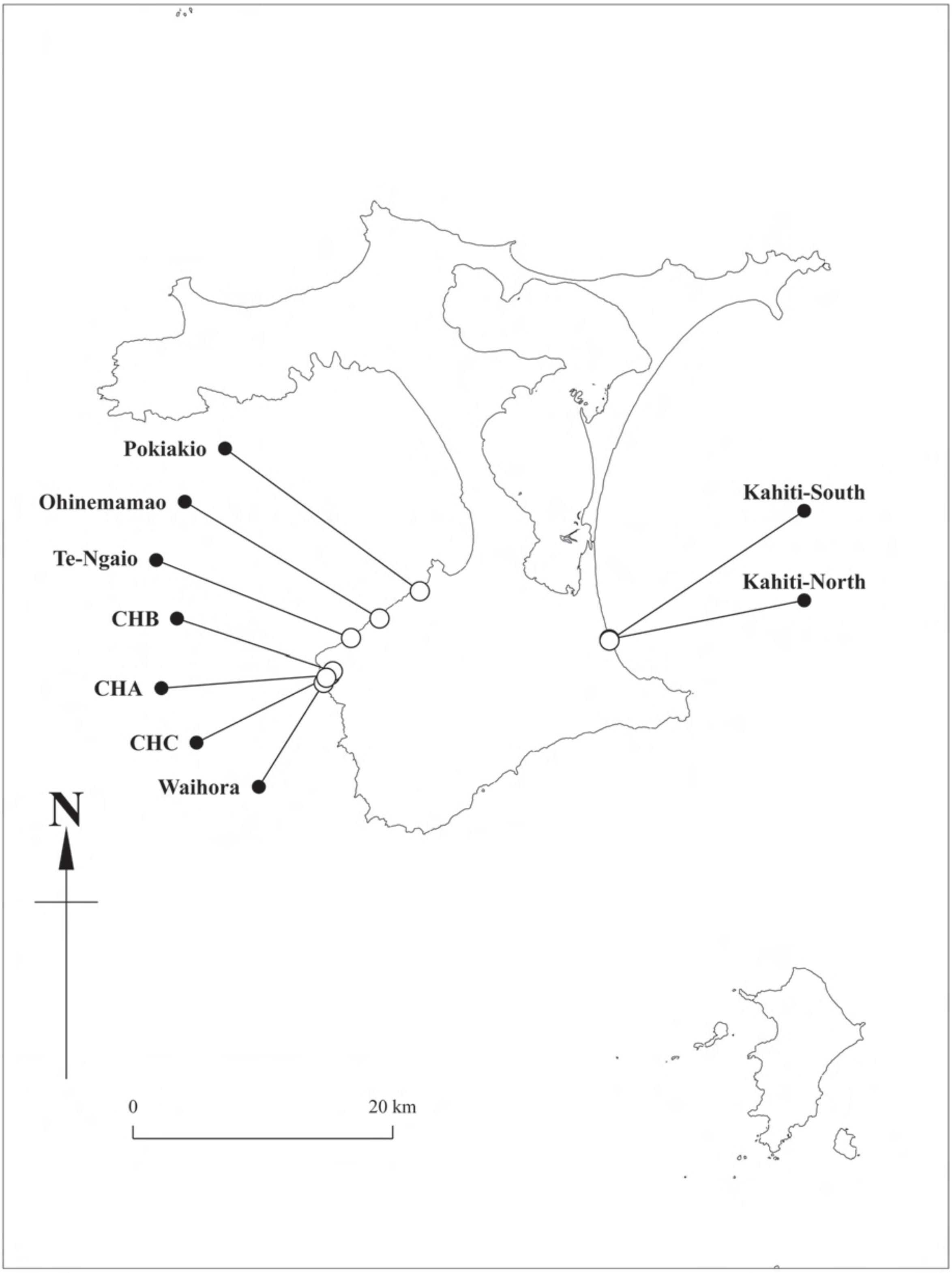

Figure A.2: Location of archaeological sites in the Chatham Islands included in the database.

Matrix of MNI Values

Family

Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	MNI
1	0	0	0	6	1	2	5	0	18	300	4	3	0	64	0	118	1	0	118	3	1	402	102	0	0	3	2	0	0	0	0	0	0	0	0	0	1153
2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
3	0	0	0	8	0	0	3	2	4	11	0	0	0	11	1	6	0	0	23	0	2	25	29	0	0	0	0	0	0	0	0	0	0	0	0	0	125
4	0	0	0	0	0	0	3	0	0	0	0	2	0	1	0	2	0	2	13	0	0	21	1	0	0	0	0	0	0	0	0	0	0	0	0	0	45
5	0	0	0	0	0	3	1	0	2	45	0	0	0	6	1	25	0	0	61	0	1	66	8	0	0	0	0	0	0	0	0	0	0	0	0	0	219
6	0	0	0	0	3	39	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	1	0	0	0	0	0	0	0	0	54
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8	0	0	51	3	1	211	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	270
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
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61	1	0	0	0	0	0	2	0	14	0	0	0	0	30	0	0	2	0	26	0	2	4	13	0	0	0	0	0	0	0	0	0	0	0	0	0	94
62	29	0	0	0	0	10	0	12	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	54
63	1	0	0	0	0	1	0	0	57	20	0	30	0	339	0	2	46	0	155	0	11	116	1354	0	0	1	0	0	1	0	0	0	0	0	0	0	2134
64	0	1	61	67	70	429	0	6	1	6	0	12	0	5	19	20	0	9	4	2	0	109	8	1	6	0	0	0	6	0	0	0	2	0	0	0	844
65	0	0	1	77	13	1	0	8	0	0	0	1	0	0	0	0	0	0	0	9	0	4	4	10	2	0	2	0	0	0	0	0	0	0	0	0	132
66	37	2	63	53	16	37	5	21	1	8	0	20	0	100	1	136	0	10	29	0	10	151	53	0	0	10	0	0	0	5	2	1	0	0	0	0	771
67	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	9
68	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	5
69	0	1	0	0	0	0	2	2	0	1	0	2	0	0	0	0	0	18	8	0	1	21	1	0	0	0	1	0	0	0	0	0	0	0	0	0	58
70	0	1	13	0	0	6	4	2	2	1	0	6	0	3	0	9	0	11	8	0	6	114	4	0	0	0	1	0	0	0	0	0	0	0	0	0	191
71	0	10	20	4	1	10	15	22	0	41	0	29	0	31	0	55	1	75	36	0	13	278	56	0	0	0	1	0	0	0	7	0	0	0	0	0	705
72	0	0	1	0	0	0	0	1	0	5	0	0	0	0	0	2	0	1	1	0	0	8	2	0	0	0	0	0	0	0	0	0	0	0	0	0	21
73	0	4	40	11	0	155	2	5	0	3	0	10	0	1	70	20	0	8	35	0	1	224	5	0	0	0	1	0	0	0	0	0	1	0	0	0	596
74	2	18	42	18	4	140	50	51	6	21	0	96	0	5	55	37	0	126	111	0	19	299	72	2	0	0	7	2	0	2	0	7	14	0	0	0	1206
75	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	5	0	0	0	0	2	0	0	0	0	0	0	0	0	0	9
76	0	0	0	0	0	0	0	0	9	0	0	1	0	106	0	0	0	0	1	0	36	0	300	0	0	0	0	0	0	0	0	0	0	0	0	0	453
77	0	0	0	0	0	0	0	0	4	0	0	0	0	1	0	0	0	0	2	0	0	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	13
78	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	1	0	0	4	6	10	0	0	0	1	0	0	0	0	0	0	0	0	0	25
79	0	0	0	0	0	0	0	0	6	0	0	0	0	9	0	0	0	0	0	0	0	0	11	0	0	0	1	0	0	0	0	0	0	0	0	0	27
80	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3
81	0	0	0	0	0	0	0	0	13	1	0	1	0	35	0	0	0	0	5	1	0	4	368	0	0	0	0	0	0	0	0	0	0	0	0	0	428
82	0	0	0	0	0	0	0	0	111	0	0	4	0	1273	0	0	0	0	0	2	9	27	1318	0	0	0	0	0	0	1	0	0	0	0	0	0	2745
83	1	0	0	0	0	0	0	0	4	0	0	0	0	1	0	0	2	1	2	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
84	1	0	2	2	4	235	7	0	11	3	0	17	0	40	56	20	0	1	11	0	0	60	103	0	0	0	5	0	0	0	0	2	3	2	0	0	585
85	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0	2	0	0	0	0	0	0	0	0	0	6
86	0	0	8	7	0	83	0	0	0	0	0	0	0	0	92	0	0	9	0	0	0	4	2	0	0	0	0	0	0	0	0	26	0	0	0	0	231
87	0	0	2	0	0	8	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	13
88	0	0	7	0	1	28	0	1	0	0	0	3	0	0	0	9	0	0	1	0	0	12	0	0	0	0	6	2	0	0	0	0	0	0	0	0	70
89	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	6
90	0	0	9	4	1	248	0	0	0	1	0	0	0	0	167	1	0	0	1	0	0	46	2	0	0	0	0	0	0	0	0	0	0	0	1	0	481
91	14	2	0	9	1	0	11	0	8	3	0	74	0	60	6	73	67	1195	1763	0	8	801	39	0	0	0	0	0	0	11	0	3	14	0	0	35	4197
92	1	0	0	0	0	0	0	0	0	0	0	9	0	0	0	21	14	147	602	0	1	89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	884
93	4	0	0	0	0	0	16	0	4	0	0	22	0	5	30	183	116	1288	3066	0	2	242	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4978
94	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
95	0	0	2	0	0	3	1	0	10	0	0	0	0	36	0	0	1	0	0	0	2	5	5	0	0	0	1	0	0	2	0	0	0	0	0	0	68
96	0	0	11	3	1	592	0	0	0	0	0	0	0	0	1	6	0	0	1	0	0	18	0	0	0	0	0	1	0	0	0	0	0	0	1	0	635
97	0	0	2	0	0	9	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	18
98	1	0	55	143	1	2207	0	0	0	0	0	2	0	1	3	3	0	0	1	0	0	2	2	0	1	0	0	2	0	0	0	0	0	0	1	0	2425
99	0	0	0	1	0	321	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	329
100	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	2	0	0	0	0	0	0	0	5
101	1	0	0	11	0	390	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0	2	0	0	0	0	0	0	176	0	0	0	0	0	0	0	584
102	1	0	1	2	1	386	0	0	0	0	0	0	0	0	0	3	0	0	1	0	0	0	1	0	0	0	0	1	4	0	0	0	0	0	0	0	401
103	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	21
104	0	0	0	0	1	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	12
105	0	0	1	0	3	20	0	0	0	0	0	4	0	1	133	7	0	1	3	0	0	26	1	0	2	0	0	0	0	0	0	0	0	0	0	0	202
106	0	0	0	0	0	4	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
107	0	0	2	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
108	1	0	3	2	3	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	1	0	0	0	0	0	0	0	25
109	1	0	1	0	0	27	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35
110	0	0	23	120	2	14	0	0	0	0	0	0	1	0	2	2	0	0	1	0	1	1	2	9	0	0	0	6	0	0	0	0	0	0	0	0	184
111	0	0	0	0	0	0	0	0	1	0	0	0	0	12	0	5	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	32
112	0	0	0	0	1	2	0	0	7	0	0	3	0	85	0	11	0	0	0	0	0	4	147	1	0	0	0	0	0	0	0	0	0	0	0	0	261
113	0	0	0	0	0	1	0	0	1	0	0	0	0	25	0	4	0	0	0	0	0	1	18	0	0	0	0	0	0	0	0	0	0	0	0	0	50
114	0	0	0	0	0	0	0	0	1	0	0	0	0	5	0	1	0	0	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	11
115	0	0	2	6	3	3	0	0	0	0	0	1	0	79	0	4	0	0	7	1	0	1	19	0	0	0	0	0	2	0	0	0	0	0	0	0	128

116	0	0	0	1	0	9	0	0	1	1	0	1	0	5	0	0	0	0	0	0	0	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	25
117	0	0	0	0	0	0	0	0	1	0	0	0	0	24	0	18	0	0	0	0	0	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	54
118	0	0	0	0	0	1	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
119	0	0	2	0	1	2	0	0	0	4	0	2	0	2	0	5	0	1	3	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36
120	0	2	0	0	0	0	0	0	5	0	0	0	0	15	0	0	2	0	7	0	0	6	17	0	0	0	0	0	0	0	0	0	0	0	0	0	54
121	0	0	0	2	0	0	0	0	1	0	0	0	0	28	0	2	5	0	22	0	0	4	81	0	0	0	0	0	0	0	0	0	0	0	0	0	145
122	0	2	0	0	3	0	0	0	3	1	0	2	0	18	0	0	5	0	15	0	0	4	53	0	0	0	0	0	0	0	0	0	0	0	0	0	106
123	0	0	0	0	0	0	0	0	9	0	0	0	0	75	0	0	0	0	1	0	3	4	48	0	0	0	0	0	0	0	0	0	0	0	0	0	140
124	0	0	0	0	0	0	0	0	3	0	0	0	0	9	0	0	0	0	0	0	0	0	93	0	0	0	0	0	0	0	0	0	0	0	0	0	105
125	0	0	0	0	0	1	0	0	1	0	0	1	0	3	0	0	0	0	1	0	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	29
126	0	0	0	0	0	0	0	0	0	1	0	6	0	3	0	1	0	2	26	0	1	13	10	0	0	0	0	0	0	0	0	0	0	0	0	0	63
MNI	**131**	**48**	**481**	**603**	**170**	**6346**	**192**	**224**	**713**	**542**	**4**	**473**	**9**	**3685**	**712**	**990**	**316**	**2967**	**6664**	**27**	**238**	**4259**	**10075**	**26**	**11**	**22**	**141**	**29**	**192**	**21**	**9**	**39**	**34**	**2**	**3**	**35**	**40433**

APPENDIX 2
GLOSSARY OF COMMON AND SPECIES NAMES

The following is a list of organisms whose common names have appeared in this volume, cross-referenced against their systematic name. The list mainly comprises New Zealand and tropical Pacific marine and freshwater fishes, but it also includes birds, shellfish and plants which have been referred to in the text. Family names appear beside some notable species.

Acanthuridae	Surgeonfishes
Albacore tuna	*Thunnus alalunga*
Albatross	*Diomedea* spp.
Alfonsino	*Beryx splendens*
Anchovy	*Engraulis australis*
Anguillidae	Freshwater eels
Aplodactylidae	Marblefishes
Arripidae	Kahawai
Atlantic silverside	*Menidia menidia*
Atlantic haddock	*Melanogrammus aeglefinus*
Atlantic croaker	*Micropogonias undulatus*
Atlantic cod	*Gadus morhua*
Australian bonito	*Sarda australis*
Balistidae	Triggerfish (incl. leatherjacket)
Banded parrotfish/wrasse	*Pseudolabrus fucicola*, Labridae
Barracouta (Pacific)	*Promethichthys prometheus*
Barracouta (New Zealand)	*Thyrsites atun*, Gempylidae
Bass groper	*Polyprion moeone*
Bearded seal	*Erignathus barbatus*
Black flounder	*Rhombosolea retiaria*
Black rockfish	*Sebastes melanops*
Black cod	*Paranotothenia magellanica*
Blind eel/hagfish	*Eptatretus cirrhatus*
Blue moki	*Latridopsis ciliaris*, Latrididae
Blue cod	*Parapercis colias*, Mugiloididae
Blue warehou	*Seriolella brama*
Blue mackerel	*Scomber australasicus*
Blue marlin	*Makaira nigricans*
Blue mussel	*Mytilus gallo-provincialis* (formerly *M. edulis*)
Bluefish	*Pomatomus saltatrix*
Bluenose	*Hyperoglyphe antarctica*
Bluff oyster	*Tiostrea lutaria*
Bony fishes	Teleostomi/Osteichthys
Breadfruit	*Artocarpus altilis*
Brill	*Colistium guntheri*
Butterfish/greenbone	*Odax pullus*, Odacidae
Cabbage tree/*tī*	*Cordyline australis*
Carangidae	Jacks, trevallies, pompanos
Carp	*Cyprinus carpio*
Centrolophidae	Raftfishes (incl. warehou)
Cheilodactylidae	Morwongs (incl. tarakihi)
Chondrichthyes	Cartilaginous fishes
Cockle	*Austrovenus stutchburyi*

Coconut	*Cocos nucifera*
Common trumpeter	*Latris lineata*
Common warehou	*Seriolella brama*
Common mackerel/blue mackerel	*Scomber australasicus* formerly *S. japonicus*
Common conger eel	*Conger verreauxi*, Congridae
Congridae	Conger eels
Crayfish/rock lobster	*Jasus edwardsii*
Dab/sand flounder	*Rhombosolea plebeia*
Dark ghost shark	*Hydrolagus novaezelandiae*
Dogfish	*Squalus acanthias*
Dolphin (dusky)	*Lagenorhynchus obscurus*
Dolphin (common)	*Delphinus delphis*
Dolphinfish/mahimahi	*Coryphaena hippurus*
Duck	*Anas* spp.
Eagle ray	*Myliobatus tenuicaudatus*
Elasmobranchii	Sharks, skates, rays
Elephant seal (southern)	*Mirounga leonina*
Elephant fish	*Callorhinchus milii*
Estuarine stargazer	*Leptoscopus macropygus*
Fern root (bracken fern)	*Pteridium esculentum*
Flax (New Zealand)	*Phormium* spp.
Flounder	*Rhombosolea* spp.
Freshwater eel	*Anguilla* spp., Anguillidae
Frostfish	*Lepidopus caudatus*
Fur seal (southern)	*Arctocephalus forsteri*
Garfish/piper	*Hyporhamphus ihi*
Gemfish	*Rexea solandri*, Gempylidae
Gempylidae	Snake mackerels (incl. barracouta)
Ghost shark	*Hydrolagus novaezelandiae*
Giant stargazer	*Kathetostoma giganteum*
Girdled wrasse	*Pseudolabrus cinctus*
Grayling	*Prototroctes oxyrhynchus*
Green wrasse	*Pseudolabrus inscriptus*
Green turtle	*Chelonia mydas*
Green mussel	*Perna canaliculus*
Greenback flounder	*Rhombosolea tapirina*
Greenbone/butterfish	*Odax pullus*, Odacidae
Grenadiers	Macrouridae
Groper/hāpuku	*Polyprion oxygeneios*, Percichthyidae
Hake	*Merluccius australis*
Half-beaks	Hemiramphidae
Hāpuku/groper	*Polyprion oxygeneios*, Percichthyidae
Hoki	*Macruronus novaezelandiae*
Horse mussel	*Atrina pectinata, A. zelandica*
Horse mackerel	*Trachurus novaezelandiae*, Carangidae
Jack mackerel	*Trachurus declivis*, Carangidae
John Dory	*Zeus faber* formerly *Z. japonicus*
Kahawai	*Arripis trutta*, Arripidae
Karaka	*Corynocarpus laevigatus*
Kelp	*Laminaria* spp.

Kiekie	*Freycinetia baueriana* formerly *F. banksii*
Kina/sea urchin	*Evechinus chloroticus*
Kingfish (yellowtail)	*Seriola lalandi*, Carangidae
Kiwi	*Apteryx* spp.
Kōhutuhutu	*Fuchsia excorticata*
Kūmara	*Ipomoea batatas*
Labridae	Wrasses (incl. spotty)
Lamprey	*Geotria australis*
Latrididae	Trumpeters (incl. moki)
Leatherjacket	*Parika scaber*, Balistidae
Leopard seal	*Hydrurga leptonyx*
Leptoscopidae	Stargazers
Ling	*Genypterus blacodes*, Ophidiidae
Long-finned eel	*Anguilla dieffenbachii*
Lookdown dory	*Cyttus traversi*
Mackerel	*Trachurus* spp., Carangidae
Maori chief	*Paranotothenia angustata*, Nototheniidae
Marblefish	*Aplodactylus arctidens*, Aplodactylidae
Marlin	*Makaira* spp.
Moa	Dinornithiformes
Moki (blue)	*Latridopsis ciliaris*, Latrididae
Monkfish	*Kathetostoma giganteum*
Moridae	Morid cods (incl. red cod)
Mu	*Monotaxis grandoculis*
Mugiloididae	Sandperches/weevers (incl. blue cod)
Mullet (grey)	*Mugil cephalus*
Mullet	Mugilidae
Muttonbird	*Puffinus griseus*
Needlefish	Belonidae
New Zealand sea lion	*Phocarctus hookeri*
Northern bastard red cod	*Pseudophycis breviuscula*
Nototheniidae	Ice cods (incl. black cod)
Odacidae	Butterfishes (incl. greenbone)
Ophidiidae	Cusk eels (incl. ling)
Orange wrasse	*Pseudolabrus luculentus*
Orange roughy	*Hoplostethus atlanticus*
Orange perch	*Lepidoperca pulchella*
Oreo dories	Oreosomatidae
Osteichthyes	Bony fishes, family not known
Paddle crab (swimming crab)	*Ovalipes catharus*
Palu (oil fish)	*Ruvettus pretiosus*
Parore	*Girella tricuspidata*, Kyphosidae
Parrotfish (Pacific)	Scaridae
Parrotfish (New Zealand)	*Pseudolabrus* spp.
Pāua	*Haliotis* spp.
Percichthyidae	Basses (incl. groper/hāpuku)
Pig	*Sus scrofa*
Pilchard	*Sardinops neopilchardus*
Pilot whale (short-finned)	*Globicephala macrorhyncha*
Pilot whale (long-finned)	*Globicephala melaena*

Piper/garfish	*Hyporhamphus ihi* Hemiramphidae
Pipi	*Paphies australis*
Pleuronectidae	Right-eyed flounders
Polar bear	*Ursus maritimus*
Porcupinefish	Diodontidae
Pūkeko	*Porphyrio porphyrio*
Red cod	*Pseudophycis bachus*, Moridae
Red gurnard	*Chelidonichthys kumu*, Triglidae
Ribaldo	*Mora moro*
Rig	*Mustelus lenticulatus*
Rock lobster/crayfish	*Jasus edwardsii*
Rock cod	*Lotella rhacinus*
Rough skate	*Raja nasuta*
Ruvettus/oil fish	*Ruvettus pretiosus*
Sand flounder/dab	*Rhombosolea plebeia*
Sauries	Scomberesocidae
Scaridae	Parrotfishes
Scarlet wrasse	*Pseudolabrus miles*, Labridae
Scarpee	*Helicolenus* spp., Scorpaenidae
School shark	*Galeorhinus australis*
Scombridae	Tunas and mackerels
Scorpaenidae	Scorpionfishes (incl. sea perch)
Scorpion fish	*Scorpaena cardinalis*, Scorpaenidae
Sea lion	*Phocarctos hookeri*
Sea perch	*Helicolenus percoides*
Sharks/skates/rays	Elasmobranchii
Short-finned eel	*Anguilla australis*
Silver warehou	*Seriolella punctata*
Silverside	*Argentina elongata*
Skates	Rajidae
Skipjack tuna	*Katsuwonus pelamis*
Snapper	*Pagrus auratus*, Sparidae
Sole (lemon)	*Pelotretis flavilatus*
Sole (common)	*Peltorhamphus novaezeelandiae*
Southern elephant seal	*Mirounga leonina*
Southern bluefin tuna	*Thunnus maccoyii*
Southern blue whiting	*Micromesistius australis*
Southern fur seal	*Arctocephalus forsteri*
Sparidae	Sea breams (incl. snapper)
Spiny dogfish	Squalidae
Spotted gurnard	*Pterygotrigla picta*, Triglidae
Spotted spiny dogfish	*Squalus acanthias*
Spotty	*Pseudolabrus celidotus*, Labridae
Sprat	*Sprattus antipodum* and *S. muelleri*
Squid (arrow)	*Nototodarus* spp.
Sting ray	*Dasyatis* spp.
Sugar cane	*Saccharum officinarum*
Sunfish	*Mola mola*
Sweep	*Scorpis aequipinnis*
Tarakihi	*Nemadactylus macropterus*, Cheilodactylidae

Taro	*Colocasia esculenta*
Teleostomi	Bony fish, family not known
Threadfish/threadfin	*Polydactylus sexfilis*
Tī/cabbage tree	*Cordyline australis*
Toheroa	*Paphies ventricosa*
Tree flax/tree lily	*Astelia* sp.
Tree fern	*Cyathea* spp., *Dicksonia* spp.
Trevally	*Caranx georgianus*/*Pseudocaranx dentex*, Carangidae
Tridacna	*Tridacna* spp., giant clam shell
Triglidae	Gurnards
Tuatua (inter-tidal)	*Paphies subtriangulata*
Tuatua (sub-tidal)	*Paphies donacina*
Tunas and mackerels	Scombridae
Tupākihi	*Coriaria* spp.
Turbot	*Colistium nudipinnis*
Uranoscopidae	Stargazers
Wahoo	*Acanthocybium solandri*
Walleye pollock	*Theragra chalcogramma*
Weka	*Gallirallus australis*
White warehou	*Seriolella caerulea*
Whitebait	*Galaxias* spp. Galaxiidae
Wrasse/parrotfish	Labridae
Yam	*Dioscorea* spp.
Yellowbelly flounder	*Rhombosolea leporina*
Yellow-eyed mullet	*Aldrichetta forsteri*, Mugilidae
Yellowtail kingfish	*Seriola lalandi*, Carangidae
Zeidae	Dories

APPENDIX 3
INSHORE AND OFFSHORE FISHING IN PRE-EUROPEAN NEW ZEALAND

In 1993 I wrote an extended discussion on the issue of where pre-European Māori were obtaining most of their fish — inshore or offshore (Leach and Boocock 1993: 20–27). This is still a topical issue, revisited in submissions to the Waitangi Tribunal, where Māori lay claim to an interest in the modern fishery well out to sea, partly on the basis of oral traditions. In the published discussion on this issue I was very critical of the view presented by Paulin, where he concluded that the Māori had "little apparent knowledge of fishes below 100 m depth" (Paul 1989: 2). Paulin reached this view after thoroughly examining recorded Māori names for fishes. He found few names for deep water species. My main point of criticism related to the use of linguistic data for the intended purpose. There are many reasons why lists of Māori names for fish species recorded during the historic period are pitifully inadequate, and Paulin himself lists seven of these. In respect of deep water species, the most important reason is that early Europeans, writing down Māori names for fish, were themselves ignorant of deep water fishes, and were thus unable to record them! The opportunity to tap into the store of traditional Māori knowledge about the deep water fishery soon passed as Māori adopted European customs and technology. The only sensible way to assess pre-European knowledge of the deep water and offshore fishery is to examine archaeological data for evidence of the species themselves. This source of knowledge does not lie and is not biased by social or ideological issues. One bone, accurately identified to species, is as close to an absolute as one could hope for. A sizeable number of bones of a deep water and/or offshore species scattered through archaeological sites in several parts of New Zealand would be irrefutable evidence of fishing away from the inshore area and, more to the point, is quantifiable. I therefore think it is useful to attempt to do just that — to quantify the relative amount of fish which pre-European Māori were obtaining inshore and offshore. This appendix is aimed at providing such an assessment.

The first thing I need to do is comment on what the terms inshore and offshore might mean in this context. For distinguishing depth, I have made an arbitrary boundary of 50 metres. As far as distance from shore is concerned, 100 metres is a suitable dividing line. If a species is almost always found either more than 100 metres offshore, or almost always at depths of more than 50 metres, I class it as offshore. This means that pelagic species like tuna that are usually in clear oceanic waters well out to sea but caught on the surface are classified as offshore. In addition, species that can be taken close to shore, but in water greater than 50 metres, such as groper, are also classified as offshore. In cases where a species can be taken in both zones I apportion the quantities below accordingly. I am sure some will argue that some of the apportions I make are unfair in some way, but that is not my intention. If anything I have probably erred in favour of the offshore position for species found in both zones. The ratio of inshore/offshore is plainly shown and different researchers can tinker with anything in the Table except the first MNI value, and recalculate the values at the bottom of the Table as they see fit. The MNI abundance values below are taken from Appendix 1.

No.	Family	Common Name	MNI	Ratio	Inshore	Offshore
1	Anguillidae	Freshwater eels	131	100: 0	131	0
2	Aplodactylidae	Marblefish	48	100: 0	48	0
3	Arripidae	Kahawai	481	60:40	289	192
4	Carangidae	Trevally, etc.	603	60:40	362	241
5	Triglidae	Red gurnard	170	60:40	102	68
6	Sparidae	Snapper	6346	90:10	5711	635
7	Congridae	Conger eel	192	80:20	154	38
8	Elasmobranchs	Sharks, etc.	224	80:20	179	45

9	Ophidiidae	Ling	713	10:90	71	642
10	Scorpaenidae	Scarpee, etc.	542	40:60	217	325
11	Uranoscopidae	Giant stargazer	4	100: 0	4	0
12	Latrididae	Blue moki, etc.	473	90:10	426	47
13	Leptoscopidae	Estuarine stargazer	9	100: 0	9	0
14	Moridae	Red cod, etc.	3685	90:10	3316	368
15	Balistidae	Leatherjacket	712	100: 0	712	0
16	Cheilodactylidae	Tarakihi, etc.	990	80:20	792	198
17	Nototheniidae	Maori chief	316	80:20	253	63
18	Odacidae	Greenbone	2967	100: 0	2967	0
19	Mugiloididae	Blue cod	6664	60:40	3998	2666
20	Pleuronectidae	Flounder, etc.	27	100: 0	27	0
21	Percichthyidae	Groper/hāpuku	238	0:100	0	238
22	Labridae	Spotty, etc.	4259	100: 0	4259	0
23	Gempylidae	Barracouta, etc.	10075	90:10	9068	1008
24	Scombridae	blue mackerel	26	0:100	0	26
25	Kyphosidae	Parore, etc.	11	100: 0	11	0
26	Centrolophidae	Blue warehou, etc.	22	10:90	2	20
27	Osteichthyes	Unidentified bony fishes	141	50:50	70	70
28	Zeidae	John Dory	29	20:80	6	23
29	Mugilidae	Yelloweyed mullet, etc.	192	100: 0	192	0
30	Callorhinchidae	Elephantfish	21	20:80	4	17
31	Merlucciidae	Hoki	9	0:100	0	9
32	Squalidae	Spiny dogfish	39	80:20	31	8
33	Myliobatidae	Eagle ray	34	100: 0	34	0
34	Dasyatidae	Sting ray	2	100: 0	2	0
35	Diodontidae	Porcupinefish	3	100: 0	3	0
36	Chimaeridae	Ghost shark	35	0:100	0	35
MNI Totals			**40433**		**33450**	**6982**
Percent					**82.7%**	**17.3%**

CONCLUSION

Thus characterised, 83% of fishes taken in the pre-European period were from the inshore environment.

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