NEW ZEALAND ARCHAEOLOGICAL ASSOCIATION NEWSLETTER

PATTERNS OF TOOTH WEAR IN PREHISTORIC NEW ZEALAND

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Of the limited work undertaken on New Zealand material by physical anthropologists, work on tooth attrition is the most prolific. Recently, Houghton (1977b, 1978a and b, 1980) has developed a model for patterns of toothwear in prehistoric New Zealanders using well provenanced skeletal samples from throughout the country.

Houghton's model can be summarised as follows:

1. Early period: little toothwear with some caries and periodontal disease,
2. Post-1500 A.D.: heavy wear with loss of crowns of teeth and the development of alveolar abscesses.

In an earlier paper Houghton (1977b) extends the model to three stages at eastern Coromandel. The third stage is a return to less wear in association with the introduction of the European potato.

The major objective of the present paper is to test Houghton's model. Further, any suggestion that a relationship between diet and latitude might be reflected in tooth wear is tested by ranking the samples according to latitude alongside a ranking according to degree of dental attrition. Note is also made as to whether any particular form or type of tooth wear (apart from the actual amount of wear) occurred for any one archaeological sample.

Materials

The collection of skeletal material examined here is drawn from nine locations throughout New Zealand. Two of these were further divided owing to differences in provenance. Thus for analysis of data, the actual number of samples becomes twelve. These were all the available, well provenanced skeletal samples for New Zealand. They represent a wide range of spatial and chronological provenances (see Fig. 1). The provenance for each sample as well as the number of individuals and their sex and age are given in Appendix 2. The largest sample, Wairau Bar, consists of 23 individuals, the smallest, of one. In total there were 57 individuals represented, 50 of whom were adults.

Method

The method of recording tooth wear was a number scale (after Molnar, 1971) which grades wear in order of severity. This scale enables three

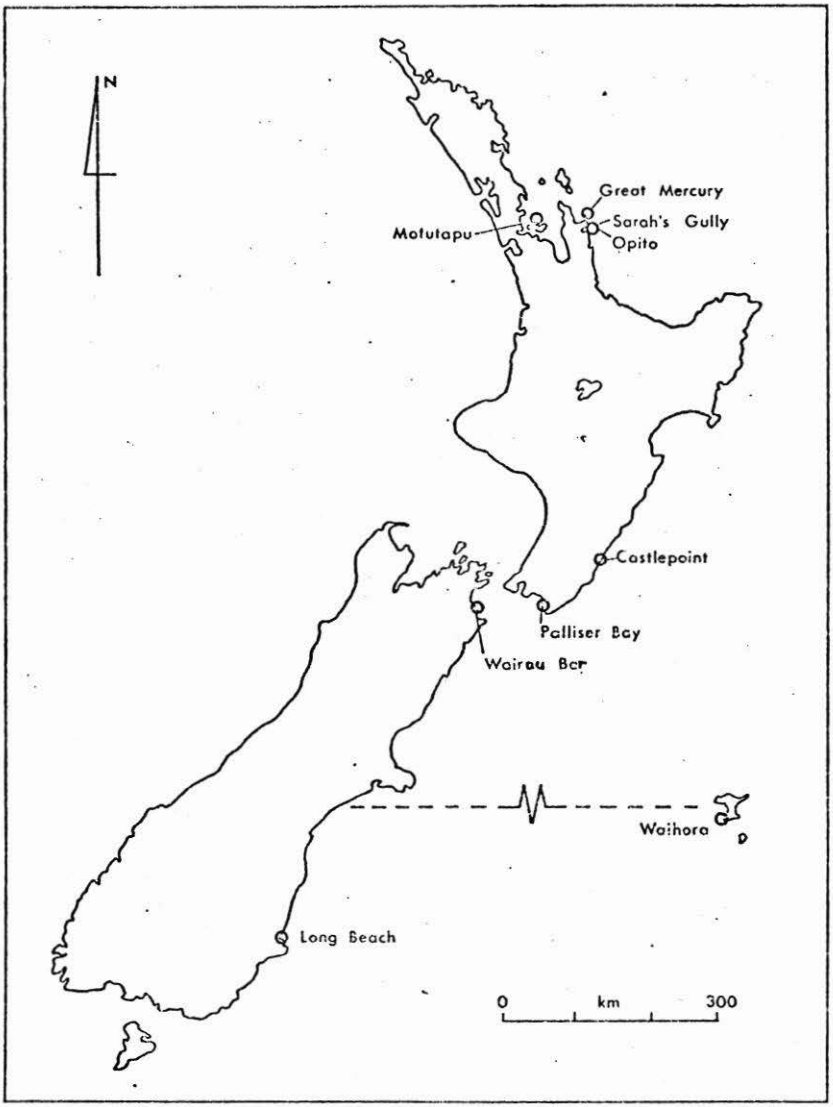

FIGURE 1. Location map.

aspects of tooth wear to be recorded; degree, direction and occlusal surface form of wear. Only the degree of wear is discussed in this paper (for discussion of the latter two aspects refer to Olsen, 1979). Molnar's scale was modified slightly by the present writer to suit the material encountered (see Table 1 and Appendix 1). In case of tooth loss, distinction was made between ante-mortem and post-mortem loss during recording.

Analysis of data

In view of the objectives of the study, the data was graphed in a manner which would show differences between males and females in five year age classes for each sample. Comparison was then made between samples. In all tabulation of data mandibles and maxillae were kept separate. Samples were too small and irregular to allow application of standard statistical tests of similarity in most cases. It was therefore decided to arrange the data for degree of wear in graph form. This was done in such a way that data for males and females, mandibles and maxillae and each quadrant per jaw could easily be distinguished.

The five year age classes were an arbitrary time unit chosen to measure the rate of toothwear and compare it between samples. They were also chosen to maximise the information available from the largest sample, Wairau Bar, where most of the individuals were aged between 20 and 30 years. However it is recognised that because of the difficulty in accurately aging adult bone material, five year age classes may not always be accurate.

On each graph, the horizontal axis represented each tooth as positioned in the dental arch. The vertical axis represented the series of five year age classes. The degree of wear was plotted for each age category. For each tooth (type) the most commonly occurring grade of wear plus the range of grades found per age class was represented. Two graphs were drawn for each sample; one for maxillae, the other for mandibles. As an example of these graphs, those for Wairau Bar are presented here in Figure 2.

There were four reasons for presenting the data in this way. Firstly, by establishing the range and the median for each tooth type from individuals of each age class, the progression of attrition and patterns of wear for the sample were clearly visible. Secondly, when each tooth was represented in this way the part of the dentition which bore more of the attritional load could easily be seen. Thirdly, all the data was expressed separately for males and females. Thus any differences in the first two points above between male and female burials could readily be observed. Finally, inter-sample comparison in patterns of wear could be made.

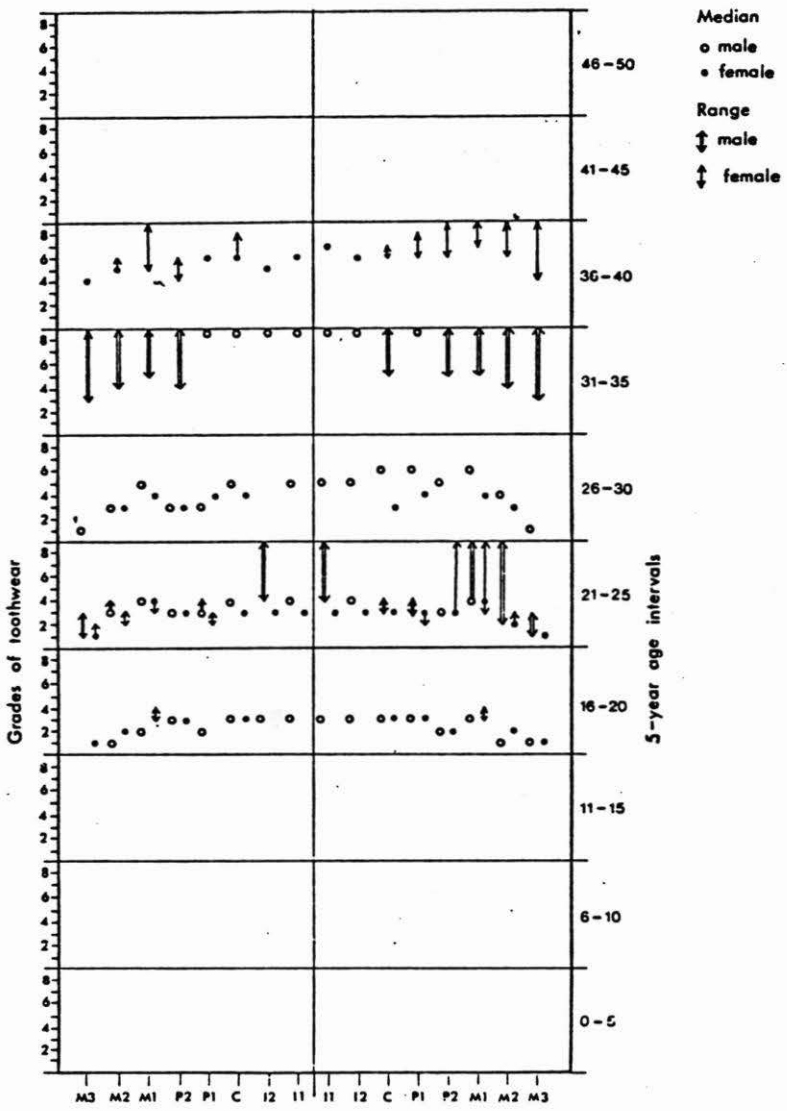

FIGURE 2a. Degree of wear in mandibles from Wairau Bar.

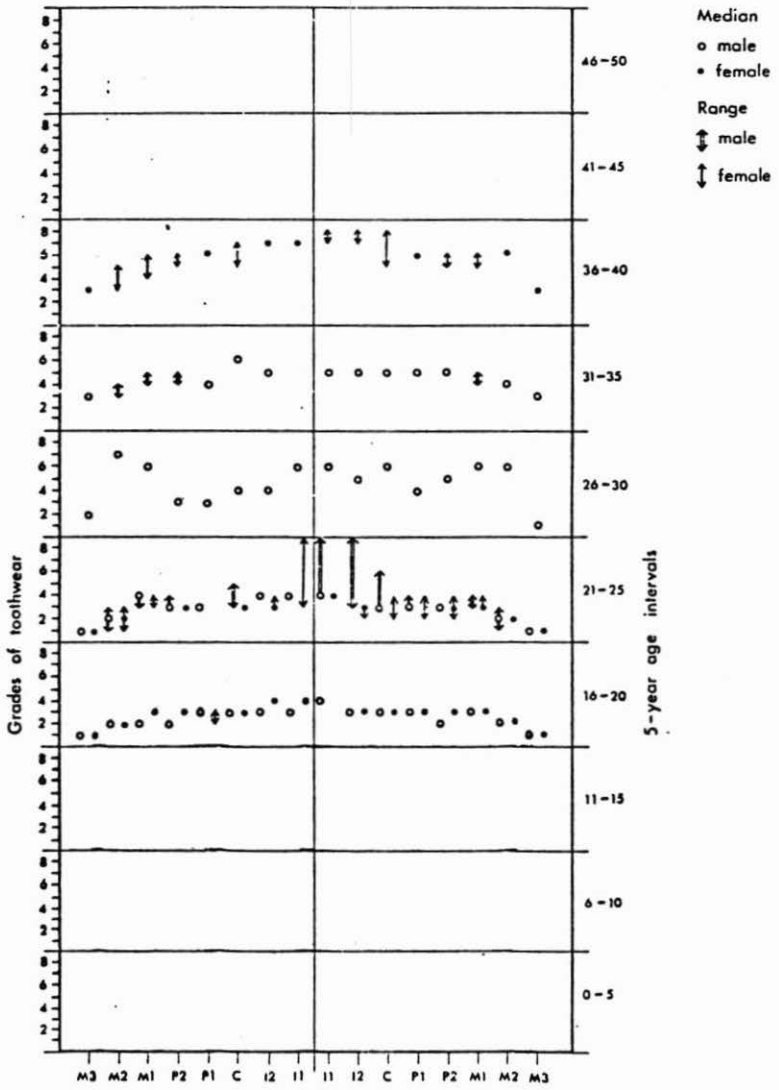

FIGURE 2b. Degree of wear in maxillae from Wairau Bar.

Samples were then arranged in a sequence from least worn to most worn, that is, order of severity of wear (see Olsen, 1979:46). The association of severity of wear with latitude and antiquity respectively was tested using the Spearmans Rho statistical test (Anderson and Sclove, 1978:599-600). Results are shown in table form (see Table 2).

Order of severity of wear		Order of antiquity	Order of latitude
Opito (13th-14th century)	1	5	7
Sarah's Gully	2	4	9
Long Beach	3	8	1
Opito (19th century)	4	12	6
Great Mercury (13th-14th century)	5	6	10
Wairau Bar	6	1	3
Castlepoint	7	2	5
Great Mercury (19th century)	8	11	11
Waihora	9	7	2
Wairarapa (Washpool Midden Site)	10	3	4
Motutapu	11	10	12
Opito (18th century)	12	9	8

TABLE 2. Order of severity of wear versus relative antiquity of samples and versus order of latitude.

Results

The following is a summary of results obtained (for detailed discussion see Olsen, 1979: Chapter 3). The samples are listed here in ascending order of severity of wear.

1. Opito (Coromandel Peninsula, 13th-14th century A.D.). The degree of wear was slight, and the rate of wear appeared to have been slower than for most other samples.
2. Sarah's Gully (Coromandel Peninsula, 13th-14th century A.D.). This sample was very similar to the above in that wear was slight-to-moderate and the rate of attrition was comparatively slow. All of the early eastern Coromandel samples have a higher frequency of evenly spread attrition than other samples.
3. Long Beach (Otago Peninsula, late Archaic period). Judging from the most intact dentition the wear was similar to that evidenced at Wairau Bar, although this is a very limited sample.
4. Opito (Coromandel Peninsula, 19th century A.D.). The degree of wear was slight to moderate again, and similar to the Great Mercury individual of the same antiquity.

	Incisor & Canine	Premolar	Molar
1.	unworn	unworn	unworn
2.	wear facets minimal in size.	wear facets, no observable dentine.	wear facets, no observable dentine.
3.	cusp pattern obliterated; small dentine patches may be present.	cusp pattern partially obliterated; small dentine patches.	cusp pattern partially obliterated; small dentine patches.
4.	dentine patch (small-moderate).	two moderate sized dentine patches.	at least three small-moderate dentine patches; still vestiges of cusp pattern.
5.	dentine patch (extensive); possibly minimal secondary dentine.	dentine extensive, still two patches or coalesced; possibly slight secondary dentine.	extensive dentine; possibly an island or peninsula of enamel on occlusal surface; possibly slight secondary dentine.
6.	secondary dentine (moderate-extensive).	entire tooth still surrounded by enamel; secondary dentine (moderate-slight).	secondary dentine (moderate-extensive); enamel still surrounds tooth.
7.	crown enamel worn away on at least one side; extensive secondary dentine.		
8.	roots functioning in occlusal surface.		
9.	tooth lost as result of severe wear.		

a. Degree of Wear

b. Direction or Slope of Wear

1. natural form
2. oblique (buccal-lingual direction)
3. oblique (lingual-buccal direction)
4. oblique (mesial-distal direction)
5. oblique (distal-mesial direction)
6. horizontal (perpendicular to the long axis of the tooth)
7. rounded (buccal-lingual direction)
8. rounded (mesial-distal direction)

c. Occlusal Surface Form

1. natural form
2. flat surface
3. one half of surface cupped
4. entire surface cupped
5. notched
6. rounded

TABLE 1. Scale for grading attrition (after Molnar, 1971).

5. Great Mercury Island (off Coromandel Peninsula, 13th-14th century A.D.). The degree of wear was slight to moderate, and was evenly spread over the dentition. Similarity is strongest with Sarah's Gully, though the rate of wear was a little faster.
6. Wairau Bar (Marlborough, 12th century A.D.). This sample had notably flat and horizontal tooth wear. While this was not so in every case, the overall appearance of the Wairau material was distinctive. There were no fern root planes. It is interesting that this sample fell midway up the order of severity of wear, as it is one of the earliest in the collection.
7. Castlepoint (Wairarapa, 12th century A.D.). This sample had every appearance of having been similar to the Wairau Bar material. The rate of wear was perhaps a little faster. The same impression of very flat wear facets was found.
8. Great Mercury Island (off Coromandel Peninsula, 19th century A.D.). Moderate wear was found in this individual. The pattern was similar to the early eastern Coromandel material, in view of the age of this individual, except the rate of wear may have been a little faster.
9. Waihora (Chatham Island, 15th-16th century A.D.). The distinctive pattern for this sample is that of heavier wear in posterior teeth, with fern root planes. This sample is somewhat similar to the Wairarapa material.
10. Palliser Bay (Wairarapa, 12th-15th century A.D.). The contrast between this sample and the contemporary Wairau Bar sample was marked, even when one considers the differences in age at death between individuals from the two samples. Wear was severe in these burials. Loss of teeth before death due to advanced attrition was prevalent. Fern root planes were present. Irregularities in the distribution of the attritional load were frequent.
11. Motutapu Island (Hauraki Gulf, 18th century A.D.). This sample had one of the most advanced rates of wear. Variability in the distribution of the attritional load was also high.
12. Opito (Coromandel Peninsula, 18th century A.D.). Tooth wear was similar to that found in the Motutapu, Waihora and Wairarapa samples. Fern root planes were present.

There was a difference in the amount of wear in male and female dentitions in four samples - Wairau Bar, Wairarapa (Washpool Midden Site), Motutapu and Sarah's Gully. In addition, in three of these samples there were differences in the distribution of the attritional load in male and female dentition. At Wairoa Bar more males than females had heavier wear in lower frontal teeth, but more females had heavier wear in lower posterior teeth. For Sarah's Gully and Motutapu on the other hand, the differences in wear in males and females may be age-related. The Wairarapa material however does not share in this difference in wear between the sexes.

Although pathological conditions in the dentitions are not analysed in this paper, they were noted. In summary, most of the pathological conditions observed occurred in samples from throughout the regional and temporal range of the collection. However, evidence of periodontal disease was observed only in the material from the early period. Calculus and caries were found more often in early material. These are also found in tropical Polynesia. Fern root planes and alveolar abscesses occurred almost equally in early and late samples with a slightly higher frequency in the latter. These are typically New Zealand pathologies.

Two interesting patterns emerged in relation to the form or type of wear for each sample. Firstly the Wairau Bar and Castlepoint teeth had notably flat occlusal surfaces. Secondly, the Waihora sample showed a distinct emphasis toward heavier wear on posterior teeth in all individuals. No other sample appeared to exhibit a consistent form of wear. All other patterns to emerge are related to the severity of wear and the rate of wear for each sample.

Discussion

The major conclusion of the study is that the severity of tooth wear for each sample was independent of both antiquity and latitude. Houghton's general model is therefore too simple.

An examination of archaeological and ethnographic evidence for diet was therefore undertaken as an attempt to explain the differences in attrition found between samples. Both the archaeological and ethnographic evidence for diet for the particular sites or areas the samples are from suggest that for each sample, the specific diet was responsible for the pattern of wear encountered (Olsen, 1979).

There are three general points about diet which apply to most samples with severe tooth wear.

1. The lack, or marginal success, of horticulture. Waihora had no horticulture. Any plant foods eaten would have been gathered. Fern root is known to have been included (Sutton, 1980). The Wairarapa had marginal conditions for horticulture (Leach and Leach, 1979). The 18th century Opito environment may also have been marginal in some respects (Banks, 1962). Motutapu is the exception - horticulture should have been successful, and storage pits were found at each site (Davidson, 1970 & 1972; Leahy, 1970; Sullivan, 1972).
2. The apparent lack of a large mammal protein source as an important food item. This applies to the Wairarapa (Leach and Leach, 1979), Motutapu (Allo, 1970; Davidson, 1972) and 18th century Opito samples. The exceptional case is the Waihora sample where seals formed the most

important item of diet (Sutton, 1980). Heavy wear there may be attributed to chewing tough vegetable foods. Following this, there are two foodstuffs common to samples with severe tooth wear.
3. These are fish and shellfish. As well as being eaten fresh, they were probably smoked or dried and eaten thus during periods of seasonal food shortages. This was evidently true for the Wairarapa (Leach and Leach, 1979), Opito in the 18th century (Banks, 1962) and probably the Motutapu samples (Davidson, 1978a). Adventitious grit associated with sea food would have caused wear.

Though these general patterns have emerged, it will be noted that one or more samples form an exception to each point. This accentuates the importance of each specific diet in determining the severity of tooth wear. However it also enables a tentative explanation to be made for the patterns of severity of wear, based on dietary evidence.

The samples listed above and described as having slight to moderate wear may be considered first. Archaeological evidence suggests that the inhabitants of Sarah's Gully (Green, 1963a) and Wairau Bar (Duff, 1977) had a wider range of protein resources available to them than any other sample. Sarah's Gully is at the bottom of the severity of wear scale, while Wairau Bar is midway up the scale. There are two possible reasons for these differences. Firstly, kumara may not have been as successful in the Marlborough region as at Coromandel. Secondly, though their relative importance is unknown, sea foods were apparently important at Wairau Bar but not especially so at Sarah's Gully. Quantities of grit in seafoods may partly account for the differences. Tooth wear at Long Beach is more similar to Wairau Bar than any other sample. Sea foods appear to have been important in the diet there (Anderson, n.d.).

Consider now the samples described as showing severe tooth wear. At Waihora, meat was the most important food. Fibrous vegetable foods, such as fern root probably accounts for the degree of tooth wear. More severely worn samples from the Wairarapa and 18th century Opito had sea foods as a protein source and probably periods of reliance on dried sea foods. In addition, fern root or other such fibrous matter was probably eaten on a seasonal basis if not all year round. The Motutapu sample remains outstanding. Horticulture should have been successful. But it would seem that fern root was eaten regularly. There is no evidence at present to suggest that protein foods were of major calorific value. It might be suggested that kumara and fern root were regularly eaten, and supplemented by fresh and/or dried sea foods.

The points raised from this discussion are summarised here.

1. The specific diet for each sample remains the most important factor in determining severity of tooth wear.
2. Within this, two important factors can be isolated: firstly, the abundance and diversity of food resources utilised; and secondly, a lack of stability in exploitable resources particularly on a seasonal basis.
3. Certain foods have different 'attrition-causing values'. These are, in increasing order of severity: kumara, fresh meat, fish and shellfish, dried protein foods, and fern root plus other fibrous vegetable material. Fern root planes occur where the diet apparently included tough and fibrous food on a regular basis. A detailed discussion of fern root planes may be found in Olsen (1979). There it was decided that these planes developed as a result of the teeth affected having been used as 'micro-tools', in the manipulation, and especially the stripping, of tough or fibrous food such as fern root or other dried foods. The particularly flat wear planes on the Wairau Bay and Castlepoint dentitions are probably also related to the particular diet of these people. It is likely that the use of teeth to manipulate small particles of generally soft food rather than tough and fibrous feed (see Olsen, 1979:7) is partly responsible.

The development of differences in the attritional load either between quadrants or upper and lower jaw, or anterior and posterior teeth becomes more pronounced with the age of the individual. It can begin with habitual use of teeth on one side of the mouth. If a tooth becomes worn to exposure of the pulp or is otherwise diseased, it will become painful and the person will naturally shift the bulk of his chewing strength to other teeth. Use of teeth for industrial purposes can also contribute to uneven wear.

Summary

While there was some tendency for a change from little tooth wear in the early period to heavy wear in the late period, the present work indicates that Houghton's model requires further examination.

The main conclusions from the research are as follows:

1. Patterns of toothwear are related to the diet or subsistence economy of each particular sample rather than to antiquity or latitude.
2. Fern root and other tough substances caused fern root planes on molar teeth.

Continued research with ethnographic material, informants and experimental work will be of major importance in further elucidating

causes of toothwear. In addition, more sophisticated methods of examining occlusal surfaces will be invaluable. The clarification of 'industrial' use of teeth is to be seen as a primary objective of future research.

Acknowledgements

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All skeletal samples were held at the Otago Medical School, except Motutapu and Opito which were in the Auckland Institute and Museum, and Long Beach, which was in the Otago Museum.

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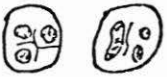
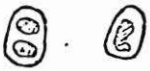
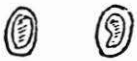
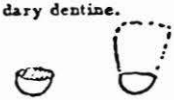
Category of Wear	Incisor and Canine	Premolar	Molars
1	Unworn.	Unworn.	Unworn.
2	Wear facets minimal in size.	Wear facets, no observable dentine.	Wear facets, no observable dentine.
3	Cusp pattern obliterated, small dentine patches may be present. 	Cusp pattern partially or completely obliterated. Small dentine patches. 	Cusp pattern partially or completely obliterated. Small dentine patches. 
4	Dentine patch (Minimal). 	Two or more dentine patches, one of large size. 	Three or more small dentine patches. 
5	Dentine patch (Extensive). 	Two or more dentine patches, secondary dentine may be slight. 	Three or more large dentine patches, secondary dentine, none to slight. 
6	Secondary dentine (Moderate to Extensive). 	Entire tooth still surrounded by enamel, secondary dentine moderate to heavy. 	Secondary dentine moderate to extensive entire tooth completely surrounded by enamel. 
7	Crown (enamel) worn away on at least one side, extensive secondary dentine. 	Crown (enamel) worn away, on at least one side, extensive secondary dentine. 	Crown (enamel) worn away on at least one side, extensive secondary dentine. 
8	Roots functioning in occlusal surface.	Roots functioning in occlusal surface.	Roots functioning in occlusal surface.

APPENDIX 1. Molnar's (1971) scale for grading tooth wear.

Sample	No. of Ind.	No.	Sex	Age In Years	Site Description	Radio-carbon Date		Nitrogen Estimate
						Charcoal	Collagen	
Motutapu N38/30 Station Bay	1	1	F	50	"in association and contemporary with Layer 4"... the first occupation. An undefended settlement.	post-1500 AD (Law, 1975)	630±40 BP* (NZ 4347, human bone collagen) (Davidson, 1979b)	1.5% "about 1400 AD" (Houghton, 1977a)
Motutapu N38/37 Station Bay	1	2	F	39	Undefended settlement. "there is no indication of the time during the site's history when the burial occurred. It could be associated with any of the other features" (Davidson, 1970)	185±71 BP** (NZ 1168) (Davidson, 1972)	520±71 BP* (NZ 4346, human bone collagen) (Davidson, 1978c)	4.0% "late eighteenth century" (Houghton, 1977a)
Motutapu N38/25 Station Bay	2	3 4	F M	28 30-35	Pa site. The tihi... "a double burial of two adults in an extended position had been placed on the floor of a pit..." (Davidson, 1972)	c200 BP* (NZ 4349, charred bracken fronds) (Davidson, 1978b)	450±30 BP* (NZ 4348, human bone collagen) (Davidson, 1978b)	Burial 4 - 3.61% Burial 3 - 3.46% "early eighteenth century" (Houghton, 1977a)
Great Mercury Island	3	I	F	25	No excavation report available.			1.06% "AD 1200-1400 period" (Houghton, 1977b)
		II	F	25-28	N40-grid 263905 on NZ Topographical Map 1:63360 Coromandel, 1965 (Houghton, 1977b) "...a simple hole in the boulder beach..." (Golson, 1955)			1.57% "AD 1200-1400 period" (Houghton, 1977b)
		III	F	30	Peach Grove, Mercury Island. N40-grid 298867 on NZ Topographical Map 1:63360 Coromandel, 1965. (Houghton, 1977b)			4.43% "early nineteenth century AD" (Houghton, 1977b)

APPENDIX 2. Provenance of samples. Radiocarbon dates have been accepted where there are both these and nitrogen estimates. Dates used here are underlined. * new $T\frac{1}{2}$ with secular correction. ** no published $T\frac{1}{2}$. *** old $T\frac{1}{2}$ without secular correction.

Sample	No. of Ind.	No.	Sex	Age In Years	Site Description	Radio-carbon Date		Nitrogen Estimate
						Charcoal	Collagen	
Opito N40/16	1	1	F	20-25	A beach midden.			4.4% "early nineteenth century" (Houghton, 1977b)
Opito N40/12	2	2	M	23	A foredune midden site at Opito Beach			1.20% "AD 1200-1400 period" (Houghton, 1977b)
		3	F	32				3.4% "early eighteenth century" (Houghton, 1977b)
Sarah's Gully N40/9	2	A B	F M	25 25-28	Archaic settlement area. Burials from platform D area. (Green, pers. comm., 1977)	600 BP** 1350±50 AD (Green, 1963b)		Burial A - 1.15% Burial B - 1.30% "AD 1200-1400 period" (Houghton, 1977b)
Castlepoint N159/17	6	2 3 4 6 7 8	M CH CH M F M	20 4 7 20 28 15	Sandy beach-front dune burial area, considerably disturbed.			c1200 AD (Houghton, n.d.)
Waihora C240/283	3	II I IV	M	26	A winnowed boulder beach burial area, between the sea and the Waihora Mound and midden area. (Houghton, 1976)	Burial I 1460±310* AD Burial II 1330±70* AD (Sutton, 1976; 1979; 1980)		Burial II - 1.19% Burial I - 4.26% Burial IV - 4.20% Burial II: "death' about 1500 AD" Burials I-IV: "about 1800 AD" (Houghton, 1976)

Sample	No. of Ind.	No.	Sex	Age In Years	Site Description	Radio-carbon Date		Nitrogen Estimate
						Charcoal	Collagen	
Wairarapa N168/22 Washpool Site	5	A B C E F	F M CH M	40 40 35 40	From the crust of Layer 5 and believed to be contemporary with Level 1. They were from a fairly confined area of $10m^2$ at the southwest corner of the site. (Leach, 1976)	1191±41 AD*** (NZ 1505) (Leach, 1976)		Burial A - 1.28% Burial B - 2.88% Burial E - 1.99% Burial F - 3.44%
Wairarapa N168/27 Cleft Burials	3	M3(2) M3(3) M3(4)	CH CH CH	5 2-3 ≤1	In a cleft which consisted of an irregular gap between a pile of large boulders. Normal excavation methods were impossible. (Leach, 1976) No discernable stratigraphy was encountered. (Sutton, 1974)	1480±70 AD*** (NZ 1638) (Leach, 1976)		Burial M3(2) 4.54% Burial M3(1)[1] 3.32%
Wairarapa N168/52 Kawakawa River	1	K1	F	35	"from an eroding site on North bank of the Kawakawa River. A salvage excavation. (Sutton, 1974)	1261±66 AD*** (NZ 1315) (Leach, 1976)		1.57% c1400 AD
Long Beach	4	1 3 2	M M	20 20-22	Three and a half feet below a thick midden layer of fish, bird, mollusca remains. (Dawson, 1949) A few yards southeast of Burial 1 nearly three feet below the midden. (Dawson and Yaldwyn, 1952) "from the deposit in which Dawson and Yaldwyn excavated" (Park, pers. comm., 1979)	"...they belong to a transition period in Maori culture." "...period between the earlier settlers and the fleet Maori" is suggested in particular by the adze found with Burial 1. (Dawson & Yaldwyn, 1952) Archaic period (Leach, H. pers. comm., 1979) later Archaic period (Anderson, n.d.)		

Sample	No. of Ind.	No.	Sex	Age In Years	Site Description	Radio-carbon Date		Nitrogen Estimate
						Charcoal	Collagen	
Wairau Bar S29/7	23	6	M	25	The most important burial area occurred on the outer fringes of the hut area. Other burials were found within the hut area and in areas containing almost no traces of occupation. (Duff, 1977)	935±110 BP*** (1015±110 AD) (Y204) 850±50 BP*** (1100±50 AD) (NZ 50) (Trotter, 1975)	780±80 BP*** (1170±80 AD) (NZ 1835 human bone collagen) 590±60 BP*** (1360±60 AD) (NZ 1838 moa bone collagen) (Trotter, 1975)	"suggest a time span of some 250-300 years...1150-1450 AD" (Houghton, 1979 pers. comm.)
		12	M	25				
		13	F	20				
		14	M	22				
		16a	F	26				
		17	F	23				
		18	F	24				
		19	F	24				
		21	M	32				
		22	F	21				
		24	M	35				
		25	M	23				
		26	F	19				
		27	M	23				
		28	M	30				
		29	M	31				
		30	F	39				
		31	F	23				
		33	M	25				
		35	M	20				
		36	M	23				
		37	F	38				
		41a	F	36				