Section 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 (Figure 118). 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).

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 & 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.

FIGURE 118

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).

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 (Shawcross 1967a: 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 (Shawcross 1967a).

The reconstruction of the "nutritional value of the foods in the [Galatea Bay] midden" (Shawcross 1967a: 123) is summarised in Table 31.

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 documen-

	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).

TABLE 31

The Reconstructed Nutritional Ingredients of the Galatea Bay Midden (based on Shawcross 1967a: 123).

> ted, 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 Section, 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 31. 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 & 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 Draper (1977, 1980), Speth (1983), Speth & Spielmann (1983), Noli & Avery (1988), 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 31.

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 & 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 32, together with the recommended daily amounts required.

	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**

TABLE 32

Essential Amino Acids and Recommended Daily Amounts for Adult Males (from Scrimshaw & Young 1976: 62).

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 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.

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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.

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 backfat	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.

TABLE 33

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.

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.

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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).

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 3-6 g/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 33 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.

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 & 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. All other foods provide energy too, and fat is by far the greatest source of energy (9 kcal/g).

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 34, which provides the energy for some common shellfish and other foods. Drying tuatua increases the good value nearly four times.

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

TABLE 34

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.

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 119 (see Davidson & Leach 2001: 119, Davidson & Leach 2002: 269).

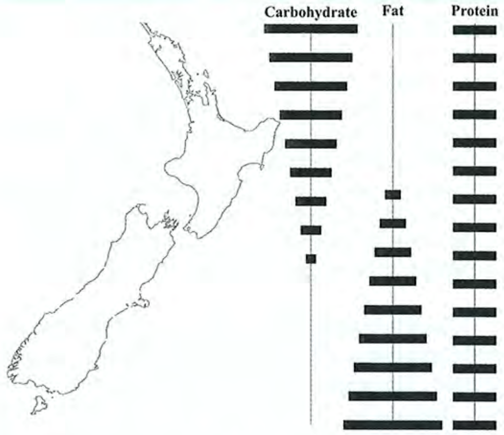

FIGURE 119

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 & Leach 2001: 119).

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 Stefannson 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).

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 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 (Figure 119).

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 & 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 & Spielmann 1983: 5-6; Noli & 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 & 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 & 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 (Denniston 1972; Anderson 1981c: 152). It has been suggested that ketonuria can be avoided in high fat diets if carbohydrates

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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 (Stefansson 1957: xvi), that there has been a consistent and serious error in reporting this experiment. The much quoted daily diet of 1 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.

comprise at least 15% of the daily diet (Davidson *et al.* 1972: 214-216; Anderson 1981c: 153). 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 & 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 (Anon. 1983). 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 & 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 (Robson & Wadsworth 1977: 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 & 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 Section.

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 120, 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 Section 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.

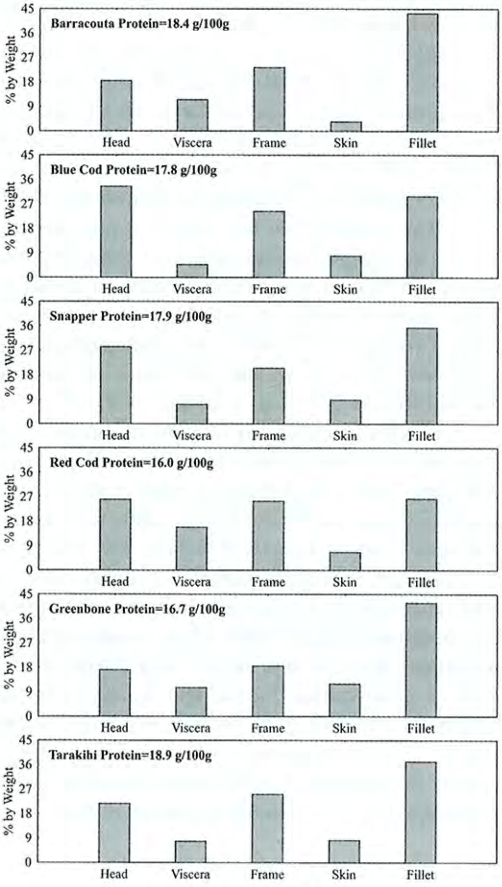

FIGURE 120

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).

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[5] The term frame is used for what remains of the body after fillets have been removed.

In Figure 120 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 121. 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 121. Unfortunately, there are no published values for the common spotty, or any other labrids for that matter. As we have seen in Sections 4 and 7, these were very important fish in pre-European New Zealand. As far as protein is concerned, the different species in Figure 121 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 again. 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 on it 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 121.

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

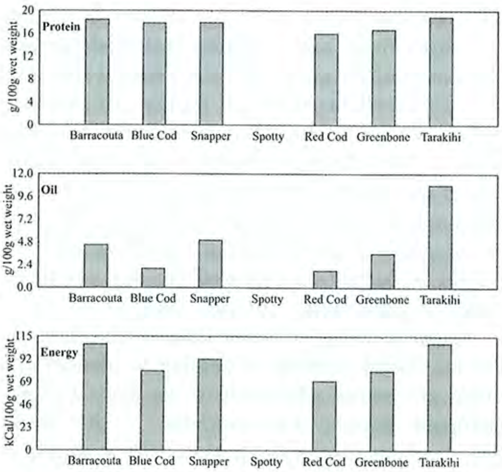

FIGURE 121

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.

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 (Shand 1896: 74, 75, 76, 80, 1897: 145, 1911; Buck 1930: 125). 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 (Polack 1838: 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 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.

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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.

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 122. This shows that oil is reasonably well spread through the body, but with some exceptions. Blue cod has by far the greatest amount of 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.

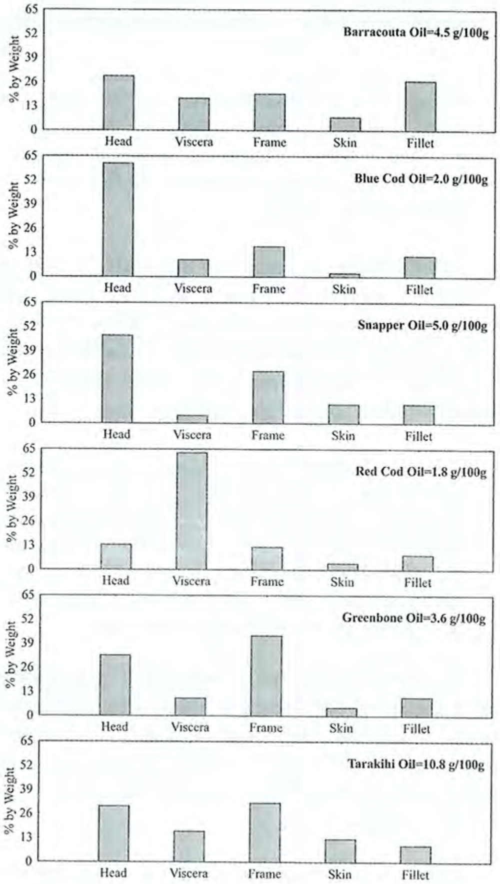

FIGURE 122

The percent distribution of oil in different body parts of common New Zealand fishes (from Vlieg 1988: 39 ff.). The cited values in g/100 are for whole fish (after Vlieg 1988: 23 ff.).

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[7] A polite expression for sexual favours.

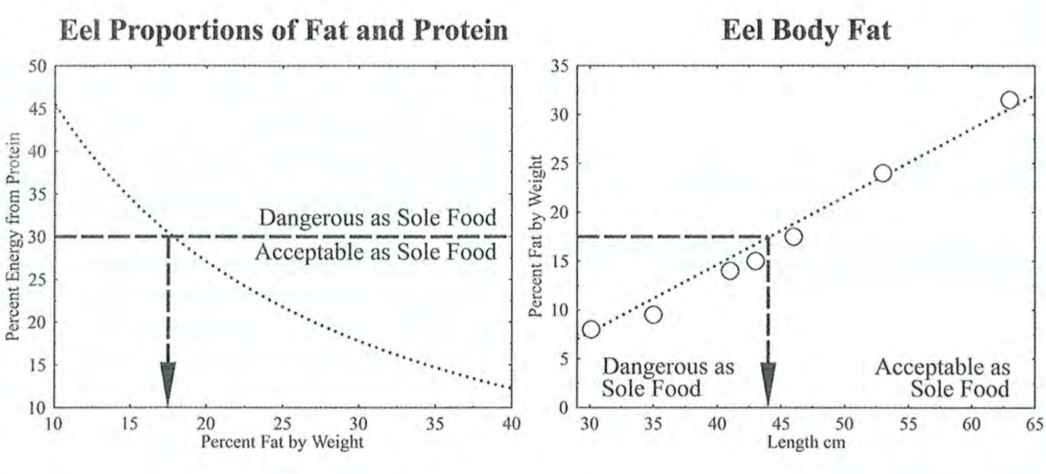
Without doubt, the type of New Zealand fish that has the greatest amount of energy are the two species of freshwater eel (*Anguilla dieffenbachii*, the long-finned eel, and *Anguilla australis*, the short finned eel). Only passing reference has been made so far to eels in this volume, the reason being 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 (Figure 121) 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 (Table 33).

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 Andersen did in their experiment cited earlier. This is illustrated on the left of Figure 123 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 123. 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


Eel Proportions of Fat and Protein

Eel Body Fat

FIGURE 123

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.

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 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 Section 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 (Crawford 1992: 6).

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**

TABLE 35

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 & Vessby 1995: 48).

An interesting nutritional study has been carried out of the people on Kitava Island in Papua New Guinea (Table 35). 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 & Lundh 1993; Lindeberg *et al.* 1994, 1996, 1997; Lindeberg & Vessby 1995). 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.

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**	**-**

TABLE 36

Estimated Dietary Composition of Two Pacific Peoples, Kitava in Trobriand Islands, and Baegu on Malaita. Percent of Total Energy. RDA=Recommended Daily Allowances (After Ross 1976: 579; Lindeberg & Vessby 1995: 48).

European foods were still very uncommon on this island, so this study provides a most useful dietary baseline (Tables 35, 36) 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 36, 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 36.

Although these people are seen to be extremely reliant on plant foods, consuming nearly 2 kg of food per person per day (Ross 1976: 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.

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).

The picture that emerges for the Galatea Bay site is shown in Figure 124. 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 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

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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.

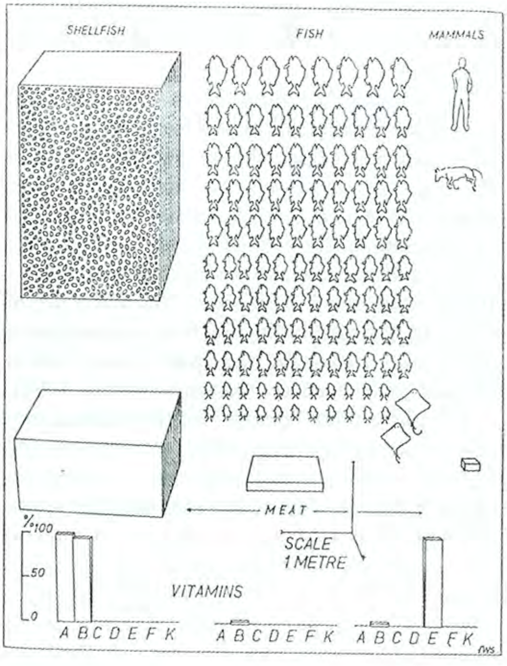

FIGURE 124

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.

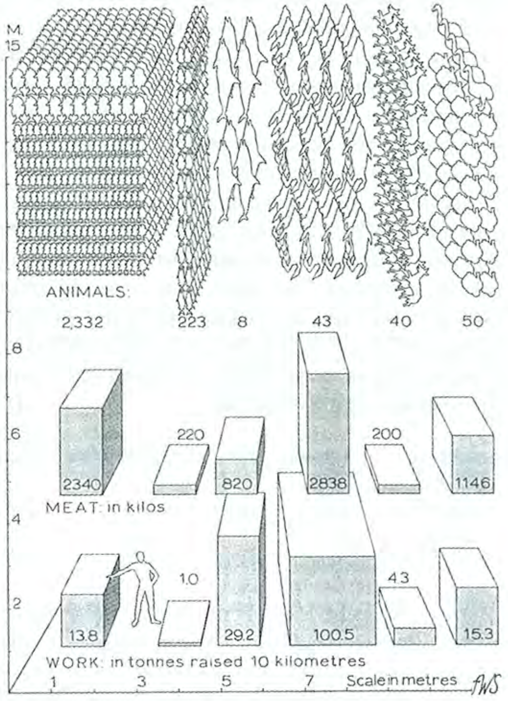

FIGURE 125

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 the Taylor & Francis (Methuen).

estimated and combined at each step in the experiment (Daish & 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 (Figure 125). 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

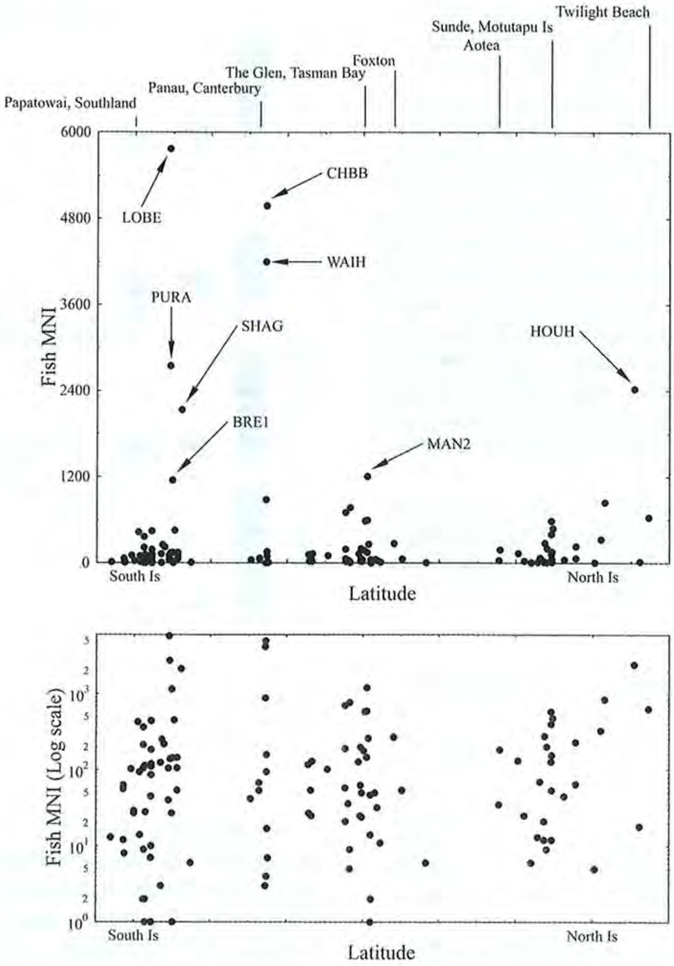

FIGURE 126

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.

sites throughout New Zealand (Figure 126). 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 using modern techniques (Anderson *et al.* 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

The central column can be used to recalculate Shawcross's assessment of Houhora (Figure 127). 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.

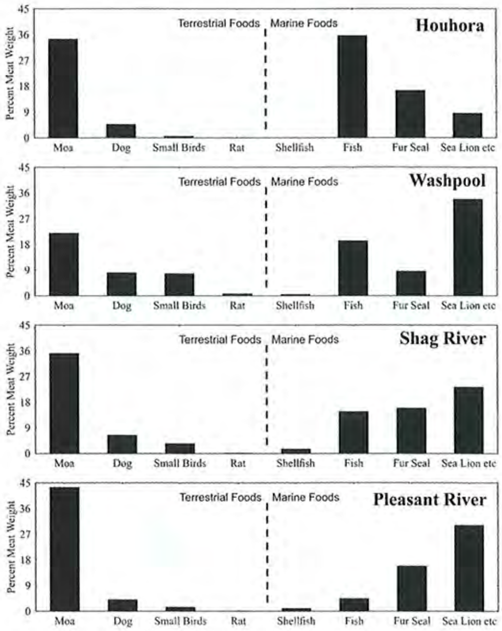

FIGURE 127

Relative meat weights of terrestrial and marine foods in some key sites in New Zealand from analysis of animal remains in archaeological sites.

Figure 127 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 (Figure 128).

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.

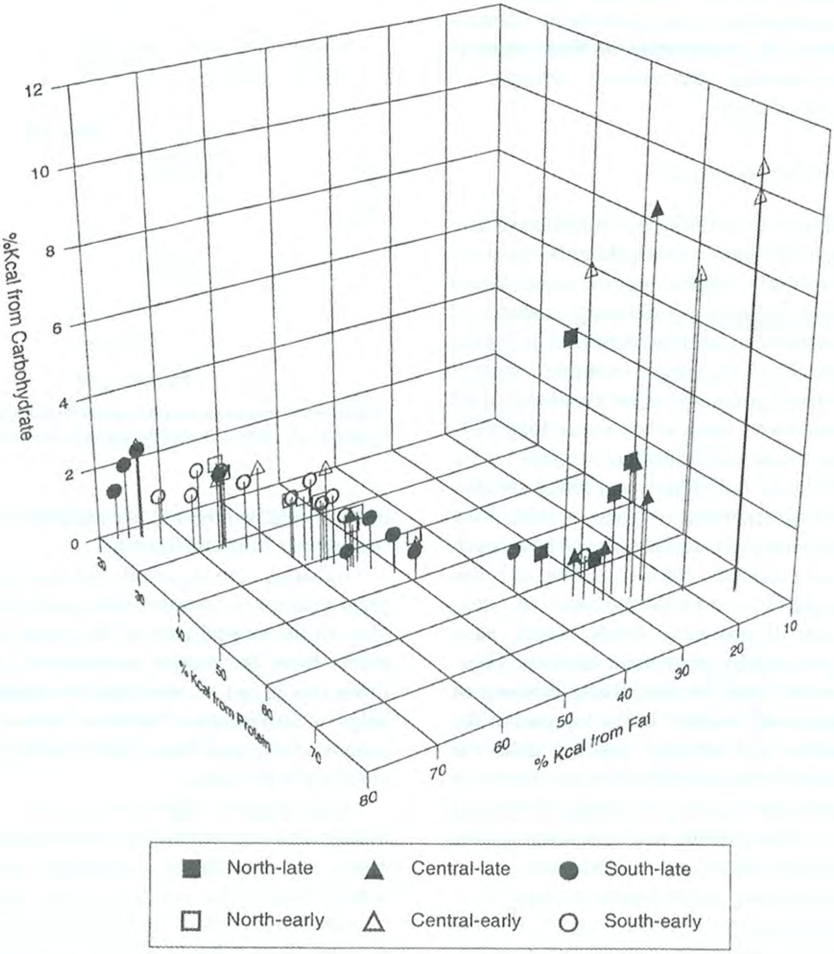

FIGURE 128

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).

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 boundaries, human remains with translocated teeth as a result of stripping fernroot, 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 129 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, 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.

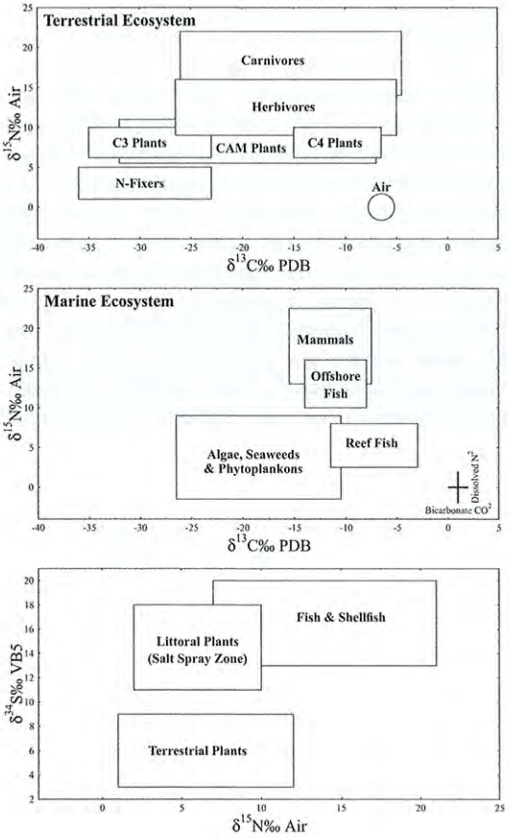

FIGURE 129

Isotope fractionation in the plant and animal kingdoms (after de France *et al.* 1996: 299, and the author's research).

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 $\delta^{13}C$ 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 $\delta^{13}C$ 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 & 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 & 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 Figure 129). 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 saltwater spray, a mixed δ^{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 130. 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 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

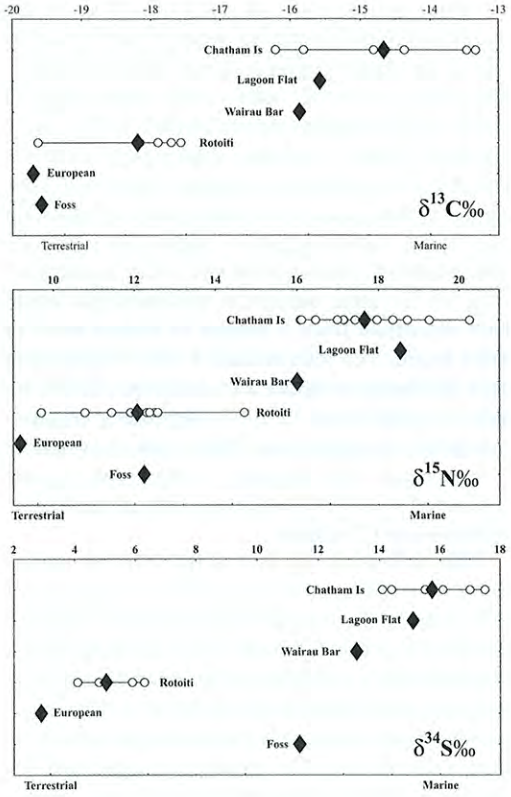

FIGURE 130

Isotope results from some New Zealand and Chatham Islands bone collagen samples.

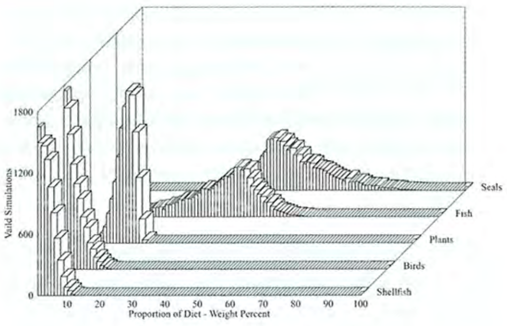

FIGURE 131

The diet of Moriori people of the Chatham Islands as reconstructed using isotope analysis and computer simulation (after Leach *et al.* 1996c: 32) 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.

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 131 is an example of the results of this simulation process for the prehistoric Moriori people of the Chatham Islands (see also Table 37). 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 δ^{13}C for C3 plants which could have been eaten, to fractionation effects in human metabolism when food with this δ^{13}C value is eaten. The basic requirements of human diet, outlined in the first part of this Section, 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

	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**

TABLE 37

Reconstructed Daily Diet for Moriori of the Chatham Islands (after Leach *et al.* 2003: 71).

composition, and go back to 1. Repeat until satisfactory statistical stability has been reached.

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 131.

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 37. 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 132, 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 133. It might be noticed that shellfish does not figure prominently in the reconstructed diets of any of these human groups in Figure 132. This is in close accord with the earlier crude estimates based entirely on meat weights from analysis of bones (Figure 127).

Earlier in this Section 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 131. Quantifying this range involves keeping track of statistical variation during the simulation process, and typical values are provided in Table 37 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.

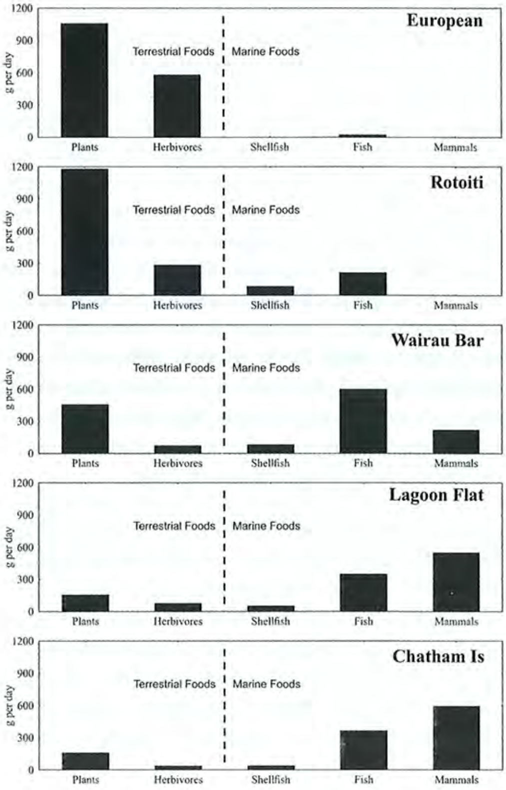

FIGURE 132

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.

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 (Figure 132).

The average diet at Rotoiti, in the interior of the North Island, is more like that of the European person than those from 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 132 and 133 are quite different. Archaeological excavations in the Chatham Islands have revealed sites containing not only very large amounts of fish remains (Figure 126), but also large amounts of sea mammals. This is evident in the dietary reconstruction shown in Figure 132. 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.

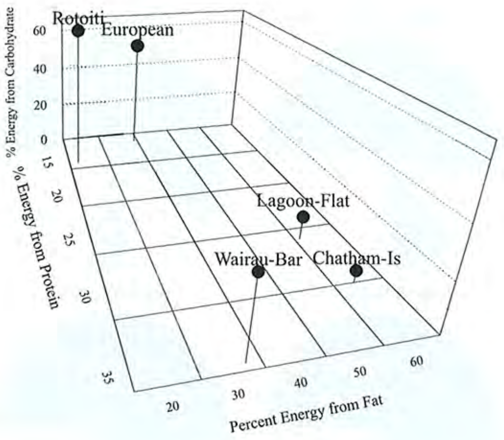

FIGURE 133

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).

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 132, 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 133 is the really important one, showing the balance between the three major foodstuffs required for healthy life.

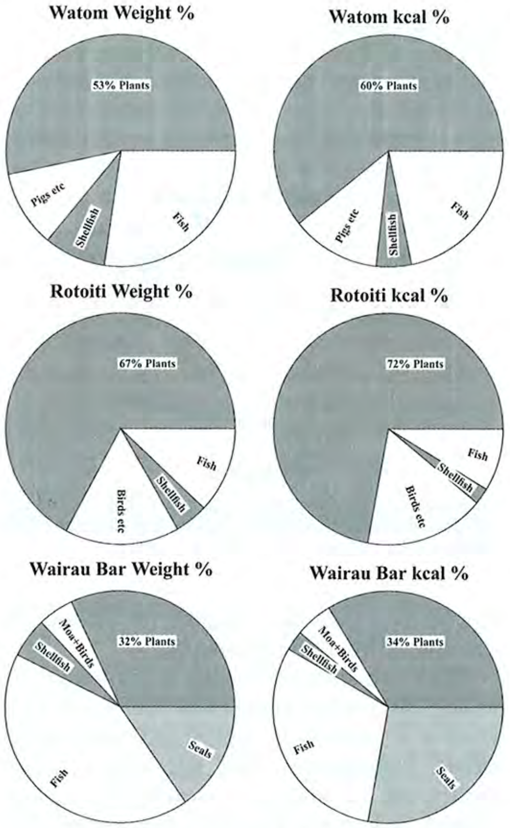

FIGURE 134

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)].

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 134. 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 36 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 133 and Table 38. 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 health 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.

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.

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

TABLE 38

The Main Dietary Constituents in Selected Prehistoric Groups. Percent of mean daily energy consumed (from Leach *et al.* 2003: 72).

DISCUSSION

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 (Figure 134). 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.