Journal of the Royal Society of New Zealand

ISSN: 0303-6758 (Print) 1175-8899 (Online) Journal homepage: http://www.tandfonline.com/loi/tnzr20

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To cite this article: M. Horrocks , M. D. Jones , R. E. Beever & D. G. Sutton (2002) Analysis of plant microfossils in prehistoric coprolites from Harataonga Bay, Great Barrier Island, New Zealand, Journal of the Royal Society of New Zealand, 32:4, 617-628, DOI: 10.1080/03014223.2002.9517712

To link to this article: http://dx.doi.org/10.1080/03014223.2002.9517712

© *Journal of The Royal Society of New Zealand,*
Volume 32, Number 4, December 2002, pp 617–628

Analysis of plant microfossils in prehistoric coprolites from Harataonga Bay, Great Barrier Island, New Zealand

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Abstract We show results of palynological and phytolith analysis of coprolites from Harataonga Bay, Great Barrier Island. Because human and dog diets may overlap considerably, the microfossil evidence does not with certainty indicate which of these two species deposited them. The coprolites give insights into prehistoric Maori agriculture, gathering of wild plants, diet, and time of year of site occupation. Gourd (*Lagenaria siceraria*) pollen found in the coprolites shows that this exotic cultigen was being cultivated in the area at the time. The presence of this taxon together with putative truffle spores in the coprolites suggests subsistence components involving both plant domestication and the gathering of wild plants.

Keywords coprolites; palynology; phytoliths; gourd (*Lagenaria siceraria*); truffles; New Zealand

INTRODUCTION

The analysis of the plant microfossil content of coprolites can yield information on the use of plants by the prehistoric local people and on the environmental conditions at the time. Most of this sort of work to date has been palynological analysis of human coprolites preserved in dry caves in the American South (e.g., Martin & Sharrock 1964; Napton & Kelso 1969; Riskind 1970; Bryant 1974a, 1975; Schoenwetter 1974; Williams-Dean & Bryant 1975; Reinhard & Bryant 1992; Gremillion & Sobolik 1996). A few other palynological studies have been carried out on coprolites from Europe (e.g., Trevor-Deutsch & Bryant 1978; Greig 1994) and New Zealand (Williams 1980; Horrocks et al. in press).

The New Zealand studies are of coprolites from a Maori settlement site at Kohika, Bay of Plenty. Horrocks et al.'s (in press) study included Williams's (1980) pollen results and also included analyses of phytoliths and diatoms. The combined results of the Kohika coprolite studies provided evidence relating to coprolite age, season of site occupation, prehistoric Maori diet, and palaeoenvironmental conditions.

In contrast to pollen analysis, phytolith analysis of coprolites has been relatively little used (e.g., Bryant 1974b; Bryant & Williams-Dean 1975; Kondo et al. 1994; Horrocks et al. in press). New Zealand studies of the phytolith component of coprolites include the Kohika study (Horrocks et al. in press), as mentioned, and Kondo et al.'s (1994) study of phytoliths in moa coprolites.

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R02002 Received 11 February 2002; accepted 23 July 2002; published 26 November 2002

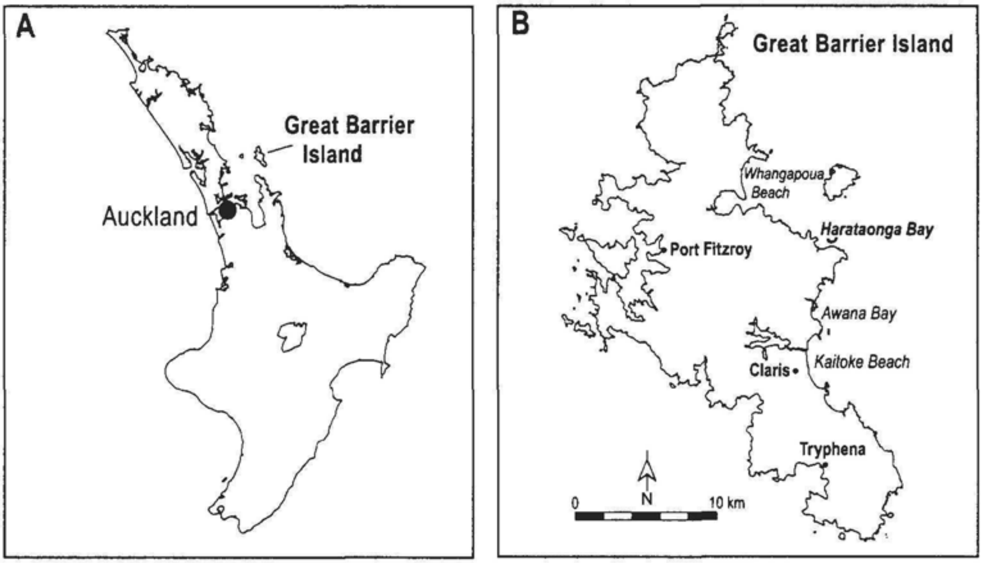

Fig. 1 **A**, North Island, New Zealand, showing location of Great Barrier Island; **B**, Great Barrier Island showing location of Harataonga Bay.

We present the results of another investigation of plant microfossils (pollen and phytoliths) in coprolites from a prehistoric Maori settlement site in New Zealand. This particular site is at Harataonga Bay on Great Barrier Island.

THE STUDY AREA AND SITE

The study area is located in a small bay, Harataonga, on the eastern coast of Great Barrier Island, northern New Zealand (Fig. 1) at 36°10′S, 175°30′E. Great Barrier Island, forming the far-eastern boundary of the Auckland region, is the largest off-shore island in New Zealand, comprising an area of c. 28 500 ha.

Harataonga Bay is c. 500 m from headland to headland and has a northerly aspect. The Harataonga watershed comprises a main watercourse that enters the sea at the western end of the beach and a much smaller watercourse at the eastern end. A dominating feature of the Harataonga shoreline is an almost unbroken line of Holocene sand dunes rising to c. 15 m above sea level. These dunes have dammed the run-off in prehuman times resulting in the development of a wetland immediately behind. The wetland is c. 2 km long in a more or less west-east direction and extends inland more than 1 km at the western end.

A pollen core from the wetland behind the dunes at Harataonga has provided a history of the local coastal environment from the mid Holocene (Horrocks et al. 2002a). Originally swamp forest then a lake, for at least the last two millenia the wetland has mainly been a Cyperaceae-dominated swamp. Large-scale Polynesian deforestation of the area was recorded in this core as occurring shortly after deposition of the 665 ^{14}C yr BP (Lowe et al. 1998) Kaharoa Tephra.

Like most of Great Barrier Island, the existing vegetation cover of the Harataonga catchment reflects a history of intense modification by prehistoric Polynesians and subsequent European settlers (Anon. 1996). Virtually all of the hill slopes of the catchment are covered in regenerating forest dominated by small trees of *Kunzea ericoides* and *Leptospermum* *scoparium*. However, one of the few small patches of coastal forest remaining on Great Barrier Island is found on top of the cliffs that form the far-eastern boundary of Harataonga Bay. The canopy of these remnant patches is dominated by *Metrosideros excelsa*, *Beilschmiedia taraire*, *B. tawa*, and *Dysoxylum spectabile*, with less common *Knightia excelsa*, *Vitex lucens*, *Corynocarpus laevigatus*, *Nestegis apetala*, and *Planchonella novo-zelandica*. Most of the swamp system at Harataonga has been drained in European times and is now pasture, although much of this is still damp underfoot with abundant Cyperaceae (*Baumea* spp.). *Leptospermum scoparium* and raupo (bulrush, *Typha orientalis*) are the dominant species in a small, undrained part of the wetland at the far-eastern end of the beach. Much of the dune system is vegetated, mainly with the sand-binding *Desmoschoenus spiralis* and *Spinifex hirsutus* and mats of kikuyu grass *Pennisetum clandestinum* (exotic) and *Muehlenbeckia complexa*.

Surfaces lived on by prehistoric Maori are buried in the dunes at Harataonga Bay. The immediate study site, from where the coprolites were excavated, is located on the dunes at the western end of the beach, in a previously identified prehistoric midden (T10/161, Law 1972). This part of the dunes is sparsely vegetated, with a mature *Metrosideros excelsa* tree directly adjacent to the site.

AGE AND ORIGIN OF THE COPROLITES

A radiocarbon age determination of material associated with the Harataonga coprolites suggests that they are at least 467 ± 60 ^{14}C years of age. This material is a carbonised twig from a short-lived species of shrub found in an organic-rich layer in the dunes immediately above (c. 5 cm) the upper pair of coprolites.

In a pre-European New Zealand context, identification of the species that deposited the Harataonga coprolites can be narrowed down to Polynesian people or their introduced, domesticated dog (kuri) (Horrocks et al. in press). However, because human and dog diets have considerable potential to overlap, there is difficulty in determining the originating animal. This difficulty may be further compounded by people eating dogs (kuri were a human food source), by dogs eating human remains, and by dogs eating human excrement. Macrofossil evidence potentially helps, but the subsamples of the coprolites that were analysed in this study did not provide any strong evidence in this respect for canine origin, such as large bone fragments (Greig 1994).

METHODS

Subsamples of c. 5 cm^3 were taken from each of four coprolites (F1, F6, F61, and F62), then sieved to remove the >130 μm fraction and split for separate pollen and phytolith extraction. Each subsample comprised fragments taken from throughout the coprolite. Pollen samples were prepared for analysis by the standard acetylation and hydrofluoric acid method (Moore et al. 1991). The pollen sum was at least 355 grains and spores. Slides were scanned and pollen types not encountered during the initial count were noted. The putative fungal spores were also studied by dispersing small portions of the subsamples in water and examining samples in lactophenol-cotton blue and in Melzers reagent.

Samples were prepared for phytolith analysis by a combination of methods given in Pearsall (2000). Organic matter was removed with nitric acid and potassium chlorate, the <5 μm fraction removed by gravity sedimentation, and phytoliths were density-separated with sodium polytungstate. The phytolith sum was at least 250 phytoliths. Sponge spicules (siliceous and therefore extracted along with phytoliths) were present but were excluded from the sum. Slides were scanned and phytolith types not encountered during the initial

Fig. 2 Coprolite F6 as excavated from the dunes at Harataonga Bay, Great Barrier Island. The scale is in cm.

count were noted. The software packages TILIA.2 and TILIAGRAPH.2 were used for construction of the pollen and phytolith diagrams (E. Grimm, Illinois State Museum, Springfield, Illinois).

The radiocarbon age determination (467 ± 60 ^{14}C yr BP, $\delta^{13}C = -24.1$) was carried out by the Rafter Radiocarbon Laboratory, Institute of Geological and Nuclear Sciences, Wellington, New Zealand (NZA-12591).

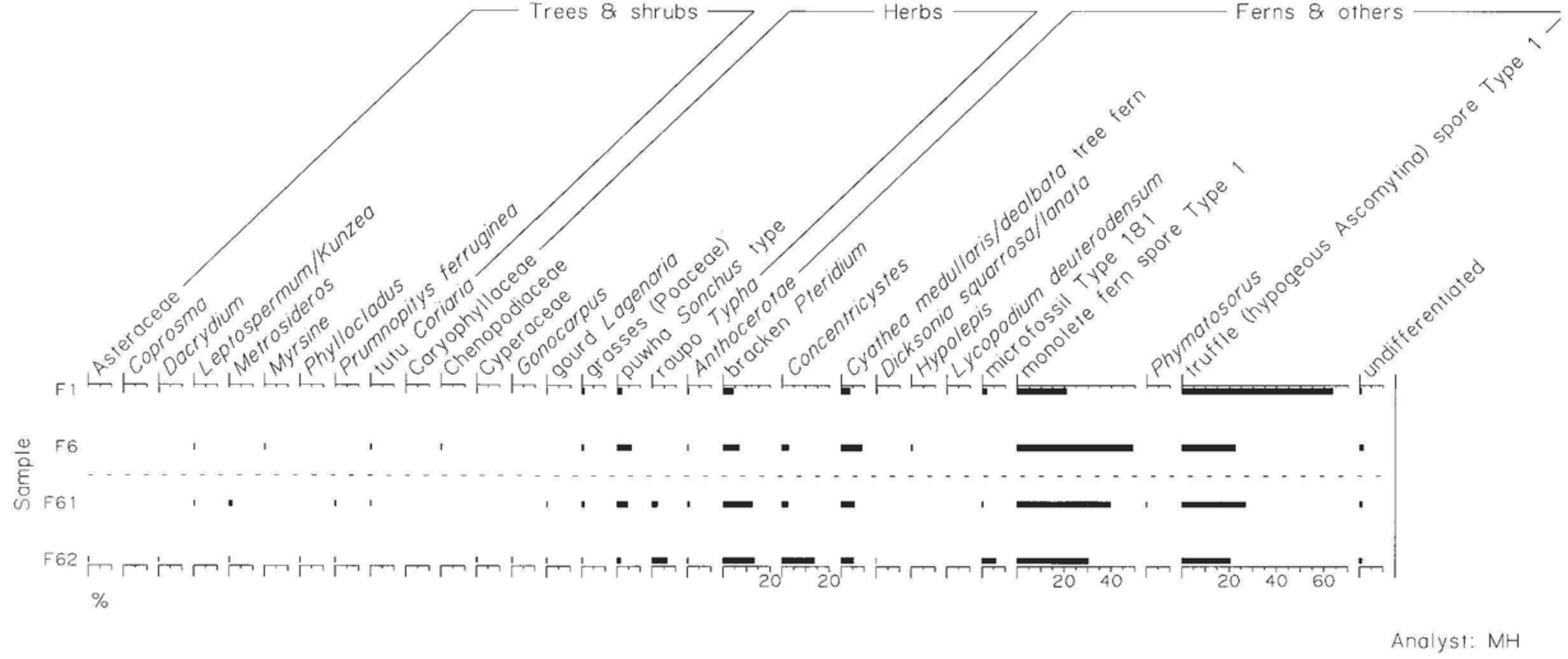

Fig. 3 Pollen and spore diagram of coprolites from Harataonga Bay, Great Barrier Island.

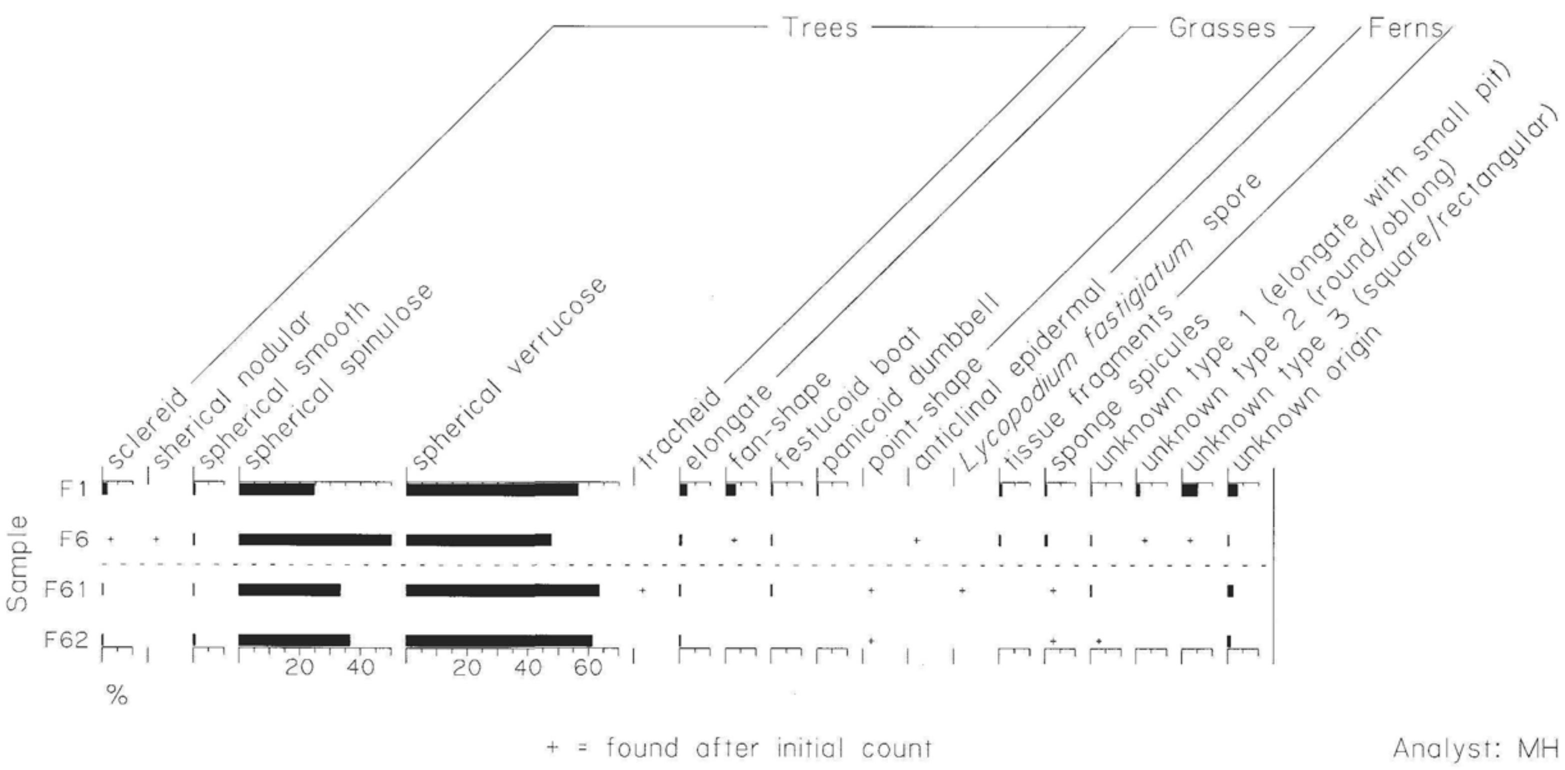

Fig. 4 Phytolith diagram of coprolites from Harataonga Bay, Great Barrier Island.

RESULTS

The coprolites analysed in this study, generally of the form shown in Fig. 2, were excavated from a 2 × 2 m test pit. They were found as two pairs directly on successive organic-rich habitation surfaces. The first pair was excavated from a depth of c. 80 cm below the surface of the dune and the samples (F1 and F6) were separated by 5 cm at the closest point. The other coprolite pair was excavated from 10–15 cm below the first pair and the samples (F61 and F62) were also separated by 5 cm at the closest point. Sterile sand between the habitation surfaces separated the two pairs of coprolites. None of the archaeological structures suggests that the lower pair of coprolites was intrusive.

Pollen analysis (Fig. 3)

Many of the pollen grains and spores in the four samples of coprolite showed signs of corrosion by bacteria and fungi. Thirteen to 19 pollen types were found. The samples within each pair show a high degree of palynological similarity. However, there are also more general similarities between the two pairs. Monolete fern spore Type 1 and a spore type tentatively identified as being from a truffle (hypogeous Ascomycotina) dominate the pollen sum of all four samples. This putative truffle spore Type 1 resembles those of the Australasian truffle genera *Labyrinthomyces*, *Dingleya*, and *Reddellomyces* but is not identifiable to any known species (Trappe et al. 1992). A representative slide of the species (#REB 1972) is deposited in herbarium PDD at Landcare Research, Auckland, New Zealand.

Cyathea tree fern type spores, bracken (*Pteridium esculentum*) spores, and puwha (*Sonchus* type) pollen were present in all samples. A trace of gourd pollen was found in Samples F61 and F62, and probably F1 (the putative gourd pollen in F1 is highly degraded). Raupo pollen was found only in Samples F61 and F62. A trace of tutu (*Coriaria*) pollen was found in Samples F6 and F61.

Algal spores of *Concentricystes* (Grenfell 1995) were found in all coprolite samples except F1. Another type of aquatic freshwater microfossil, known as Type 181 (van Geel et al. 1983; Verden et al. 2001), was found in all samples except F6.

All samples contained microscopic charcoal fragments. In F61 and F62, this charcoal included water-conducting cells (xylem) of *Leptospermum*/*Kunzea*.

Phytolith analysis (Fig. 4)

Phytoliths appeared generally well preserved in all four samples. As with the pollen, the phytolith assemblages within each pair show a high degree of phytolithic similarity. However, there are also more general similarities between the two pairs. Spherical verrucose and spinulose types dominate the phytolith sum in all four samples. Fan-shape and unknown types 2 and 3 phytoliths were found only in Samples F1 and F6. Traces of sponge spicules were found in all samples. Diatoms, which are siliceous and therefore would have been extracted along with the phytoliths if present, were not found in any of the samples.

DISCUSSION

The close similarity of the pollen and phytolith assemblages within each pair of coprolites and the close physical proximity of the respective pair members to one another may indicate that each pair was deposited at the same time by the same individual. That is, each coprolite pair may represent a single "defecation event".

The only possible clue we detect in the microfossil evidence from the Harataonga coprolites to suggest species is the small number of pollen types (13–19), which suggests that they are human. If they were canine, we might expect them to display more of a "vacuum cleaner effect", as appears to have been shown by the coprolites from Kohika (Horrocks et al. in press) which contained a generally higher number of pollen types (e.g., one had 34). That is, if canine we would probably expect the Harataonga coprolites to reflect the ingestion of more than 13–19 pollen types. This is because of the tendency of dogs, unlike humans, to be constantly sniffing and eating a variety of things off the ground. As pollen accumulates on the ground and as insect transported types spend little time in the atmosphere compared with wind transported types, ground surfaces would be expected to have a greater range of pollen types than the air above them. However, in this particular case the small number of pollen types in the Harataonga coprolites may simply be a result of poor pollen preservation. Thus, the pollen evidence does not with certainty indicate which of these two species deposited the Harataonga coprolites. This also applied to the Kohika coprolites (Horrocks et al. in press), although evidence in that case other than that provided by plant microfossils indicated that they were most likely canine. Analysis of more coprolites from a variety of New Zealand sites is clearly required to resolve this issue.

The presence of gourd pollen in the Harataonga coprolites is significant because it provides direct evidence that this cultigen was being cultivated in the area at the time. This evidence also gives a possible minimum date of 467 ± 60 ^{14}C yr BP for the introduction of this cultigen to New Zealand. Gourd is one of the half dozen (Leach 1979) cultigens introduced to New Zealand and being cultivated by prehistoric Polynesians at European contact. Reliable chronologies for these introductions are currently lacking.

Gourd pollen was also found in a sediment core from the small, undrained swamp a few hundred metres distant at the opposite end of Harataonga Beach (Horrocks et al. 2002b). This core was taken from within a few metres of a Maori living surface buried in the dunes. The gourd pollen in the core was present below the 665 ± 15 ^{14}C yr BP (Lowe et al. 1998) Kaharoa Tephra, possibly providing an earlier minimum date for the introduction of gourd to New Zealand than that given by the coprolites. However, there is uncertainty as to whether this tephra in the core was primary or had been reworked.

Gourd pollen has also been found in soil from a Maori stone mound at Pouerua (Horrocks et al. 2000), which is on the mainland c. 170 km to the north-west of Great Barrier Island. However, due to mixing of pollen in the mound, it was not established whether this pollen was pre- or post-European arrival.

If the Harataonga coprolites are human, they may also provide evidence that gourd was eaten by the people that deposited them. According to early ethnographic accounts the fruit was eaten by Maori at the stage of growth before the rind had hardened and was used as a calabash after the rind had hardened (Best 1925; Riley 1988). As gourd is insect-pollinated and therefore produces only a small amount of pollen not widely dispersed, the trace of gourd pollen in the Harataonga coprolites was possibly ingested during deliberate consumption of flowers, or as a residue on the young fruit. Many of the pollen studies of coprolites from the American Southwest show evidence for the consumption of flowers or inflorescences (e.g., Bryant 1974a, 1975; Schoenwetter 1974; Williams-Dean & Bryant 1975). On the other hand, as gourd also has separate male and female flowers and thus may have required hand pollination by gardeners (Best 1925), accidental ingestion of gourd pollen as "background" (Williams-Dean & Bryant 1975) pollen is also a possibility in this case.

The presence of truffle spores in the coprolites is also significant because it suggests foraging of wild plants. For the purposes of the discussion we assume that our identification is correct, but note that definitive proof will require finding fruit bodies (sporocarps) of the putative truffle. While three species of truffles closely resembling this unknown example have been found in New Zealand, they are all rarely found and it is probable that undescribed species occur. Most truffles are ectomycorrhizal, growing in intimate association with host plant roots and producing sporocarps in close proximity. The most likely host plants for the truffle to be associated with are species of *Leptospermum* and/or *Kunzea*. We can rule out post-depositional intrusion of the coprolites by truffles because three of the four coprolites were intact when excavated, showing no signs of tree root or truffle intrusion. Also, enclosing sediments were virtually devoid of *Leptospermum*/*Kunzea* pollen (M. Horrocks unpubl. data), strongly suggesting that plants of these genera (which tend to produce pollen locally in abundance) were absent from the immediate vicinity of the coprolites at the time of, and after, their deposition.

The high proportion of truffle spores in the coprolites strongly suggests that the sporocarps were actively ingested. If the coprolites are human, this provides direct evidence for Polynesian foraging of wild plants for food in prehistoric times. Trappe (1988) recorded that truffles have long been esteemed by various indigenous peoples around the world. Together, the gourd pollen and truffle spore evidence suggests Polynesian subsistence involving both plant domestication (i.e., farming) and the gathering of wild plants.

Plants representing some of the other pollen types found in the Harataonga coprolites—puwha type (leaves and young shoots), raupo (young shoots, roots, and pollen), tutu (petals and juice of petals), *Cyathea* tree fern (pith of the trunk, bases of the frond stems, new shoots), and bracken (rhizomes and young fronds)—were all recorded by early Europeans as being used as food by Maori (Best 1942; Crowe 1981; Riley 1988). However, the likelihood that some of the bracken spores in the Harataonga coprolites were ingested as background pollen is high (see also Horrocks et al. in press). This is because bracken may form dense, extensive stands following repeated (i.e., anthropogenic) burning of forest (McGlone 1983, 1989), and it produces abundant spores that may be well dispersed (McGlone 1982). *Cyathea* tree fern type spores are also produced in abundance and may be widely dispersed. However, although raupo and puwha type pollen may also be produced in abundance, the fact that neither of these two pollen types is particularly well dispersed makes a stronger case for the deliberate ingestion of raupo and puwha plants as food. Several of the coprolites from Kohika (Horrocks et al. in press) contained extremely high percentages of raupo and puwha type pollen, providing compelling evidence that these two taxa had been eaten by the individuals that deposited the coprolites.

The monolete fern spore Type 1 present in relatively high proportions in the Harataonga coprolites may have come from one or more of many different species of New Zealand ground ferns that have this same spore type. The habitation surfaces that the coprolites were deposited on also contain high proportions of this spore type (M. Horrocks unpubl. data), suggesting that dense stands of ground ferns grew on the surfaces. If fernland on the dunes at the time of coprolite deposition was the case, ingestion of this type of spore as background spores would have been highly likely with people (or dogs) wading through dense ferns. However, if these fern spores came from the parent plants that were eaten, they may be from either mouku (*Asplenium bulbiferm*) or paretao (*A. obtusatum*), the two species of ground fern recorded by Crowe (1981) as having been used as food (young shoots) by Maori that appear to have this spore type (Large & Braggins 1991).

As coprolites have high temporal resolution relative to many other archaeological deposits, they have potential to provide evidence for the time of year of deposition, and therefore of site occupation. The flowering times (Allan 1961) of several taxa represented in the Harataonga coprolites may provide evidence of this (Horrocks et al. in press): puwha (August–April, late winter–autumn), gourd and tutu (October–March, spring–summer), and raupo (December–January, midsummer). Schoenwetter (1974) provided pollen evidence from coprolites for the very early spring use of the Salt Cave archaeological site in the American Southeast. In the Southwest, Williams-Dean & Bryant (1975) found pollen of the same genus (cattail, *Typha latifolia*) as raupo in presumed human coprolites from the Antelope House archaeological site, and suggested that some of it could have come from eating fresh cattail heads or from eating pollen in pure form.

The presence of algal spores of *Concentricystes* and Type 181 microfossils in the Harataonga coprolites provides evidence for both diet and local palaeoenvironmental conditions. *Concentricystes* is of the Zygnemataceae (Grenfell 1995), of which most members inhabit shallow, stagnant, clean, oxygen-rich waters where they form green slimy masses ("pond scums") on the surface (van Geel & Grenfell 1996). Likewise, microfossils of Type 181 indicate stagnant, shallow, open water with eutrophic conditions (van Geel et al. 1983). This evidence gives an idea of conditions in the wetland behind the dunes at the time. It also suggests that the individuals that deposited the coprolites had been using this wetland, not surprisingly, as a source of drinking water. The Kohika coprolites (Horrocks et al. in press) also provided evidence for diet and local palaeoenvironmental conditions by the presence of wetland microfossils. However, in that case the relevant microfossils were *Myriophyllum* (an aquatic) and Cyperaceae pollen, and diatoms. The diatom evidence suggested that the Kohika drinking water, presumably from the adjacent wetland, was weakly alkaline and that aquatic plants were abundant.

The charcoal fragments in the Harataonga coprolites are most likely a result of eating food cooked over an open fire or, at least, in the presence of fire. Xylem of *Leptospermum/Kunzea* found in the charcoal of one of the coprolite pairs suggests the use of this small tree as fuel. *Leptospermum/Kunzea* is often found in abundance in disturbed areas throughout New Zealand (Allan 1961) and is favoured for its dense, slow-burning wood. The Kohika coprolites (Horrocks et al. in press) also contained this type of xylem.

As the phytolith flora of New Zealand (and elsewhere, Pearsall 2000) has been little researched compared with the pollen flora, the phytolith evidence from the Harataonga coprolites is more difficult to interpret. Like the pollen, an uncertain proportion of the phytoliths in the coprolites may be background phytoliths (see also Horrocks et al. in press). This is most likely the case with the most abundant phytolith type, found also in the Kohika coprolites (Horrocks et al. in press), spherical verrucose. This type is found in New Zealand in the leaves and wood of the tree taxa *Nothofagus* subgenus *Fuscospora* and *Knightia excelsa*, and in the rushes *Empodisma minus* and *Leptocarpus similis* (Kondo et al. 1994). None of these appear to have featured in Maori diet at European contact (Crowe 1981; Riley 1988).

A food source for the spherical spinulose phytoliths in the Harataonga coprolites is possible (see also Horrocks et al. 2002a). Spherical spinulose type in New Zealand is from the leaves of nikau palm *Rhopalostylis sapida* (Kondo et al. 1994). Early ethnographic accounts noted that the heart formed by the bases of the immature leaves was used as a food by Maori (Crowe 1981; Riley 1988).

The presence of a trace of sponge spicules in the coprolites is most likely the result of accidental ingestion as background spicules (e.g., wind-blown or in drinking water). These siliceous spicules, from the internal skeletons of marine and freshwater sponges, are often found in phytolith assemblages (Piperno 1988).

ACKNOWLEDGMENTS

This study is part of a joint research project between the Centre for Archaeological Research at the University of Auckland and the trust boards of Ngatiwai and Ngati Rehua, funded by the Foundation for Research, Science and Technology. R. E. Beever also acknowledges funding from the Foundation, and M. Horrocks also acknowledges funding from New Zealand Lotteries and Dumbarton Oaks. We thank the Department of Conservation and the West family for access to the site.

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