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# Pre-European Catches of Barracouta, *Thyrsites atun*, at Long Beach and Shag River Mouth, Otago, New Zealand

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ABSTRACT: Two archaeological sites with abundant remains of barracouta (*Thyrsites atun*) were subjected to intensive study. Long Beach produced a MNI of 4,504 fish from a NISP of 29,233 barracouta bones, of which 15,558 were able to be measured. Shag River Mouth had an MNI of 1,354 fish from a NISP of 6,319 bones, of which 1,920 could be measured. The measurements were used to estimate live fork length and ungutted body weight. Size-frequency curves representing the original fish catches were reconstructed. Fish size decreased significantly at Long Beach over some 500 years, and there are signs of a similar decrease at Shag River Mouth over a shorter period. These observed changes are not thought to be caused by human impact on the fishery.

The barracouta catches at both sites show a dominance of fish older than six years. Separation of the size-frequency curves into constituent age-grades reveals a pattern whereby both early assemblages are dominated by fish of one or two ages, whereas the late assemblage has four age-grades of similar proportions. This observed pattern may indicate that the age-growth relationship for barracouta was different 600 years ago from what it is now, and that the actual age mix in the past may have been similar throughout the sequence.

The barracouta at these sites represent a rich source of protein and oil. However, the people would have needed a source of food rich in carbohydrate in addition to fish. Fern root (*Pteridium esculentum* var. *aquilinum*) and *tī* (cabbage tree, *Cordyline australis*) are two possibilities. *Tī* is a superior food in many respects. We estimate that a minimum of 45% by weight of such a plant food would have been required for a nutritionally adequate diet, in addition to the readily available sources of protein and oil such as barracouta and seal blubber. The economy of these people would have been a delicate balancing act, striving to avoid two dietary dangers - azotaemia on the one hand, and ketonuria on the other.

KEY WORDS: ARCHAEOLOGY, ARCHAEOZOOLOGY, NEW ZEALAND, FISH, BARRACOUTA, *Thyrsites atun*.

RESUMEN: En el presente trabajo se lleva a cabo un pormenorizado estudio de dos yacimientos arqueológicos con abundantes restos de sierra (*Thyrsites atun*). En Long Beach se contabilizó un NMI de 4.504 individuos procedentes de 29.233 huesos de este pez, 15.558 de los cuales resultaron mensurables. En Shag River Mouth el NMI fue de 1.354 individuos y el NR de 6.319, 1.920 de ellos mensurables. Las medidas tomadas en los huesos se utilizaron para inferir la longitud corporal a la horquilla caudal y el peso corporal no eviscerado. A partir de estos datos se reconstruyeron curvas de frecuencia de tamaño que representaban las capturas originales de estos peces. Las tallas de los peces decrecen de modo significativo en Long Beach a lo largo de unos 500 años y existen señales de una disminución parecida en Shag River Mouth en un lapso temporal más corto. No se piensa que estos cambios hayan sido provocados por el impacto humano sobre la pesquería.

Las capturas de sierra en ambos yacimientos evidencian una dominancia de ejemplares por encima de los 6 años. La separación de las curvas de frecuencia-tamaño en sus elementos constituyentes según cohortes evidencia un patrón por el cual las muestras iniciales en ambos casos vienen dominadas por peces de una o dos cohortes mientras que las muestras tardías tienen cuatro grupos de edad en similares proporciones. Este patrón puede indicarnos que la relación de crecimiento cronodependiente en la sierra era diferente hace 600 años de lo que es en la actualidad y que la mezcla de cohortes detectada en el pasado puede haber sido similar a lo largo de toda la secuencia.

Las sierras en ambos yacimientos suponen una rica fuente de proteínas y de aceites. No obstante la gente habría necesitado asimismo una fuente nutricia rica en hidratos de carbono además del pescado. Dos posibilidades las presentan el helecho (*Pteridium esculentum* var. *aquilinum*) y el *tī* o árbol de la col (*Cordyline australis*). En muchos aspectos el *tī* es un nutriente de superior calidad. Estimamos que un mínimo de 45% en peso de tal nutriente vegetal habría sido necesario para una dieta nutricionalmente equilibrada, además de las fuentes siempre disponibles de proteínas y aceites como la sierra y la grasa de foca. La economía alimentaria de estas poblaciones habría sido por tanto un cuidadoso ejercicio de equilibrio diseñado para evitar dos peligros asociados con la dieta: la azotemia y la cetonuria.

PALABRAS CLAVE: ARQUEOLOGÍA, ARQUEOZOOLOGÍA, NUEVA ZELANDA, PEZ, SIERRA, *Thyrsites atun*.

## INTRODUCTION

The New Zealand barracouta, *Thyrsites atun*, is widespread and common around New Zealand, although it is generally more abundant about and south of Cook Strait. Barracouta swim in schools, are voracious surface-feeding carnivores and are easily caught on a trolling lure. In the past, Māori often caught them by jigging with a feather- and/or shell-decorated lure or even a plain piece of wood with a bone hook inserted through it. Early commercial fishermen also jig-fished surface-feeding barracouta using a piece of red wood with a nail driven through it on a short line (Graham, 1956: 310 ff.).

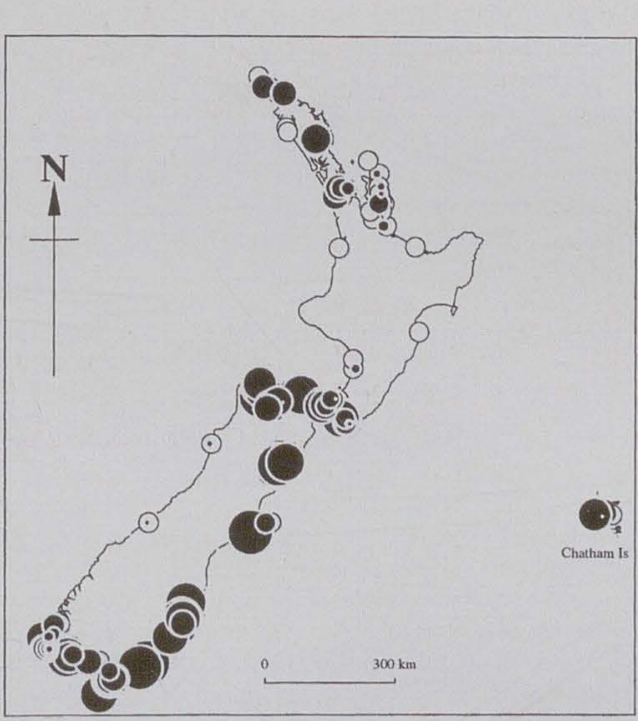


FIGURE 1

The proportions of barracouta MNI at 96 of the 126 New Zealand archaeological sites where archaeological fish remains have been studied. The size of the black circle indicates the relative abundance (logarithmic scale).

Barracouta are present in most archaeological sites in New Zealand. Their relative abundance is documented in Appendix 1, and illustrated in Figure 1. They are found in 96 of the 126 archaeological sites for which we have detailed knowledge about pre-European fish catches of Māori and Moriori.

Two of these 96 sites, Long Beach and Shag River Mouth, account for 58% of all barracouta identified from archaeological sites in New Zealand. Excavations at these sites covered considerable areas and resulted in large assemblages, in which barracouta were especially plentiful. Long Beach has stratified layers representing a considerable period of time; Shag River Mouth, while also containing stratified layers, is believed to cover a relatively short period of time. Because of the large size of the barracouta samples and the fact that they are stratified over a significant period, these two assemblages offer an excellent opportunity for detailed study of this species. The purpose of this paper is to reconstruct the original fish catches at these two sites (the size frequency diagrams) and to examine these for possible changes over time. We also explore some dietary implications.

## THE LONG BEACH ARCHAEOLOGICAL SITE (I44/23)

Long Beach is a sandy, north-facing bay just north of Dunedin on the east coast of the South Island. It has long been known as a productive source of artefacts. In 1977, Atholl Anderson undertook investigations to establish the extent of the site and the nature of any remaining undisturbed material. Although evidence of occupation was found to extend over nearly 30 ha of old consolidated dunes inland of the more recent beach dunes, only 2 ha appeared to be undisturbed by curio hunting. An area of 5 x 10 m was excavated in November-December 1977 by Helen Leach and Jill Hamel (Leach & Hamel, 1981).

Two major occupations were identified, separated by a layer of wind-blown dune sand. The upper occupation (Layer 2) was "a mosaic of patches of dense fish bone midden and working floors with the wall of a substantial house at one end of the excavation" (Leach & Hamel, 1981: 112). This layer contained artefacts of Classic Māori type and yielded a radiocarbon date of AD 1630 ± 89. The lower occupation was represented by three midden layers (4a, 4b, 4c) containing artefacts of Archaic types, scoop hearths and a child burial. Radiocarbon dates considered acceptable by the excavators

| Family | Common Name | MNI | % | SE | NISP | % | SE |
|---|---|---|---|---|---|---|---|
| Gempylidae | Barracouta, etc. | 4504 | 78.06 | ± 1.08 | 29233 | 85.89 | ± 0.34 |
| Moridae | Red cod, etc. | 823 | 14.26 | ± 0.91 | 3553 | 10.44 | ± 0.30 |
| Ophidiidae | Ling | 240 | 4.16 | ± 0.52 | 901 | 2.65 | ± 0.16 |
| Osteichthyes | Other bony fishes | 103 | 1.79 | ± 0.35 | 150 | 0.44 | ± 0.07 |
| Percichthyidae | Groper | 58 | 1.01 | ± 0.27 | 146 | 0.43 | ± 0.06 |
| Labridae | Spotty, etc. | 22 | 0.38 | ± 0.17 | 28 | 0.08 | ± 0.03 |
| Nototheniidae | Maori chief | 7 | 0.12 | ± 0.09 | 9 | 0.03 | ± 0.02 |
| Latrididae | Blue moki, etc. | 6 | 0.10 | ± 0.09 | 7 | 0.02 | ± 0.02 |
| Mugiloididae | Blue cod | 5 | 0.09 | ± 0.08 | 6 | 0.02 | ± 0.01 |
| Cheilodactylidae | Tarakihi, etc. | 1 | 0.02 | ± 0.04 | 1 | 0.003 | ± 0.007 |
| Centrolophidae | Blue warehou | 1 | 0.02 | ± 0.04 | 1 | 0.003 | ± 0.007 |
| **Total** | | **5770** | **100** | - - | **34,035** | **100** | - - |

TABLE 1

MNI and NISP of fish at Long Beach (all provenances combined).

| Family Name | | Early | Late | Early | | Late | | Total | % |
|---|---|---|---|---|---|---|---|---|---|
| Gempylidae | Barracouta, etc. | 3831 | 550 | 81.7± | 1.1 | 64.3± | 3.3 | 4381 | 79.0 |
| Moridae | Red cod, etc. | 583 | 177 | 12.4± | 1.0 | 20.7± | 2.8 | 760 | 13.7 |
| Ophidiidae | Ling | 182 | 38 | 3.9± | 0.6 | 4.4± | 1.4 | 220 | 4.0 |
| Osteichthyes | Other bony fishes | 72 | 16 | 1.5± | 0.4 | 1.9± | 1.0 | 88 | 1.6 |
| Percichthyidae | Groper | 10 | 47 | 0.2± | 0.1 | 5.5± | 1.6 | 57 | 1.0 |
| Labridae | Spotty, etc. | 6 | 12 | 0.1± | 0.1 | 1.4± | 0.8 | 18 | 0.3 |
| Nototheniidae | Maori chief | 3 | 4 | 0.1± | 0.1 | 0.5± | 0.5 | 7 | 0.1 |
| Latrididae | Blue moki, etc. | 1 | 5 | 0.02± | 0.1 | 0.6± | 0.6 | 6 | 0.1 |
| Mugiloididae | Blue cod | - | 5 | - - | - | 0.6± | 0.6 | 5 | 0.09 |
| Cheilodactylidae | Tarakihi, etc. | - | 1 | - - | - | 0.1± | 0.3 | 1 | 0.02 |
| Centrolophidae | Blue warehou | 1 | - | 0.02± | 0.1 | - - | - | 1 | 0.02 |
| **Total** | | **4689** | **855** | **100** - | - | **100** - | - | **5544** | **100** |

TABLE 2

MNI of fish at Long Beach, early and late periods.

were AD 1217 ± 59 for the dense fish bone midden of layer 4c and AD 1460 ± 58 for the thin midden of layer 4a (Hamel & Leach, 1979; Leach & Hamel, 1981: 112).

Excavation was by hand trowel according to natural layer. All deposits were sieved through ¼ inch (6.4 mm) mesh, and all material retained by the sieves was bagged by 1m$^2$ and layer and sent to the laboratory for analysis. Fish bone was analysed initially by Fyfe (1982) and later reanalysed in the Archaeozoology Laboratory of the Museum of New Zealand Te Papa Tongarewa (Leach & Boocock, 1993).

As Leach & Hamel note (1981: 109), it is uncommon for Classic Māori assemblages to be stratified above Archaic assemblages in Otago sites. The Long Beach excavation provided an important instance of two chronologically and culturally distinct occupations, each associated with abundant fish remains.

The relative abundance of fish families at Long Beach, from all provenances combined, is listed in Table 1, where both NISP and MNI are given. The fish catch at the site was very heavily dominated by barracouta. Apart from barracouta, only red cod contributed more than 10% and ling more than 2% of the catch. The category Osteichthyes consists of fishes which could not be matched in the comparative collection. Table 2 gives the MNI according to early and late assemblages and excludes some bones from mixed or uncertain provenances. It is apparent that there was a significant decline in the proportion of barracouta through time and a concomitant increase in red cod, although barracouta was still by far the most important fish in the catch of the late period. Also significant is an increase in groper and possibly in labrids and blue cod.

## THE SHAG RIVER MOUTH ARCHAEOLOGICAL SITE (J43/2)

The Shag River Mouth site, situated on the sand spit at the mouth of the Shag River in north Otago, is one of the best known archaeological sites in southern New Zealand. It was first excavated during the 1870s, during the controversy about the relationship between moa-hunter and Māori, and has been the scene of numerous subsequent investigations. Between 1987 and 1989 a series of excavations was carried out under the direction of Anderson, Allingham & Smith (Anderson *et al.* [eds.], 1996). These centred in two main areas: a high dune towards the southern and landward end of the sand spit, and the northern and inner edge of the low-lying sand flat on the inner side of the dune, although extensive test pitting was carried out over much of the site.

Cultural deposits were relatively shallow on the sand flat, but deep stratigraphy was encountered in the high dune, where seven distinct occupation layers were separated by layers of wind-blown sand.

Forty-six radiocarbon samples of charcoal, marine shell, moa bone collagen, moa eggshell and flax were dated at two laboratories. After a through review of the results, it was concluded that "...Shag Mouth was continuously occupied for a period of perhaps 20-50 years in the 14$^{th}$ century AD." (Anderson, Smith & Higham, 1996: 67).

Excavation was by trowel according to natural layer (except for some test pits dug by spade, and removal of dune overburden by bulldozer). Items were either hand picked during excavation or extracted during screening through ⅛ inch (3.175 mm) sieves. Unsieved bulk samples from all major stratigraphic layers were retained. However, fish bone recovered by sieving was processed in the field "to extract the skeletal elements most useful for identification to species" (Smith & Anderson, 1996: 70) and the rest discarded. This procedure may have introduced some bias, as those doing the field extraction would not have been well trained in fish anatomy, and has also precluded further analysis of other skeletal elements.

Fish remains from the dune excavation were identified by Angela Boocock using the procedures of the Archaeozoology Laboratory at the Museum of New Zealand Te Papa Tongarewa, and the data entered in the Archaeozoology Laboratory's database. Fish remains from other areas of the site were identified by Anderson. All identifications were also entered in the Shag Mouth data base and NISP, MNE and MNI tabulated and reported by Anderson & Smith (1996). They noted differences in MNI for the dune calculated by themselves, by Boocock (n.d.) and by Leach and preferred to use their figures. In this paper, we use the fish remains from the dune and the figures calculated from the Archaeozoology Laboratory database. For the purposes of this study the barracouta bones were remeasured in the Archaeozoology Laboratory in Wellington.

As a result of their analysis, Anderson & Smith (1996: 240) concluded that the lower layers of the dune (layers 6 to 11) stood out from all other deposits. According to this analysis, barracouta were less important than elsewhere in the site (37%), although still dominant, while there were higher proportions of blue cod (21%), labrids (12%), trumpeter (10%) and black cods (7%). Anderson & Smith suggest that almost two thirds of the fish from these layers were probably caught with baited hooks over rocky ground and reefs. There was a marked trend towards an increase in barracouta through time and a decrease in blue cod and other species. In the upper layers of the dune and elsewhere in the site, barracouta made up 67% to 80% of the catch and Anderson & Smith argue for deliberate targeting of this schooling species. Unfortunately, the sample sizes from all parts of the site except the upper dune layers are far too small for this interpretation to be other han suggestive.

Table 3 shows the relative abundance of fish families in the total catch from the dune excavation. A wider range of families is represented than at Long Beach, and several families besides barracouta and red cod were making a reasonable contribution to the catch. Even so, barracouta still dominate, at a level comparable to that in the late catch at Long Beach.

## MODERN BARRACOUTA RESEARCH CATCHES

When examining archaeological fishes catches, it is necessary to have some form of baseline for comparison, particularly if one is interested in changes in catch composition through time and the effects of human exploitation on fish stocks. Fortunately, fisheries scientists have been studying barracouta in New Zealand waters for some years so there is a sizeable database to draw upon. Size-frequency diagrams may be drawn from research trawl data held by the National Institute of Water and Atmospheric Research (NIWA), and some of these are presented in Figure 2. These derive from trawls in the vicinity of the Chatham Islands and from Stewart Island southwards. For comparison, the archaeological catches (described below) are also shown in Figure 2.

Several things are evident from the size-frequency diagrams. Firstly, some of the different age grades of barracouta, particularly the younger fishes, are clearly separated. Secondly, the age mixture is markedly different from one trawl area to another. It is also notable that the youngest age grades seem to be mainly present in shallower waters down to 100 m.

| Family | Common Names | MNI | % | SE | NISP | % | SE |
|---|---|---|---|---|---|---|---|
| Gempylidae | Barracouta, etc. | 1354 | 63.45 | ± 2.07 | 6319 | 78.95 | ± 0.90 |
| Moridae | Red cod, etc. | 339 | 15.89 | ± 1.57 | 1022 | 12.77 | ± 0.74 |
| Mugiloididae | Blue cod | 155 | 7.26 | ± 1.12 | 230 | 2.87 | ± 0.37 |
| Labridae | Spotty, etc. | 116 | 5.44 | ± 0.99 | 169 | 2.11 | ± 0.32 |
| Ophidiidae | Ling | 57 | 2.67 | ± 0.71 | 102 | 1.27 | ± 0.25 |
| Nototheniidae | Maori chief | 46 | 2.16 | ± 0.64 | 71 | 0.89 | ± 0.21 |
| Latrididae | Blue moki, etc. | 30 | 1.41 | ± 0.52 | 40 | 0.50 | ± 0.16 |
| Scorpaenidae | Scarpee, etc. | 20 | 0.94 | ± 0.43 | 28 | 0.35 | ± 0.14 |
| Percichthyidae | Groper | 11 | 0.52 | ± 0.33 | 13 | 0.16 | ± 0.09 |
| Cheilodactylidae | Tarakihi, etc. | 2 | 0.09 | ± 0.15 | 3 | 0.04 | ± 0.05 |
| Anguillidae | Freshwater eels | 1 | 0.05 | ± 0.12 | 2 | 0.03 | ± 0.04 |
| Sparidae | Snapper | 1 | 0.05 | ± 0.12 | 2 | 0.03 | ± 0.04 |
| Centrolophidae | Blue warehou | 1 | 0.05 | ± 0.12 | 2 | 0.03 | ± 0.04 |
| Mugilidae | Yelloweyed mullet, etc. | 1 | 0.05 | ± 0.12 | 1 | 0.01 | ± 0.03 |
| **Totals** | | **2,134** | **100** | - - | **8,004** | **100** | - - |

TABLE 3

MNI and NISP of fish at Shag River Mouth dune excavation (all provenances combined).

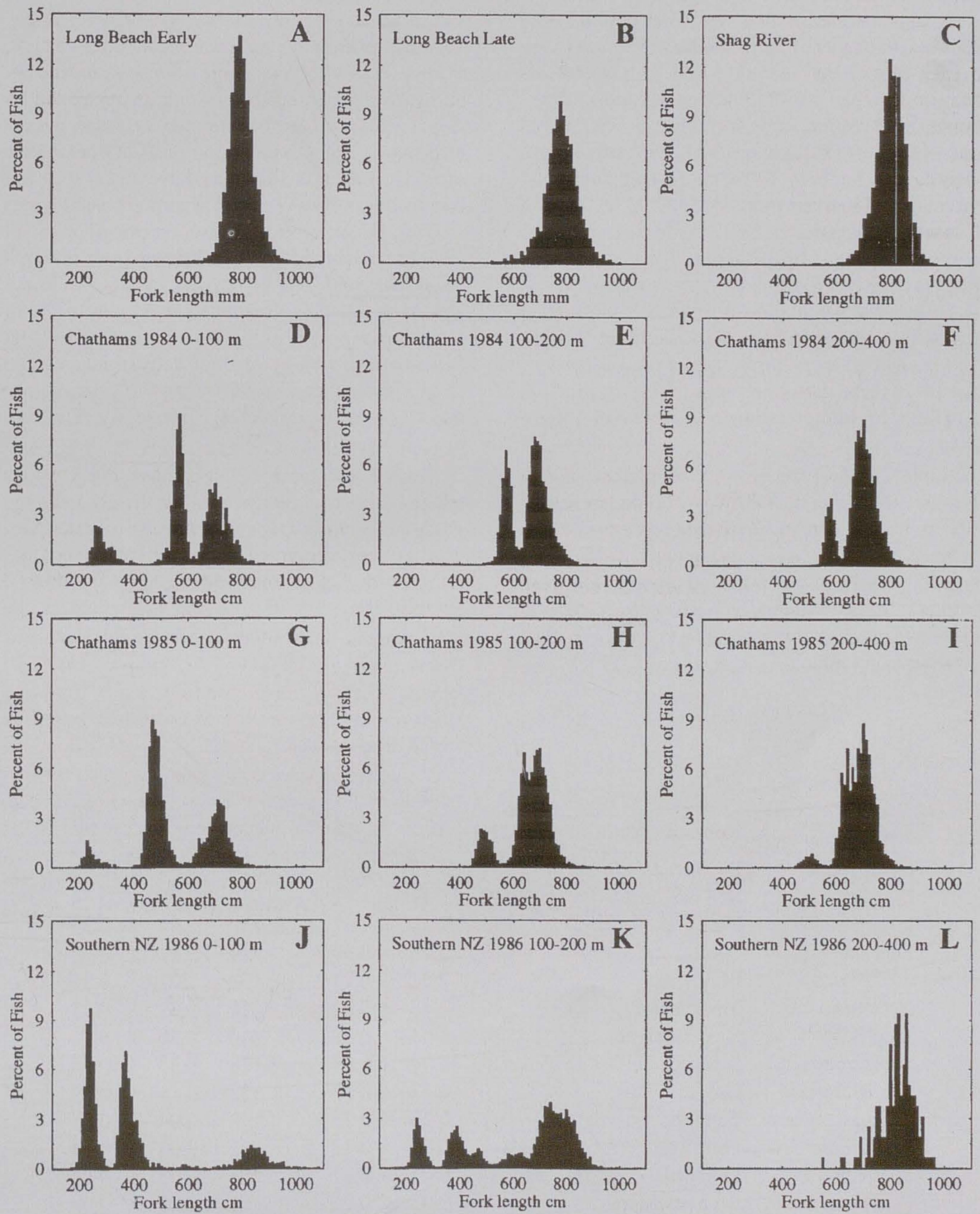


FIGURE 2

D to L: Length frequency diagrams of barracouta from research trawls at various depths in southern New Zealand and the Chatham Islands. Different age grades are evident. The archaeological catches are shown in A, B and C for comparison.

## PRE-EUROPEAN BARRACOUTA CATCHES

A large sample of modern specimens of barracouta was studied to work out the relationship between fork length and ungutted body weight. A sub-sample of 278 fish was macerated, the head bones measured, and statistical analysis carried out. This permits the original live length and weight to be estimated from archaeological bone measurements with an acceptable margin of error (Leach *et al.,* 1996).

The large assemblages of barracouta bones from Long Beach and Shag River Mouth provide an opportunity unique in New Zealand to collect a large number of measurements so that variations in reconstructions based on different parts of the anatomy can be investigated. At Long Beach there was a total MNI of 4,504 barracouta with a NISP of 29,233, and at Shag River Mouth the MNI was 1,354 with a NISP of 6,319. The ratio of NISP/MNI is somewhat different for the two sites, being 6.49 for Long Beach and 4.67 for Shag River Mouth.

The relative abundance of the different parts of barracouta anatomy which were identified is given in Table 4, from which it will be seen that the spread is very even. Taking the larger assemblage (Long Beach), the percentage spread is as follows:

| | |
|---|---|
| Premaxilla | 22% |
| Dentary | 21% |
| Maxilla | 19% |
| Articular | 19% |
| Quadrate | 18% |
| **Total** | **99%** |

The figures for Shag River Mouth are not quite as even, but the sample size is smaller, which may account for this. Dentaries are represented by 25% of the total number, and quadrates by only 16%.

In this kind of study, the whole bone is measured wherever possible. Measurements can be taken on broken bones also, and where more than one measurement is possible on a bone, the largest dimension is always taken. Only one measurement is made on any one bone. In all, 15,558 measurements were made on barracouta bones from Long Beach and 1,920 on bones from Shag River Mouth.

These data were entered into a database, using a program custom written for this purpose called FORKING. This program records the bone provenance information in a convenient form using a mouse and pull-down menus cross-linked to the identification software called KUPENGA, described by Leach (1997). Diagrams of the various bones belonging to any one fish species are thrown up on the monitor and the mouse is used to select predefined measurement options. Measurements are entered into the database using digital callipers integrated with FORKING through the serial port. Various checking procedures are invoked to minimise errors. These programs run under Windows 3 environment.

Additional software was written to estimate live fork length and ungutted weight from the bone measurements that had been entered in the database, using the regression constants published by Leach *et al.* (1996).

When these steps have been completed, size-frequency diagrams can be established which represent the original fish catches for different layers and squares in the excavation. The Long Beach site has two quite distinct phases of human habitation, one relatively early in the New Zealand pre-

| | Long Beach | | Shag River Mouth | |
|---|---|---|---|---|
| **Anatomy** | **Left** | **Right** | **Left** | **Right** |
| Dentary | 3084 | 3097 | 822 | 809 |
| Articular | 2823 | 2835 | 562 | 556 |
| Quadrate | 2640 | 2630 | 518 | 488 |
| Premaxilla | 3250 | 3186 | 734 | 687 |
| Maxilla | 2815 | 2873 | 604 | 539 |
| **Total NISP for Barracouta** | **29,233** | | **6,319** | |
| **Total NISP for all species** | **34,035** | | **8,004** | |
| **Percent Barracouta by NISP** | **85.9** | | **78.9** | |

TABLE 4

Barracouta NISP by anatomy at Long Beach and Shag River Mouth dune (all provenances combined).

European sequence, and the other much later. Size-frequency diagrams were established for these two time periods. However, Shag River Mouth is believed to have been occupied only for a relatively short period early in the sequence, so the catch is presented in one size-frequency curve.

These curves are illustrated in Figure 2, which also shows the modern research trawl data for barracouta. It is immediately apparent that the archaeological fish catches are dominated by very large fish and do not contain younger age grades which are so evident in the modern catches.

The two size-frequency curves are close to normal in their distributional characteristics. The Long Beach catch has very slight but significant negative skewness (gl/wl = -0.03/9.3), and significant positive kurtosis (g2/w2 = 4.9/47.4). At Shag River Mouth the same pattern is observed (g1/w1 = -0.4/11.5, g2/w2 = 3.8/7.0). The mean fork

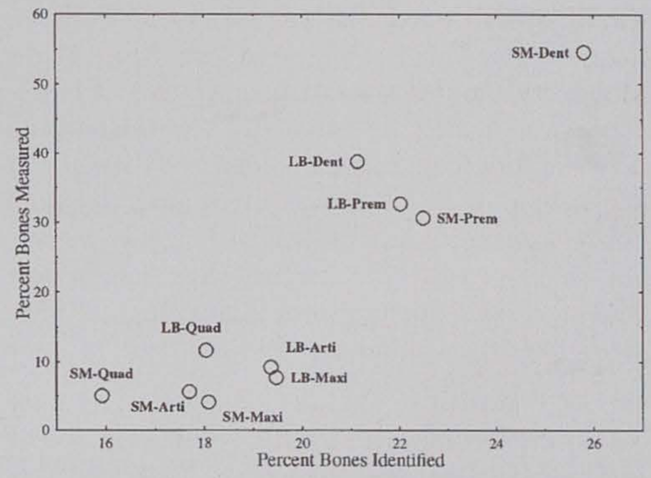


FIGURE 3

Comparison between the proportion of bones identified for each part of the anatomy and the proportion able to be measured. LB = Long beach, SM = Shag River Mouth. Bones from Shag River Mouth are more fragmented than at Long Beach. Note that with the exception of dentary and premaxilla, only a small proportion of bones from Shag River Mouth were able to be measured.

| **LONG BEACH** | | **Whole Bones** | | | **Bone Fragments** | |
|---|---|---|---|---|---|---|
| **Anatomy** | **Code** | **Left** | **Right** | **Code** | **Left** | **Right** |
| Dentary | LD1/RD1 | 108 | 92 | LD2/RD2 | 1123 | 1086 |
| Dentary | - | - | - | LD3/RD3 | 1764 | 1859 |
| Articular | LA1/RA1 | 6 | 3 | LA2/RA2 | 767 | 660 |
| Quadrate | LQ1/RQ1 | 945 | 866 | - | - | - |
| Premaxilla | LP1/RP1 | 10 | 11 | LP2/RP2 | 2536 | 2522 |
| Maxilla | LM1/RM1 | 128 | 121 | LM2/RM2 | 489 | 462 |
| **Sub-Totals** | | **1197** | **1093** | | **6679** | **6589** |
| **Sub-Totals** | | **2,290** | | | **13,268** | |
| **Total** | | | | **15,558** | | |
| **Proportions** | | **14.7%** | | | **85.3%** | |

| **SHAG RIVER MOUTH DUNE** | | **Whole Bones** | | | **Bone Fragments** | |
|---|---|---|---|---|---|---|
| **Anatomy** | **Code** | **Left** | **Right** | **Code** | **Left** | **Right** |
| Dentary | LD1/RD1 | 12 | 8 | LD2/RD2 | 47 | 41 |
| Dentary | - | - | - | LD3/RD3 | 459 | 481 |
| Articular | LA1/RA1 | 6 | 8 | LA2/RA2 | 46 | 48 |
| Quadrate | LQ1/RQ1 | 55 | 42 | - | - | - |
| Premaxilla | LP1/RP1 | 0 | 2 | LP2/RP2 | 300 | 286 |
| Maxilla | LM1/RM1 | 3 | 5 | LM2/RM2 | 38 | 33 |
| **Sub-Totals** | | **76** | **65** | | **890** | **889** |
| **Sub-Totals** | | **141** | | | **1,779** | |
| **Total** | | | | **1,920** | | |
| **Proportions** | | **7.3%** | | | **92.7%** | |

TABLE 5

Number of measurements of barracouta according to anatomy, and whole and fragmentary bones.

length is very similar at the two sites (Table 6; Long Beach 795.2 ± 0.4 mm and Shag River Mouth 794.6 ± 1.2 mm).

## SAMPLING STRATEGIES AND TAPHONOMIC EFFECTS

As mentioned above, not all the barracouta bones from these sites were complete, and measurements were therefore also taken on fragmentary bones. It is useful to examine the relative number of whole and fragmentary parts of the anatomy in case bias could be introduced in assessing changes in dispersion statistics between sites, or over time. The number of measurements able to be captured for various parts of the anatomy at the two sites is presented in Table 5. In Figure 3 each piece of anatomy is plotted out as a percentage of the total number of bones measured against the percentage of total number identified.

At Long Beach, we were able to measure 15,558 of the 29,233 barracouta bones (53.2%); whereas at Shag River Mouth only 1,920 bones could be measured of the 6,319 available (30.4%). This indicates that the degree of fragmentation was much greater at Shag River Mouth. Why this should be so is not known, but it was certainly a noticeable feature during analysis, and is borne out by these figures.

It is also notable that the dentary and premaxilla were far more numerous at Shag River Mouth than other bones, and a much higher proportion of dentaries could be measured than at Long Beach. It is possible that selective bias was involved during the retention stage of sorting. It can be noted that not all fish remains were kept from either of these sites. At Long Beach, as many fish bones as possible were collected at the site and processed in the laboratory. However, after sorting, only those bones able to be identified by Fyfe (1982) were retained, and the rest were dumped. At Shag River Mouth dune excavation, fish remains were sorted on site and only those standardly used in identification were retained; the rest were discarded. The retention strategy at these two important sites has been criticised elsewhere (Leach, 1997: 23).

This large database of bone measurements may be split up so that dispersion statistics relating to fish size can be calculated for different parts of the anatomy. Once again, it is useful to do this in order to see whether various forms of bias could be involved in

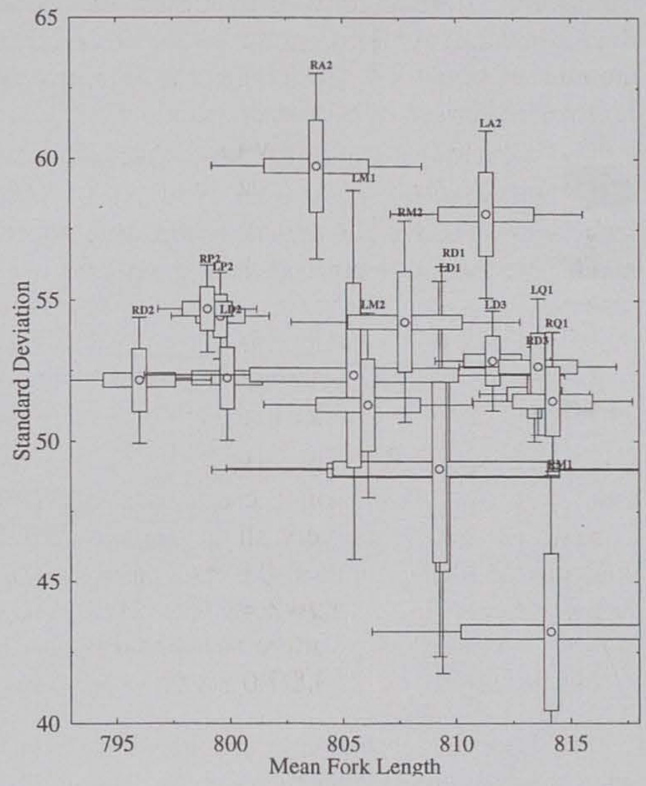


FIGURE 4

Estimated mean fork length and standard deviation, together with standard errors, for each part of the anatomy in the Long Beach barracouta assemblage, all layers combined (15,558 measurements on 29,233 bones).

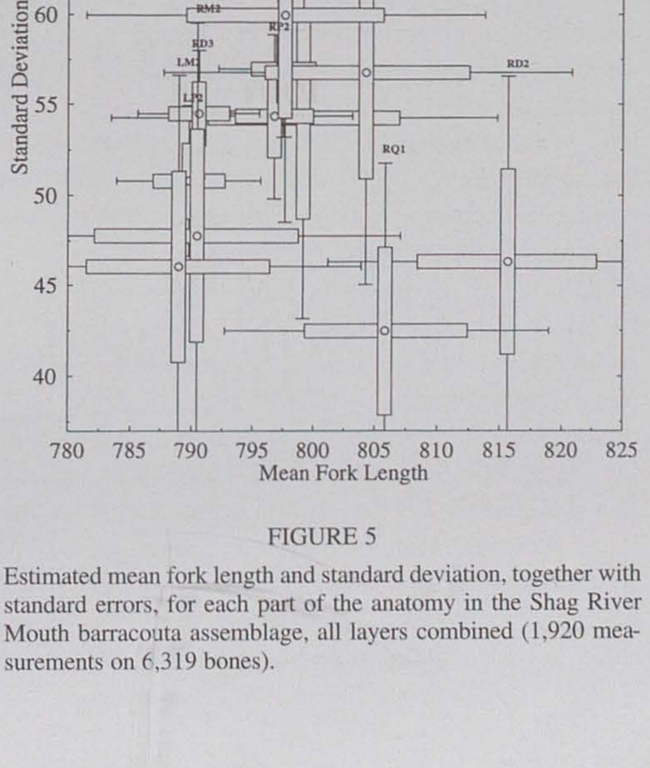


FIGURE 5

Estimated mean fork length and standard deviation, together with standard errors, for each part of the anatomy in the Shag River Mouth barracouta assemblage, all layers combined (1,920 measurements on 6,319 bones).

this analysis, particularly in relation to the bone retention strategy. This study produced a large amount of statistical data which can be conveniently summarised by illustrations.

Figures 4 and 5 show the individual means (x axis) and standard deviations (y axis) of fork lengths for each bone measurement able to be taken. The measurement codes are as follows:

| Left | Right | Anatomy |
|---|---|---|
| LD1 | RD1 | Dentary Maximum Length |
| LD2 | RD2 | Dentary Fragment 1 |
| LD3 | RD3 | Dentary Fragment 2 |
| LA1 | RA1 | Articular Length |
| LA2 | RA2 | Articular Fragment 1 |
| LQ1 | RQ1 | Quadrate Maximum Length |
| LP1 | RP1 | Premaxilla Maximum Length |
| LP2 | RP2 | Premaxilla Fragment 1 |
| LM1 | RM1 | Maxilla Maximum Length |
| LM2 | RM2 | Maxilla Fragment 1 |

The Long Beach example (Figure 4) has some interesting features. Pairs of measurements (e.g., the pairs LD2/RD2, LQ1/RQ1, LD3/RD3, etc.) plot quite close to each other and their standard errors overlap, which is what we would expect. It is noticeable that some pairs of measurements provide significantly different fork lengths than other pairs. Thus, the pair LD2/RD2 plots at the lower end of the fork length range, while LQ1/RQ1 plots at the upper end of the range. A number of possible explanations might be offered for these patterns, some plausible, but all hard to verify. For example, we could propose that the quadrates provide a relatively large estimate of the mean fork length because these bones are small and do not break easily, but those from small specimens might more easily be missed in sorting through large quantities of bones, or might even pass through the sieves. In theory, this hypothesis is at least testable in that the material that passed through the sieves could be examined. Unfortunately, as pointed out earlier, only the identified bones have been retained from both Long Beach and Shag River Mouth, so this explanation cannot be tested in reality. However, this would be worth examining on some future occasion at another excavation. It is not so easy to explain why LD1/RD1 form a pair with practically identical mean and standard deviation at the large end of the fork length range, whereas the pair LD2/RD2 form a second tight cluster at the lower end of the fork length range. This suggests that small dentaries break more easily into fragments than large dentaries. This does not seem very plausible, but once again could be tested experimentally.

The spread of these mean values in fork length, derived from different parts of the anatomy and from both whole and broken bones, is about 20 mm overall. This must be seen in perspective. The mean and standard deviation of the fork length of the Long Beach barracouta catch as a whole are 795 mm and 51 mm (Table 6). The variation observed amongst these different parts of the anatomy is therefore less than 3% of the mean, and less than half of the standard deviation. Nevertheless, there are interesting patterns here which warrant further investigation at another site when all the bone material is retained.

The overall range in the Shag River Mouth barracouta remains is rather greater at about 45 mm (Figure 5), but the standard errors are considerably larger too, since a much smaller sample size is available. The pairs of measurements do not form such tight clusters of mean fork length as in the case of Long Beach. Again, this is mainly due to smaller sample size, evident in the much larger standard errors in the graph.

## CHANGES THROUGH TIME

Anderson & Smith (1996: 241 ff.) have suggested that at Shag River Mouth there was an increase over time in barracouta fishing as a targeted activity, and a concomitant decrease in blue cod and other inshore rocky species. The information on possible changes in relative abundance of different species is plotted out in Figure 6 for Long Beach and in Figure 7 for Shag River Mouth. Unfortunately, as so often happens with statistics relating to prehistoric fish catches, problems of small sample size make it difficult to be certain about these suggested changes. Some appear significant, while others do not. However, there does seem to be a trend at Shag River Mouth whereby barracouta increase towards the more recent layers and blue cod decrease. The Layer 1 data are probably unreliable, as this material was disturbed and may actually be derived from spoil thrown out, possibly from several layers, by Teviotdale, an earlier investigator.

At Long Beach, the situation is clearer because sample sizes are much larger. In this case, barracouta clearly decrease significantly over archaeological time, even though they are always by far the most dominant fish in the catch. Red cod in this

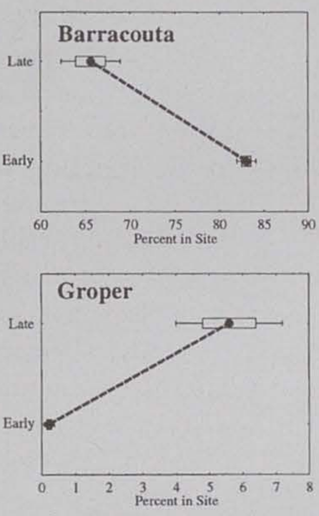


FIGURE 6

Changes in relative abundance of some fish species over time at Long Beach. Barracouta decrease significantly, whereas other species increase in importance.

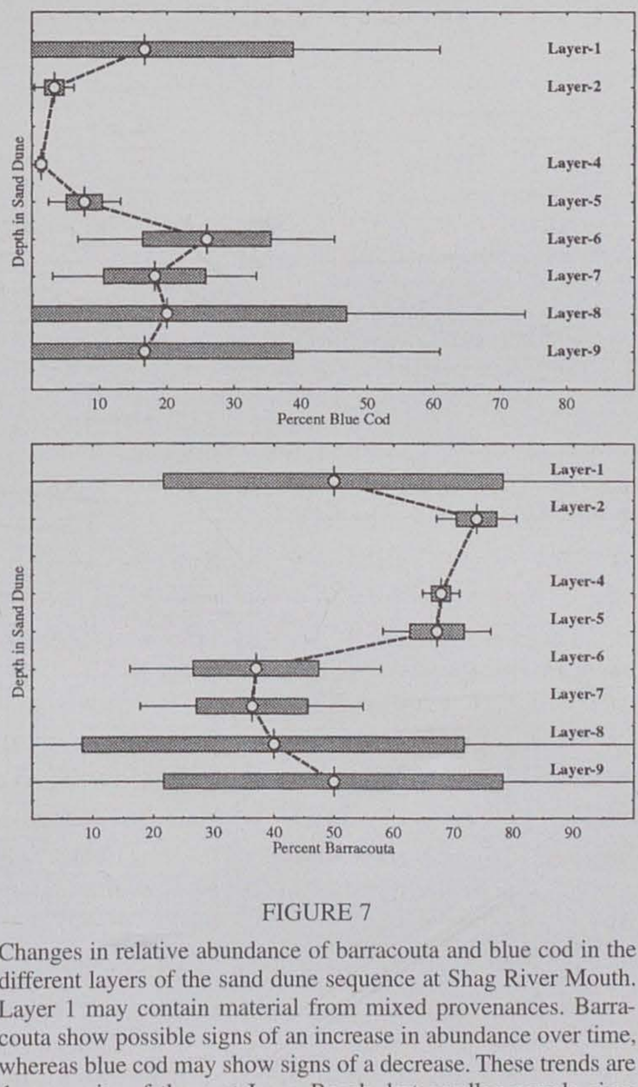


FIGURE 7

Changes in relative abundance of barracouta and blue cod in the different layers of the sand dune sequence at Shag River Mouth. Layer 1 may contain material from mixed provenances. Barracouta show possible signs of an increase in abundance over time, whereas blue cod may show signs of a decrease. These trends are the opposite of those at Long Beach, but smaller sample sizes make it difficult to establish statistical significance.

case increase in importance, as do groper and much less certainly, labrids and blue cod.

The second aspect of possible change through time which can be explored concerns fish size. The figures for mean fork length in the various layers at Shag River Mouth are plotted out in Figure 8 (from Table 6). Although the standard errors are large and there is considerable overlap, there seems to be a trend towards decreasing size over time. It is very difficult to know how to interpret

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

* This layer may incorporate disturbed and redeposited material.

TABLE 6

Fork lengths of archaeological barracouta.

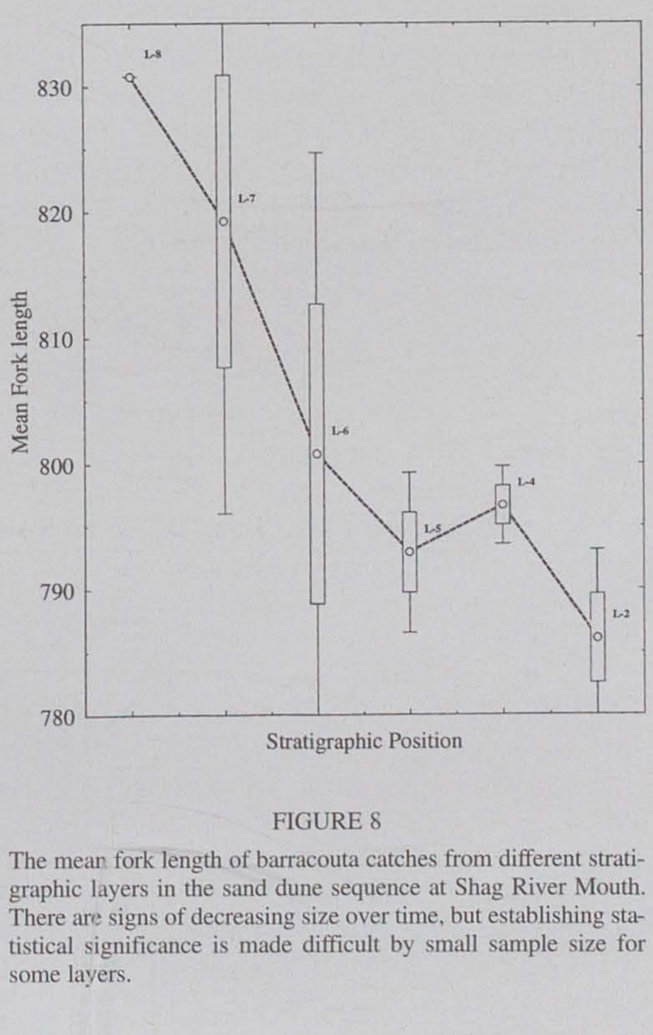


FIGURE 8

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

this. The apparent trend could be entirely due to chance, given the large size of the standard errors. However, it is certainly intriguing.

In the case of Long Beach, there is no such ambiguity - here the barracouta mean size decreases by 21 mm (Table 6) and is highly significant (Student's t = 11.89 with 14,841 degrees of freedom). Moreover, the standard deviation increases by 15.3 mm over time. This is again highly significant (standard error = 1.1 mm).

Barracouta grow very quickly for the first few years of their life, so it is possible to determine their age from fork length with reasonable accuracy. Hurst and Bagley (1987: 20) provide suitable mean and standard deviation figures which are given below.

| Age Years | Fork Length mm | SD mm |
|---|---|---|
| 1 | 289 | 33 |
| 3 | 578 | 35 |
| 4 | 665 | 35 |
| 5 | 702 | 35 |
| 6 | 752 | 33 |
| 7 | 778 | 30 |
| 8 | 795 | 46 |
| 9 | 843 | 47 |
| 10 | 850 | 17 |

When these values are plotted out over the top of the size-frequency diagrams of the prehistoric barracouta fish catches (Figure 9) it is clear that the fish being captured were all relatively old individuals. This is also apparent in Figure 2, where the modern research trawl data are shown.

It is possible to decompose a size-frequency diagram where there is a mixture of age components like this. A considerable amount has been

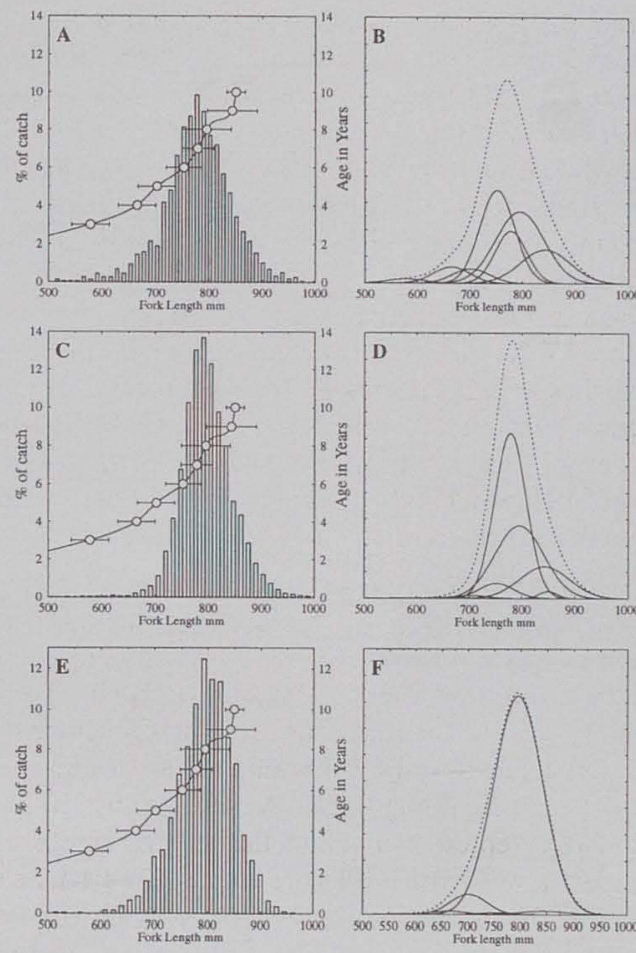


FIGURE 9

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

| Age in Years | Long Beach Early | Long Beach Late | Shag River Mouth |
|---|---|---|---|
| 3 | 0.1 | 1.5 | 0.3 |
| 4 | 0.4 | 5.4 | 1.2 |
| 5 | 1.0 | 4.8 | 6.7 |
| 6 | 4.7 | 28.8 | 0.7 |
| 7 | 46.8 | 14.7 | 0.001 |
| 8 | 31.8 | 30.9 | 95.2 |
| 9 | 14.1 | 14.9 | 1.7 |
| 10 | 1.1 | 0.001 | 0.001 |

TABLE 7

Percentage age composition of archaeological barracouta.

published on the subject (Everitt & Hand, 1981; MacDonald, 1987; MacDonald & Pitcher, 1979; McLachlan & Basford, 1988; Schnute & Fournier, 1980; Titterington *et al.,* 1985). Peter Macdonald at McMaster University in Canada has developed an algorithm which is now widely used for separating age grades of fish from trawl catch data. By using the MIX software iteratively until the $\chi^2$ value is lowest, indicating the best fit, the proportions of the different age grades in the barracouta catches may be estimated. We used the MIX program (version 3.0) to separate out the age components in the catch diagram from Long Beach (early and late assemblages) and Shag River Mouth. The results are provided in Table 7 and Figure 9.

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

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

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

## SOME DIETARY ASPECTS OF BARRACOUTA

The ungutted meat weights of the barracouta catches at these sites can be estimated. Various calculations can be made to assess the edible meat weights, caloric value, and the amounts of protein, fat, and carbohydrate which these catches represent. The procedures involved are given in Appendix 2. The catches represent 10,572 kg of fish at Long Beach and 3,355 kg at Shag River Mouth. The caloric energy represented by these catches is 8,505,000 and 2,702,000 kcal respectively.

This energy is made up of 64% from protein, 35% from fat, and 0.7% from carbohydrate. For a number of reasons, humans could not survive on a diet consisting entirely of barracouta. The nutritional issues are discussed in Appendix 2, but we note here that the proportion of energy deriving from protein is far too high, and would lead to toxicity. The people living in this region would need a source of energy deriving from carbohydrate. This is far too far south for the tropical cultigens introduced into New Zealand by early Polynesian settlers.

There are only two possible sources of significant carbohydrates which these people could have had access too - fern root (*Pteridium esculentum* var. *aquilinum*) and *tī* (cabbage tree, *Cordyline australis*). The latter is a superior food in many respects (Fankhauser, 1986). Assuming that adequate supplies of *tī* were readily available, it would have been possible to live on barracouta and this plant alone; although of course this would have been a monotonous diet and is not seriously suggested. Special earth ovens used to cook *tī* are very common in the Otago district (Frankhauser, ibid.). The absolute minimum amount of *tī* which would be required to sustain life in a nutritionally adequate manner would have been 35% by weight (see Appendix 2 for details). Thus, the 9,075 kg of barracouta represented by the fish remains from the early period at Long Beach would have required the harvesting of a minimum of 3,176 kg of *tī* to form the basis of a satisfactory diet. At this level of contribution of *tī* in the diet, caloric energy from protein is almost 32%, which is still very high. To bring this down to 27% would require *tī* at a level of 49% by weight and barracouta at 51% by weight (see Appendix 2 for further details). It can be readily seen that obtaining satisfactory carbohydrate must have been a critically important factor for people living in this region.

## DISCUSSION AND CONCLUSIONS

These two sites in the Otago area of New Zealand were significant settlements where a wide variety of fish and other animals were prepared for consumption. Barracouta were clearly very important to the people living at these sites.

It has been shown that fish size decreased significantly at Long Beach over the lengthy period of settlement at this site. There are modest signs of a similar decrease at Shag River Mouth, but the time period in this case is much shorter. There is an accompanying trend of increase in inshore fishing at Long Beach, which could possibly relate to worsening sea conditions for offshore canone-based fishing (Leach & Anderson, 1979). These observed changes could not be caused by human impact on the fishery - the biomass of barracouta in this region is far too large for such a low human population to have any significant effect.

The barracouta catches at both these sites show a dominance of fish older than six years. Fish younger than this certainly frequent the inshore Otago waters, and Graham (1956: 310 ff.) recorded large migrations of immature fish (100-130 mm long) coming into the Otago Harbour in early summer and autumn. Young fish do not appear to have been caught by the pre-European Māori; the reason for this is a mystery. Barracouta catches early in the sequence of habitation at these two sites were dominated by a smaller number of age grades than is found later in time. The late catch shows four age grades of similar relative abundance, though again these are all older fish. There are a number of possible explanations for this, but deciding between them is difficult. One possibility is that the biological relationship between growth and age was different 600 years ago than it is today and, since we are using modern parameters in trying to decompose the catch into its age constituents, the results for the earlier catches may be incorrect. For example, if the standard deviations of the fork length for each age grade were narrower in the past than today, the age structures of the catches at different periods might have been more similar than they appear. Similarly, if the growth rate was higher 600 years ago, with warmer sea conditions, than it is today, this would also explain why the earlier catches were somewhat larger fish. These suggestions are speculative at this stage because we do not have reliable information on surface sea water temperatures around New Zealand during the last thousand years. This points to a need for quality research in this field, perhaps through otolith studies from archaeological sites.

The clear dominance of older individuals in the catches at both these archaeological sites at all periods is somewhat puzzling. Graham (1956) observed large numbers of younger barracouta migrating into shallow inshore Otago waters during the summer months, but it appears that these fish were not being caught by pre-European fishermen. Their absence from the archaeological catches is mysterious. It is possible that the catching techniques employed (lure) preferentially favoured large fish, but this does not seem likely. Alternatively, small fish may have been discarded. This does not seem likely either, as there is ample evidence that very small specimens of other species were caught in abundance (Leach, n.d.).

Barracouta are a rich source of protein and oil, and would have been an excellent food for people living in these southern parts of New Zealand. They can be mass harvested during summer months and would need to be sun-dried and stored for winter use. However, a source of carbohydrate-rich food would have been needed in addition to fish. Fern root and *tī* are possibilities. We estimate that a minimum of 45% by weight of such plant food would have been required for a nutritionally adequate diet.

## ACKNOWLEDGEMENTS

Sincere thanks are due to Larry Paul at the National Institute of Water and Atmospheric Research (NIWA) for many useful discussions about fishing and fisheries issues over a long period. We are grateful to Neil Bagley, also of NIWA, and Mr Ling Lim of Seafresh Fisheries (NZ) Ltd, who provided many of the fish specimens for this study. Penny Leach, research assistant in the

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## APPENDIX 1

## BARRACOUTA IN NEW ZEALAND ARCHAEOLOGICAL SITES

The relative abundance of barracouta in New Zealand archaeological sites can be documented from the fish bone database maintained by the Archaeozoology Laboratory, Museum of New Zealand. This database has grown over many years and at present contains information from 126 sites throughout New Zealand, with a total NISP of 137,041 identifications, representing an MNI of 44,553. Of these sites, 96 contain barracouta. These are listed below.

| Site Nº | Site Name | Site MNI | % Barracouta |
|---|---|---|---|
| P26/218 | Titirangi Pa, Marlborough | 1 | 100.00 |
| O31/5 | Takahanga Post Office Site, Kaikoura | 120 | 90.83 |
| O31/15 | Peketa Pa, Kaikoura | 54 | 90.74 |
| G47/50 | Papatowai, Catlins | 27 | 88.89 |
| J44/4 | Pukekura Pa, Taiaroa Head | 105 | 88.57 |
| C46/31 | Sandhill Point 3, Foveaux Strait (SHP/3) | 363 | 86.23 |
| H47/1 | Pounawea, Otago | 428 | 85.98 |
| O32/8 | Omihi, Kaikoura | 118 | 81.36 |
| J44/77 | Taiaroa Head, Otago Peninsula | 40 | 80.00 |
| N37/12 | Tumbledown Bay, Banks Peninsula | 39 | 79.49 |
| P26/217 | Titirangi Cattleyards, Marlborough | 14 | 78.57 |
| I44/23 | Long Beach, Otago | 5770 | 78.06 |
| G47/50 | Papatowai (S184/5), Otago | 29 | 75.86 |
| C46/31 | Sandhill Point 1, Foveaux Strait (SHP/1) | 214 | 70.56 |
| I43/1 | Huriawa Peninsula, Areas A, B, Salvage | 453 | 66.23 |
| J43/2 | Shag River Mouth, Otago | 2134 | 63.45 |
| C46/16 | Port Craig Cave, Foveaux Strait (PC/1) | 114 | 63.16 |
| O32/10 | Hudson's Site, Goose Bay, Kaikoura | 27 | 59.26 |
| N26/214 | N26/214, Tasman Bay | 261 | 56.32 |
| J43/4 | Pleasant River (Smith), Otago | 145 | 55.86 |
| S28/54 | Makotukutuku M3 Fort Site, Palliser Bay | 8 | 50.00 |
| P26/229 | Goose Bay Midden, Titirangi, Marlborough | 2 | 50.00 |
| J43/4 | Tumai, Pleasant River Mouth South | 106 | 50.00 |
| J42/22 | Waianakarua Mouth, North Otago | 6 | 50.00 |
| C46/31 | Sandhill Point 2, Foveaux Strait (SHP/2) | 2 | 50.00 |
| P26/208 | Titirangi Sandhills, Marlborough | 45 | 48.89 |
| I44/21 | Purakanui Inlet, Otago | 2745 | 48.01 |
| N26/18 | Awaroa (N26/18), Tasman Bay | 32 | 43.75 |
| O31/30 | Old Pier Point, Avoca, Kaikoura | 24 | 41.67 |
| I44/1 | Omimi, Otago | 27 | 40.74 |
| S28/48 | Makotukutuku M1 Camp Site, Palliser Bay | 5 | 40.00 |
| E49/15 | Kelly's Beach, Stewart Island | 13 | 38.46 |
| N26/16 | Bark Bay, Tasman Bay | 50 | 36.00 |
| I44/17 | Mapoutahi (S164/13), Otago | 140 | 34.29 |
| I44/5 | Otokia Mouth, Brighton Beach, Otago | 3 | 33.33 |
| R27/42 | Makara Terrace Midden, Wellington | 19 | 31.58 |
| J43/4 | Pleasant River (Anthropology), (S155/8) | 54 | 31.48 |

| Site N° | Site Name | Site MNI | % Barracouta |
|---|---|---|---|
| Q27/30 | Te Ika a Maru, Eastern Flat, Wellington | 60 | 30.00 |
| E48/30 | Te Kiri Kiri, Ruapuke Island (KK/1) | 56 | 28.57 |
| N25/50 | Taupo Point, Tasman Bay | 11 | 27.27 |
| E48/34 | Parangiaio, Ruapuke Island (PP/1) | 11 | 27.27 |
| C240/277 | Te Ngaio, Petre Bay, Chatham Island | 4 | 25.00 |
| O27/56 | Haulashore Island, Tasman Bay | 25 | 24.00 |
| B45/1 | Cascade Cove, Dusky Sound (CC/1) | 123 | 23.58 |
| Q7/58 | Northland Harbour Board Site, Whangarei | 5 | 20.00 |
| C46/31 | Sandhill Point 4, Foveaux Strait (SHP/4) | 105 | 20.00 |
| R27/41 | Makara Beach Midden, Wellington | 44 | 18.18 |
| O27/1 | Rotokura, Tasman Bay | 585 | 17.61 |
| R11/142 | Hamlins Hill (N42/137), Auckland | 12 | 16.67 |
| E48/29 | West Point, Ruapuke Island (WP/1) | 63 | 15.87 |
| N27/118 | Appleby, Nelson | 128 | 14.84 |
| R11/898 | Westfield (N42/941), Auckland | 21 | 14.29 |
| B45/23 | Milford, Fiordland | 7 | 14.29 |
| R10/38 | Davidson Undefended Site, Motutapu Is | 50 | 14.00 |
| D46/38 | Wakapatu, Western Southland | 94 | 13.83 |
| E48/36 | Lee Island Site, Ruapuke Island (LI/1) | 8 | 12.50 |
| I43/22 | Ross Rocks, Otago | 139 | 12.23 |
| B45/14 | Southport 4, Cave Site, Fiordland (SP/4) | 86 | 11.63 |
| N3/582 | Aupouri Dune Middens, 90 Mile Beach | 18 | 11.11 |
| S28/103 | Black Rocks Fan, Palliser Bay | 20 | 10.00 |
| B44/41 | Breaksea Sound 1, Discovery Cove (BSS/1) | 1153 | 8.85 |
| R26/122 | Paremata, Wellington | 140 | 8.57 |
| S28/104 | Black Rocks BR4 Crescent Midden, Palliser | 683 | 8.20 |
| U12/5 | Slipper Island, Coromandel | 13 | 7.69 |
| N36/72 | Panau, Banks Peninsula | 68 | 7.35 |
| C46/19 | Port Craig Midden, Foveaux Strait (PC/4) | 28 | 7.14 |
| S28/49 | Washpool Site, Palliser Bay | 750 | 7.07 |
| R10/26 | Station Bay Pa, Motutapu Island | 145 | 6.90 |
| B45/11 | Southport 1, Fiordland (SP/1) | 439 | 6.83 |
| Q27/36 | Te Ika a Maru, Flat at Base of Pa | 194 | 6.70 |
| R26/141 | Mana Island North Settlement (R26/141) | 1155 | 6.23 |
| E47/13 | Tiwai Point, Bluff Harbour | 102 | 5.88 |
| B45/15 | Southport 5, Cave Site, Fiordland (SP/5) | 120 | 4.17 |
| B44/22 | Coopers Island, Dusky Sound (CI/1) | 219 | 3.65 |
| U13/1101 | Midden 8, Matakana Island | 124 | 3.23 |
| B44/1 | Long Island, Dusky Sound (LI/1) | 250 | 2.80 |
| B45/17 | Southport 7, Fiordland (SP/7) | 111 | 2.70 |
| B45/16 | Southport 6, Fiordland (SP/6) | 185 | 2.70 |
| T9/139 | Port Jackson, Coromandel | 42 | 2.38 |
| B45/22 | Chalky Is, Chalky Inlet, Southport (CH/1) | 45 | 2.22 |
| S28/104 | Black Rocks BR3 Black Midden, Palliser | 189 | 2.12 |
| K30/2 | Fox River, Te Onumata, Potikohua River | 100 | 2.00 |
| G36/1 | Bruce Bay, south Westland | 54 | 1.85 |
| S28/104 | Black Rocks BR2 Pond Midden, Palliser | 56 | 1.79 |
| O27/13 | The Glen, Tasman Bay | 179 | 1.12 |
| V15/80 | Kohika, Bay of Plenty (N68/104) | 184 | 1.09 |
| O6/317 | Kokohuia, Hokianga | 838 | 0.95 |
| C240/283 | Waihora, Chatham Islands | 4197 | 0.93 |

| Site Nº | Site Name | Site MNI | % Barracouta |
|---|---|---|---|
| T8/3 | Harataonga Bay Pa, Great Barrier Island | 231 | 0.87 |
| R26/141 | Mana Island South Midden (R26/141A) | 591 | 0.85 |
| T11/115 | Hot Water Beach, Coromandel | 277 | 0.72 |
| T11/242 | Hahei, Coromandel (N44/215) | 202 | 0.50 |
| T10/399 | Cross Creek Site, Coromandel | 481 | 0.42 |
| S24/3 | Foxton, Manawatu | 270 | 0.37 |
| R10/25 | Sunde Site soft shore midden, Motutapu Is | 401 | 0.25 |
| N3/59 | Houhora, Northland | 2425 | 0.08 |

## APPENDIX 2
## SOME CALCULATIONS ON BARRACOUTA IN DIET

In the following discussion, Long Beach All refers to all samples from Long Beach, including bone collections from mixed provenances. Thus, the MNI figures include bones other than those listed elsewhere in this paper as from the early and late provenances. Shag River All refers to all samples from the dune area, including bone material from mixed provenances.

The ungutted weight (g) of the various samples can be estimated using the regression information provided by Leach *et al.* (1996)

| Sample | Mean | - | SE | SD | - | SE |
|---|---|---|---|---|---|---|
| Long Beach Early | 2369 | ± | 4 | 448 | ± | 3 |
| Long Beach Late | 2220 | ± | 14 | 570 | ± | 10 |
| Long Beach All | 2347 | ± | 4 | 471 | ± | 3 |
| Shag River All | 2478 | ± | 11 | 473 | ± | 8 |

The Edible Weight of barracouta is approximately 0.7 * Total Weight (Smith, 1985), thus:

| Sample | MNI | x | Mean | = | Weight kg | Edible Wgt |
|---|---|---|---|---|---|---|
| Long Beach Early | 3831 | x | 2369 | = | 9706 | 6353 |
| Long Beach Late | 550 | x | 2220 | = | 1221 | 855 |
| Long Beach All | 4504 | x | 2347 | = | 10572 | 7400 |
| Shag River All | 1354 | x | 2478 | = | 3355 | 2349 |

In the example at the end of this Appendix we will use the figure of 9076 kg referring to the Long Beach Early assemblage.

Barracouta whole fish protein is 18.4 g/100g, oil is 4.5 g/100g (Vlieg, 1988: 23), and carbohydrate is 0.2 g/100g (ibid.: 5). Barracouta gross caloric energy is 107 kcal/100g (ibid.: 48). The figures for kcal/100g for protein, fat and carbohydrate (400, 900 and 400) derive from Smith (1985: 131). The various samples then represent:

| Sample | Edible kg | Protein kg | Oil kg | Carb kg |
|---|---|---|---|---|
| Long Beach Early | 6353 | 1169 | 286 | 13 |
| Long Beach Late | 855 | 157 | 38 | 2 |
| Long Beach All | 7400 | 1362 | 333 | 15 |
| Shag River All | 2349 | 432 | 106 | 5 |

It is possible to calculate the amount of energy derived from the protein, oil and carbohydrate in barracouta as follows:

| | Protein | Oil | Carb | Total |
|---|---|---|---|---|
| Energy kcal/100g | 400 | 900 | 400 | |
| Whole Barracouta g/100g | 18.4 | 4.5 | 0.2 | |
| So, kcal/100g whole fish | 73.6 | 40.5 | 0.8 | 114.9 |
| So, the energy percent values are | 64.1 | 35.2 | 0.7 | 100.0 |

NB: This total compares favourably with Vlieg's figure of 107 kcal/100g for whole fish. So these samples provided energy as follows:

| Sample | Protein kg x 4000 | Oil kg x 9000 | Carb kg x 4000 |
|---|---|---|---|
| Long Beach Early | 1169 = 4676000 | 286 = 2574000 | 13 = 52000 |
| Long Beach Late | 157 = 628000 | 38 = 342000 | 2 = 8000 |
| Long Beach All | 1362 = 5448000 | 333 = 2997000 | 15 = 60000 |
| Shag River All | 432 = 1728000 | 106 = 954000 | 5 = 20000 |

Therefore, the Total Energy is:

| | |
|---|---|
| Long Beach Early | 4,676,000 + 2,574,000 + 52,000 = 7,302,000 |
| Long Beach Late | 628,000 + 342,000 + 8,000 = 978,000 |
| Long Beach All | 5,448,000 + 2,997,000 + 60,000 = 8,505,000 |
| Shag River All | 1,728,000 + 954,000 + 20,000 = 2,702,000 |

However, the upper limit to the amount of food energy which can be derived from protein is 20-30% of average daily needs, say 25% (Leach, n.d.: Chapter 8). If this figure is exceeded, unhealthy conditions arise, such as azotaemia (excess nitrogen) and a rise in plasma ammonia concentrations which can be lethal (Noli & Avery, 1988: 397). Moreover, there is an upper limit to the amount of caloric energy which can be derived from fat without dangerous levels of acidic ketone bodies accumulating in the bloodstream (ketonuria); this is about 40% of daily caloric needs (Leach, n.d.: Chapter 8).

What this analysis shows is that one could not live on barracouta alone, since the percentage of energy deriving from the three main ingredients (protein 64.1, fat 35.2, and carbohydrate 0.7) is out of balance for a satisfactory human diet. A diet of barracouta is far too rich in protein. It would easily provide all the daily protein and fat requirements, but there is a dramatic shortage of carbohydrates. We can hypothesise an unknown source of carbohydrate (perhaps fern root and/or *tī*) to the level required to bring down the contribution of protein from barracouta to say 25% of caloric needs. *Tī*, for example, provides protein at 2 g/100g, fat at 6 g/100g and carbohydrate at 30-74 g/100 (say average of 50). This is equivalent to caloric energy levels of:

| | | |
|---|---|---|
| *Tī* Protein | 2 * 4 = | 8 kcal = 3.1% |
| *Tī* Fat | 6 * 9 = | 54 kcal = 20.6% |
| *Tī* Carbohydrate | 50 * 4 = | 200 kcal = 76.3% |
| Total kcal/100g for *tī* | | 262 |

We could therefore have a diet mixture providing caloric energy for the main three components along the following lines:

| | Proportions of Caloric Energy | | |
|---|---|---|---|
| | Protein% | Oil% | Carb% |
| Barracouta | 64.1 | 35.2 | 0.7 |
| *Tī* | 3.1 | 20.6 | 76.3 |

This could be a satisfactory dietary mix, assuming that adequate supplies of *tī* were available. A series of simple calculations can be made to assess the energy which would derive from various levels of contribution of *tī*. These are given below for the Long Beach early assemblage in which the total weight of barracouta was 9076 kg. *Tī* could be added to this source of protein-rich food in varying amounts from 5% to 50% of the weight of fish eaten.

**Apportionment of Food Energy deriving from Protein, Oil and Carbohydrate**

| Fish kg | *Tī* kg | Proportion | Blubber kg | Protein % | Oil % | Carb % |
|---|---|---|---|---|---|---|
| 9076 | 454 | 0.05 | 0 | 55.5 | 33.2 | 11.3 |
| 9076 | 908 | 0.10 | 0 | 49.1 | 31.7 | 19.3 |
| 9076 | 1361 | 0.15 | 0 | 44.0 | 30.4 | 25.5 |
| 9076 | 1815 | 0.20 | 0 | 40.0 | 29.5 | 30.5 |
| 9076 | 2269 | 0.25 | 0 | 36.7 | 28.7 | 34.6 |
| 9076 | 2723 | 0.30 | 0 | 33.9 | 28.0 | 38.1 |
| 9076 | 3176 | 0.35 | 0 | 31.6 | 27.5 | 41.0 |
| 9076 | 3630 | 0.40 | 0 | 29.5 | 27.0 | 43.5 |
| 9076 | 4084 | 0.45 | 0 | 27.8 | 26.5 | 45.7 |
| 9076 | 4538 | 0.50 | 0 | 26.3 | 26.2 | 47.6 |
| 5 Percent by weight of blubber added | | | | | | |
| 9076 | 454 | 0.05 | 454 | 37.5 | 54.9 | 7.6 |
| 9076 | 908 | 0.10 | 454 | 34.5 | 51.9 | 13.6 |
| 9076 | 1361 | 0.15 | 454 | 32.0 | 49.4 | 18.6 |
| 9076 | 1815 | 0.20 | 454 | 29.9 | 47.3 | 22.8 |
| 9076 | 2269 | 0.25 | 454 | 28.0 | 45.5 | 26.5 |
| 9076 | 2723 | 0.30 | 454 | 26.4 | 43.9 | 29.7 |
| 9076 | 3176 | 0.35 | 454 | 25.0 | 42.5 | 32.5 |
| 9076 | 3630 | 0.40 | 454 | 23.8 | 41.2 | 35.0 |
| 9076 | 4084 | 0.45 | 454 | 22.7 | 40.1 | 37.2 |
| 9076 | 4538 | 0.50 | 454 | 21.7 | 39.1 | 39.2 |

It can be seen from this that *tī* has to be added to the weight of barracouta to a level of more than 50% by weight of the total fish available if the energy deriving from protein is to be low enough to avoid azotaemia (this was earlier mentioned as about 25% of energy intake). On the other hand, it will also be observed that if an additional source of high energy oil from seal blubber is added to the diet, the proportion of *tī* required falls. Adding blubber to a level of 5% by weight of the fish means that *tī* can be lowered by a similar amount, to say 45% of the weight of fish. Energy from fat sources now rises uncomfortably close to the 40% threshold where ketonuria might result.

This shows that a carbohydrate food like *tī* would be required to a level of 45% to 50% of the weight of fish consumed, and that it would have been a delicate balancing act, striving to avoid two dietary dangers - azotaemia on the one hand, and ketonuria on the other.

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