

# Introduced Māori Cultigens and Intestinal Parasites found in Microfossil Records from Taranaki, New Zealand

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## ABSTRACT

The study of Māori horticulture has a long history of research, starting with early ethnographic accounts, then many 100s of archaeological surveys and excavations, and within the last two decades plant microfossils. While microfossil studies are showing promise, many regions, including the North Island's west coast, have received little attention. Here we address this with microfossil analysis of archaeological substrates at Pohokura in one such region, Taranaki, to shed light on local Māori subsistence activity. Results are similar to previous pre-contact studies from other regions, showing large scale landscape disturbance by people and agricultural activity with the discovery of remains of the Māori introduced cultigens cf. *Colocasia esculenta*, *Cordyline* cf. *fruticosa*, and cf. *Ipomoea batatas*. Given the highly variable production and preservation of different plant and animal tissues, the study also illustrates the value of combining the three different types of analyses for the study of early human activity. The addition of parasitological analysis, in this case identifying eggs of *Ascaris lumbricoides* and *Toxocara canis*, parasites that could have adversely affected local people and their dogs, extends the combined approach to the realm of helminthiasis.

*Keywords:* Agriculture, Ethnobotany, Gardens, Introductions, Parasite eggs, Polynesia

## INTRODUCTION

Based largely on phytogeographic data and early ethnographic accounts, it has been established that ancestors of the Polynesians introduced a large number (70+) of plant cultigen species to the Pacific Islands (Whistler 2009). The number reduced with remoteness and latitude, with New Zealand having only six recorded species cultivated by Māori at the time of early European arrival in the late 18th century. These were *Broussonetia papyrifera* (aute, paper mulberry), *Colocasia esculenta* (taro), *Cordyline fruticosa* (tī pore), *Dioscorea alata* (uwahi, greater yam), *Ipomoea batatas* (kūmara, sweet potato), and *Lagenaria siceraria* (hue, bottle gourd) (Anderson & Petchey 2020; Best 1976).

Archaeological excavation and palynological sediment core records from throughout New Zealand document extensive deforestation commencing after Polynesia

settlement in AD 1320–1350 (Anderson 2013; McGlone 1983; McWethy *et al.* 2010; Walter *et al.* 2017). Further major deforestation occurred following European immigration commencing in the latter half of the 19th century.

From far northern North Island to the northern half of the South Island there is widespread evidence in New Zealand for Māori horticulture. This evidence can take the form of crop storage pits, ditches/drains, stone structures, terraces, borrow pits, and 'made' or modified soils. Details of this evidence are given in the works of Barber (2004), Barber and Higham (2021), Furey (2006), and Gumbley (2021). Despite extensive mapping and detailed descriptions of these features, macro-botanical remains of cultigens are limited. For example, macro-botanical remains have only been found at one site as charred *Ipomoea batatas* tubers found in a crop storage pit at Pouerua in far northern North Island (Leahy & Nevin 1993; Yen & Head 1993). This paucity is presumably largely a result of generally poor preservation of plant fossil remains.

Analysis of plant micro-remains from archaeological sites allows the direct identification of cultigens and during the last two decades a substantial body of this data has been collected. As well as traditional pollen analysis, formerly confined largely to palaeoecological studies using wetland and lake sediment cores, the addition of other plant microfossil types, notably phytoliths and starch grains, have enabled identification of specific crop species at archaeological sites (Barber & Higham 2021; Horrocks 2020; Horrocks, Dodd *et al.* 2024; Horrocks *et al.* 2022,

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2023a, 2023b; Prebble *et al.* 2019).

While an increasing number of archaeological microfossil studies of New Zealand sites have provided direct, combined microfossil evidence of specific crops (Barber & Higham 2021; Handley *et al.* 2020; Horrocks, Dodd *et al.* 2024; Horrocks *et al.* 2008, 2023a, 2023b; Prebble *et al.* 2019), the west coast of the North Island, notably the central, extensive Taranaki region, has received relatively little attention, limited to only one pollen investigation from northern Taranaki (Horrocks *et al.* 2022). The latter was part of a multi-regional study that provided evidence of the former southernmost distribution of *Cordyline cf. fruticosa* by the presence of its pollen in archaeological substrates. As the region has a generally mild climate with a good supply of fairly evenly distributed rainfall (Chappell 2014) and fertile volcanic soils, it can be expected to have been utilised by Māori for extensive, possibly intensive, horticulture following forest clearance. The importance of environmental conditions for cultivating warm season, Polynesian introduced crops is increased in New Zealand because of its location at the coolest edge of Polynesia (Barber 2004).

An archaeological investigation in conjunction with a natural gas infrastructure project at Pohokura (Q19/54), northern Taranaki, provided the opportunity to initiate combined plant microfossil research in the region (Gibb 2011) (Fig. 1). The current study uses this approach, enhanced by parasitology, to actively uncover insights into Māori horticultural practices and other activities in an under-researched region. The goal is to shed light on evidence of past vegetation and its correlation with human impacts.

## STUDY AREA AND SITES

The Taranaki region is situated on the west coast of the North Island, surrounding the volcanic peak of Mt Taranaki (Fig. 1). The subject property is located on a coastal plain at the northern end of the Taranaki ring plain. The local soils, free-draining, friable, yellow-brown loams, are of volcanic origin and generally fertile.

As the present study is focused on combined archaeo-microfossil analyses, which is novel for the region, previous regional archaeological studies are briefly summarised below. The pre-contact Māori population of Taranaki was relatively sparse, with an estimated 9750 to 13650 Māori present in the area at the time of European contact (Prickett 1983). Most of the inhabitants lived along a narrow strip of deforested coastline and established kainga, pā, and gardens, with the interior at the time still forested prior to extensive clearing, the latter of which occurred after European settlement from the mid-19th century. Walton (2000) concluded that the focus on lowland coastal settlement in the Taranaki region was largely related to the importance of fishing and gardening as food sources. This pattern of occupation is reflected

in the archaeological record, although garden sites are generally underrepresented due to limited research and the largely underdeveloped nature of the area around the subject property, which is predominantly farmland with scattered natural gas well sites and gas and methane production facilities (Gibb 2011). Further details on the regional archaeological studies are given in the works of Prickett (1983), Walton (2000), and Gibb (2011).

Late Quaternary pollen core records from wetlands in the region showed a pattern of major deforestation typical of records elsewhere in New Zealand, albeit commencing much later (1640–1675 AD vs 1320–1350 AD), with an abrupt appearance of *Pteridium esculentum* (bracken) spores and charcoal coincident with a major decrease in forest tree pollen (Bussell 1988; Lees & Neall 1993; McGlone *et al.* 1988; Wilmshurst *et al.* 2004). Despite the later deforestation, Māori were known to have been using the forested coast for hunting and gathering from at least 1300 AD.

Our sampling site descriptions, as follows, briefly summarise relevant parts of the formal site report to which we refer (Gibb 2011). Detailed, comprehensive descriptions and results are given in that work, which is freely available on the Heritage New Zealand Pouhere Taonga website ([www.heritage.org.nz](http://www.heritage.org.nz)).

The excavation (Q19/54) covered a 4.8 ha area and revealed a dense archaeological landscape with over 3000 features (Gibb 2011). These included storage pits, fire features, and postholes, with nine assemblages interpreted as feature complexes (Fig. 1). Within the area were also former wetlands where wooden tools were placed for storage and stone artefacts recovered. The total artefact assemblage contained a significant number of stone sinkers, adzes, wooden tools, and metal implements representing pre- and post-contact periods. Faunal evidence was limited.

## Sediment Core site

Two swamps (Swamp 1 and 2) that had formed from small tributaries of the Waipapa Stream were investigated, with a sediment core taken from Swamp 1. A section taken next to the core location revealed a stratigraphy of mixed topsoil, overlaying sand, then peat, then more sand, and then more peat to a depth of approximately 2 m. The swamp was in a shallow valley below Area T (Fig. 1).

## Pit Feature 2

This pit was situated in Feature Cluster 1, a group of nine large rectangular storage pits located in excavation Area A (Fig. 1). It measured 4.0 × 1.4 m across and 1.25 m deep and comprised several fill layers (Fig. 2A). A centrally placed row of five postholes was excavated in the pit base and a step had been formed at one end of the pit in line with the central axis. There was a thin charcoal lens on the pit base. Heat fractured rocks/hangi stones were recovered from the layers.

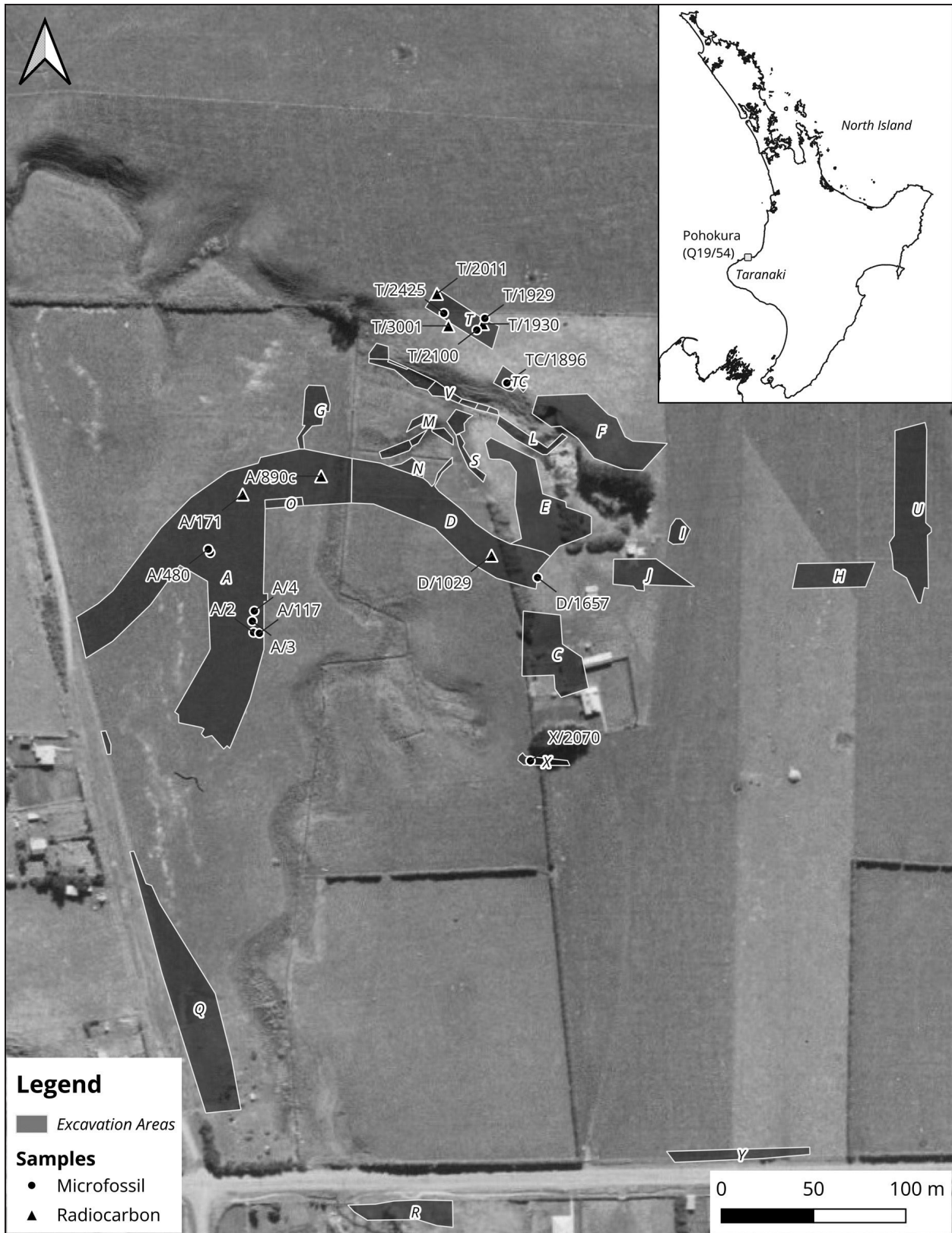


Figure 1. Map showing location of Pohokura, excavation areas, and sample locations (aerial image from Retrolens.nz SN259 Run 1782/7 dated 14/08/1950).

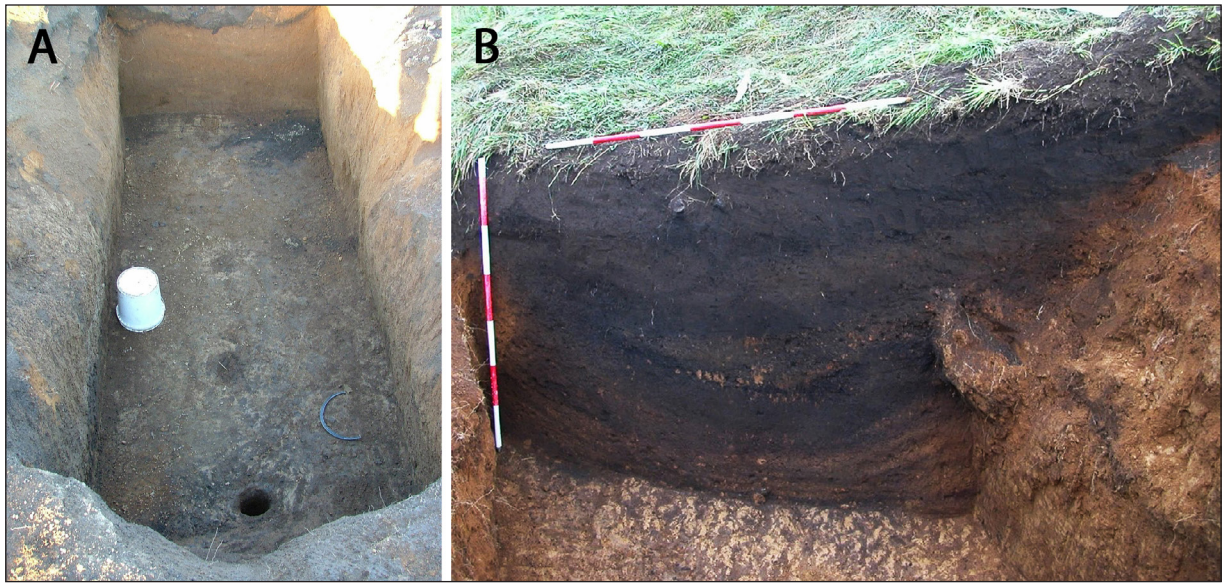


Figure 2. Pohokura Features 2 (A), 4.0 × 1.4 m across and 1.25 m deep; and 1876 (B), 2.8 × 2.3 m across and 1.1 m deep.

### Pit Feature 1876

This pit was situated in Area TC, a small area adjoining Area T immediately above Swamp 1 (Fig. 1). It measured 2.8 × 2.3 m across and 1.1 m deep and comprised several fill layers (Fig. 2B). Heat fractured rocks/hangi stones were recovered from the layers.

### Other dryland features and wetland areas (discrete samples)

Locations of remaining sampled dryland features were—Area A: 3, 4, 117, 139, 480; Area D: 1657; Area T: 1929, 2100, 2425; and Area X: 2070 (Fig. 1). The two wetland samples A and L were from swampy locations in their respective area codes.

### METHODS

Six samples were collected for <sup>14</sup>C dating. A wetland sediment core and various archaeological features were analysed for microfossils. The core was analysed for pollen only, from the following depths: 8 cm, 19 cm, and then every 10 cm from 30–100 cm. The features were analysed for pollen, phytoliths, starch and associated material, and helminth eggs. The features comprised two dryland pits, and dryland and wetland substrates (12 and two base scrape samples, respectively). Six and eight layers from the two dryland pits (Features 2 and 1876), respectively, were sampled. Microfossil graphs and photomicrography are shown in Figures 4–10 and 11–13, respectively.

### Plant microfossils

Identification of pollen, phytoliths, and starch and associated material was aided using a modern reference collection of specimens of species cultivated by Polynesians. The collection is housed at Microfossil Research Ltd., Auckland. The software package Tilia 2.6.1 was used to construct the graphical diagrams. Photomicrographs of microfossils were taken with a Canon EOS 600D camera mounted on a Nikon 400E microscope, with a blue light filter. Measurements were made using a calibrated ocular micrometer.

#### *Pollen and spores*

Samples were prepared for pollen analysis by the standard acetolysis method (Horrocks 2020; Moore *et al.* 1991). A sum of at least 200 pollen grains and spores was counted for each core sample and at least 150 for each of the other samples. Slides were scanned for pollen and spore types not found during the counts. *Basidiosporites* spores were not included in the sum. Microscopic charcoal fragments were extracted with pollen during preparation.

#### *Phytoliths and other biosilicates*

Samples were prepared for phytolith analysis by density separation with sodium polytungstate (Horrocks 2020; Piperno 2006). A sum of at least 150 phytoliths were counted for each sample and slides were scanned for types not found during the counts. Other biosilicates, in this case fragments of diatoms and sponge spicules, were not included in the sum.

## Starch and associated material, and helminth eggs

## RESULTS

Samples were prepared for combined starch and helminth analysis by density separation (1.7–1.8 specific gravity) with sodium polytungstate (David & Linquist 1982; Horrocks 2020), and presence/absence noted.

<sup>14</sup>C dating

Results for <sup>14</sup>C dating are given in Table 1 and Figure 3. The dates span from 1400 AD to modern times, likely indicating three or four distinct phases of occupation prior to European settlement. The earliest phase, represented by

Table 1. <sup>14</sup>C dates from Pohokura using short-lived plant species and marine shell with reported Conventional Radiocarbon Age (CRA) calibrated using ShCal20 (Hogg *et al.* 2020), Marine20 with  $\Delta R = -154 \pm 38$  (Heaton *et al.* 2020) using OxCal v4.4 (Bronk Ramsey 2009). \*AMS.

Lab no.	Area/Feature	Feature	Material	CRA BP	Cal AD ( $\pm 1\sigma$ )	Cal AD ( $\pm 2\sigma$ )
Wk-24678	T/1930	fireplace	charcoal <i>Coprosma</i> sp., <i>Melicytus ramiflorus</i> , <i>Schefflera digitata</i>	549 $\pm$ 35	1410–1440	1395–1455
Wk-24673	T/3001	midden	marine shell <i>Austrovenus stutchburyi</i>	676 $\pm$ 30	1545–1730	1495–1835
Wk-24676	T/2011	shallow pit base	charcoal <i>Coprosma</i> sp., <i>Pseudopanax arboreus</i>	354 $\pm$ 31	1510–1630	1485–1645
Wk-24674	D/1029	hangi	charcoal <i>Aristotelia serrata</i> , <i>Melicytus ramiflorus</i>	275 $\pm$ 35	1630–1800	1510–1805
Wk-24677	A/890c	hangi	charcoal <i>Coriaria</i> sp., <i>Melicytus ramiflorus</i> , <i>Pseudopanax arboreus</i>	261 $\pm$ 35	1645–1800	1510–1810
Wk-24675*	A/171	rua base	charcoal <i>Pteridium esculentum</i>	179 $\pm$ 30	1675–1950	1670–1950

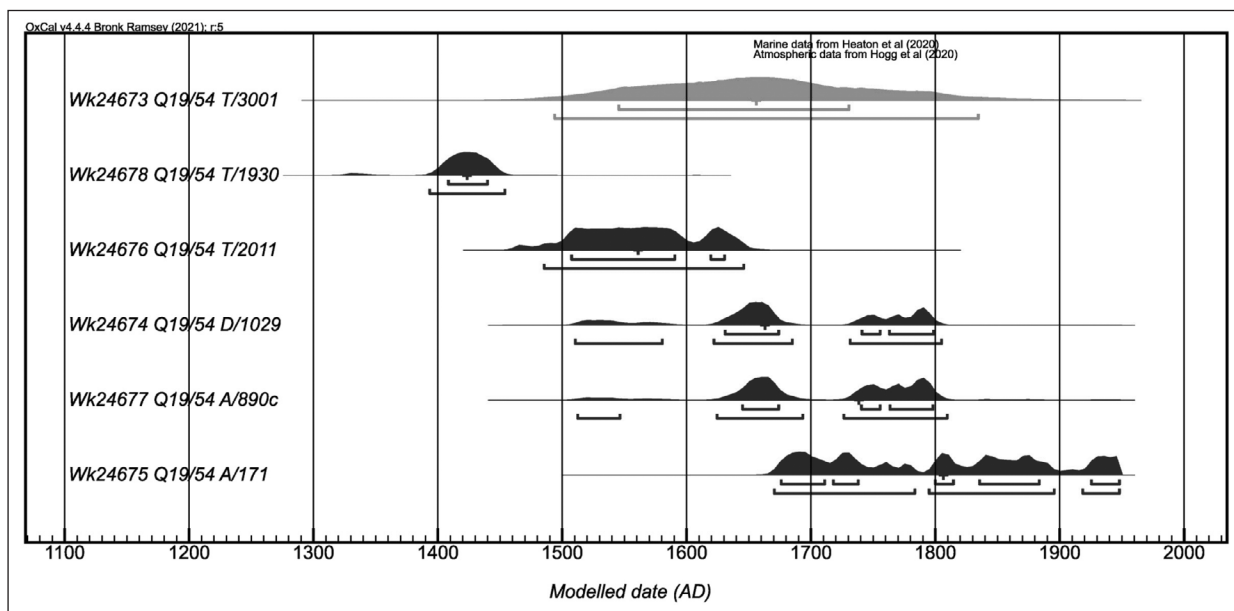


Figure 3. Calibrated <sup>14</sup>C dates from Pohokura using short-lived plant species and marine cockle using ShCal20 (Hogg *et al.* 2020), Marine20 with  $\Delta R = -154 \pm 38$  (Heaton *et al.* 2020), using OxCal v4.4 (Bronk Ramsey 2009).

fireplace T/1930 in Area T (Fig. 1), dates to approximately 1400–1450 AD. This period aligns with the end of the ‘Archaic’ era, signifying a transition towards an increased focus on horticulture among Māori populations (e.g., Anderson 2016; Bunbury *et al.* 2022). Two additional dates from Area T, of features T/2011 and T/3001 (Fig. 1), suggest a reoccupation around a century later, possibly continuing to the late 1600s AD. The microfossil samples from Area T and nearby TC/1896 are more likely related to the later dates from T/3001 and T/2011.

Dates from Areas A and D (Fig. 1) overlap with the later phase of occupation in Area T. However, the trimodal distribution from the calibration of the dates Wk-24674 and Wk-24677, giving date ranges in the 1500s, mid-1600s, and mid-late 1700s AD (Fig. 3), introduces some complexity. The results of the remaining date from Area A (A/171 Wk-24675) make it plausible that these areas of the site, A and D, were occupied from the mid-1600s to the end of the 1700s AD. This date range seems applicable to the microfossil samples from areas A and D, although the dates from Area A are from features 70–90 m north of the microfossil samples from pits A/2–A/4.

The microfossil sample from Area X to the south is not clearly associated with any of the dates.

### Sediment core profile

The core comprised sandy peat. Abundant charcoal fragments were observed in all samples. The pollen and spore assemblages of the lower half of the core were dominated by spores of *Pteridium esculentum* (bracken), *Cyathea*, and ferns with monoete spores (Fig. 4). These spores decreased in the upper half of the core as pollen of Poaceae (grasses), *Sochus/Taraxacum* (puha/dandelion) type (Fig. 4, Fig. 11A), Cyperaceae (sedges), and *Typha orientalis* (raupo), increased. *Coriaria* sp. (tutu) pollen and hornwort (Anthocerotopsida) spores were observed throughout the core profile, as was pollen of European introduced plants, namely *Pinus* (pine) and *Plantago lanceolata* (narrow leaved plantain). Pollen of Cupressaceae (cypresses), probably also introduced, was present in the upper part of the core. Pollen of Māori introduced *Cordyline* cf. *fruticosa* was identified in the samples from 50 and 30 cm depths (Table 2; Fig. 11B).

### Feature A/2 (pit layers profile)

Abundant charcoal fragments were observed in all samples. The pollen and spore assemblages were variably dominated by *Pteridium* and *Cyathea* spores (Fig. 5). A large amount of Poaceae pollen was found in Layer G/H. *Coriaria* and *Sonchus/Taraxacum* pollen and Anthocerotopsida spores were also observed in several samples. Pollen of *Dactylanthus taylorii* (dactylanthus) was found in Layer G/H sample and of European introduced *Plantago lanceolata* in the top layer sample.

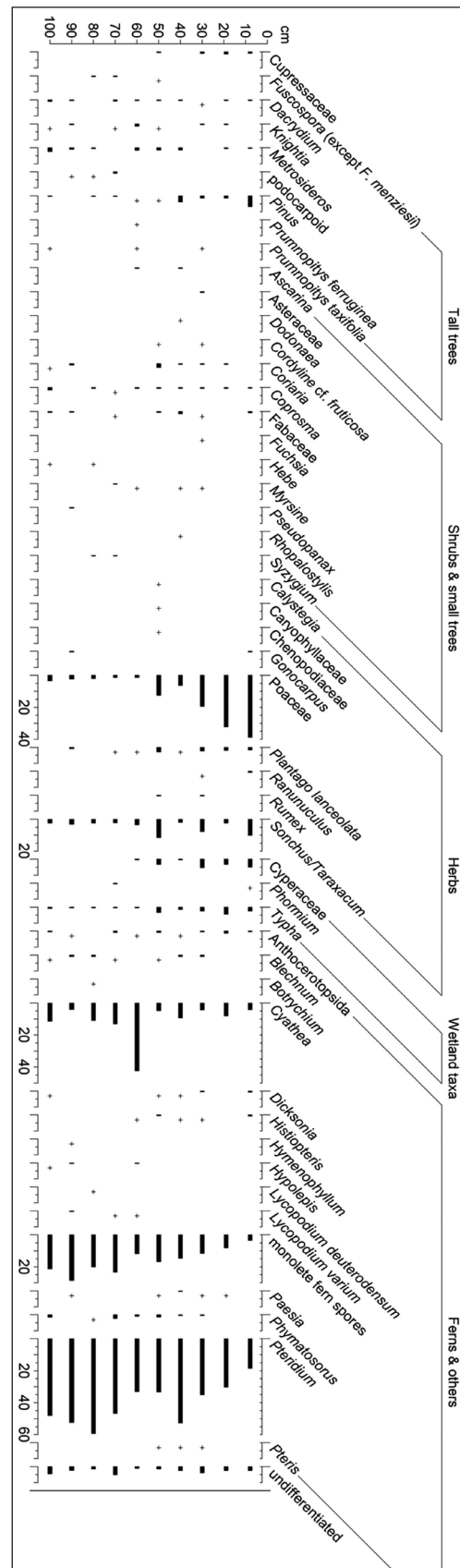


Figure 4. Pollen and spore percentage diagram of core from Pohokura (+ = found after count).

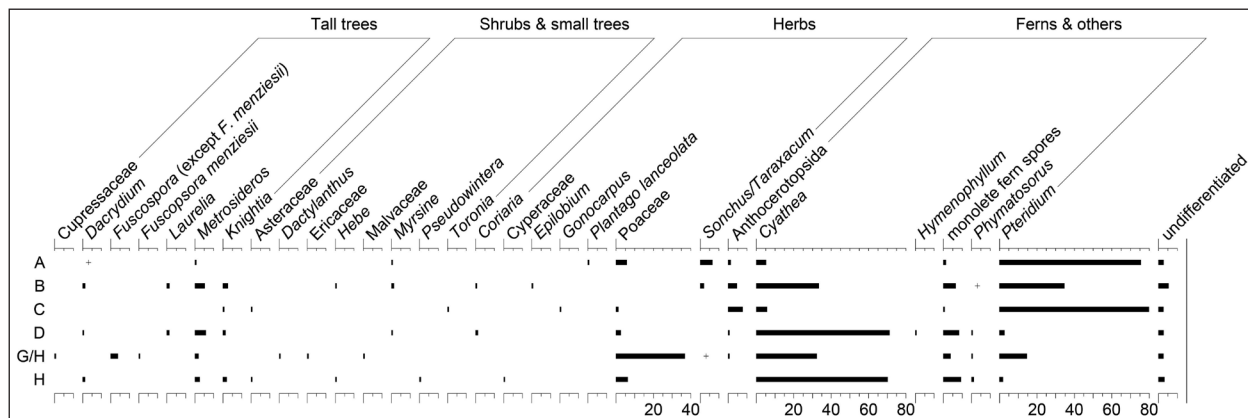


Figure 5. Pollen and spore percentage diagram of Feature 2, Pohokura (+ = found after count).

The phytolith assemblages were variably dominated by tree and shrub phytoliths, mostly *Rhopalostylis sapida* (nikau), with some spherical nodular and spherical verrucose types (Fig. 6). A large amount of Poaceae rondel phytoliths was observed in Layer G/H. Other biosilicates, in this case fragmented sponge spicules, were present in small amounts in several samples.

Two types of starch were identified in this profile. The first type, observed in Layer H, comprised individual grains and remains of amyloplasts consistent with the tuberous root of cf. *Ipomoea batatas* (Table 2; Fig. 11F–I). The second type, found in Layers D and G/H, comprised amyloplast remains consistent with the corm of *Colocasia esculenta* (Table 2; Fig. 11J, K; Fig. 12A).

**Feature TC/1876 (pit layers profile)**

Abundant charcoal fragments were observed in all samples. The pollen and spore assemblages of the lower six of

the eight samples were dominated by pollen of *Sonchus/Taraxacum*, peaking up to almost 80% in the central part of the profile (Fig. 7). The upper two samples were dominated by *Pteridium* and *Cyathea* spores. Pollen of *Coriaria* and Brassicaceae (Fig. 11C) and spores of Anthocerotopsida were also observed in several samples. In addition, spores of cf. *Basidiosporites* sp. were observed in the samples, in very high concentrations in the lowermost five samples, peaking in the central part of the core then reducing to very low concentrations towards the top sample (Fig. 7, Fig. 11A).

The phytolith analysis showed an increase in tree and shrub phytoliths, mostly *Rhopalostylis*, at the expense of Poaceae rondel phytoliths (Fig. 8). Other biosilicates, in this case fragmented diatoms and sponge spicules, recorded small amounts in several samples.

One type of starch was identified in this profile. This type, found in Layers E, G, and H, comprised amyloplast remains consistent with the corm of *Colocasia esculenta* (Table 2; Fig. 11J, K; Fig. 12A).

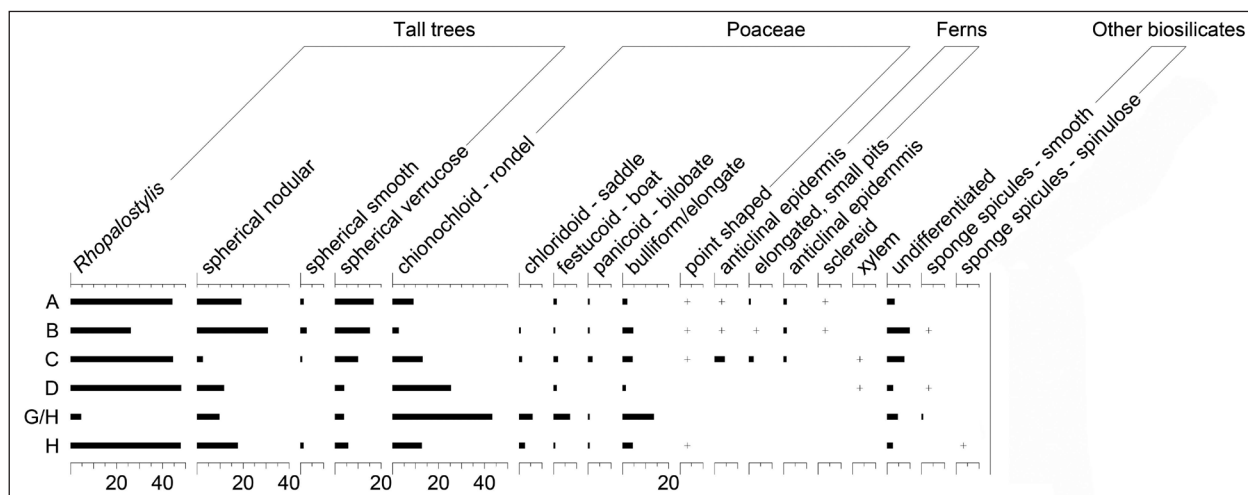


Figure 6. Phytolith percentage diagram of Feature 2, Pohokura (Other biosilicates not included in sum, + = found after count).

Table 2. *Cultigen material and helminth eggs from Pohukura.*

	<i>Cf. Colocasia esculenta</i>	<i>Cordyline cf. fruticosa</i>	<i>Cf. Ipomoea batatas</i>	Helminth eggs
<b>Core</b>				
30 cm		pollen		
50 cm		pollen		
<b>Feature 2</b>				
D	starch			
H			starch	
G/H	starch			
<b>Feature 1876</b>				
E	starch			
G	starch			
H	starch			
<b>Others</b>				
F3	starch			
F4	starch			
117	starch			
139	starch			
480	starch			<i>Toxocara canis</i>
1929	starch			<i>Ascaris lumbricoides</i> <i>Toxocara canis</i>
2100			starch	
Wetland A	starch, raphides			
Wetland L	starch, raphides		starch	

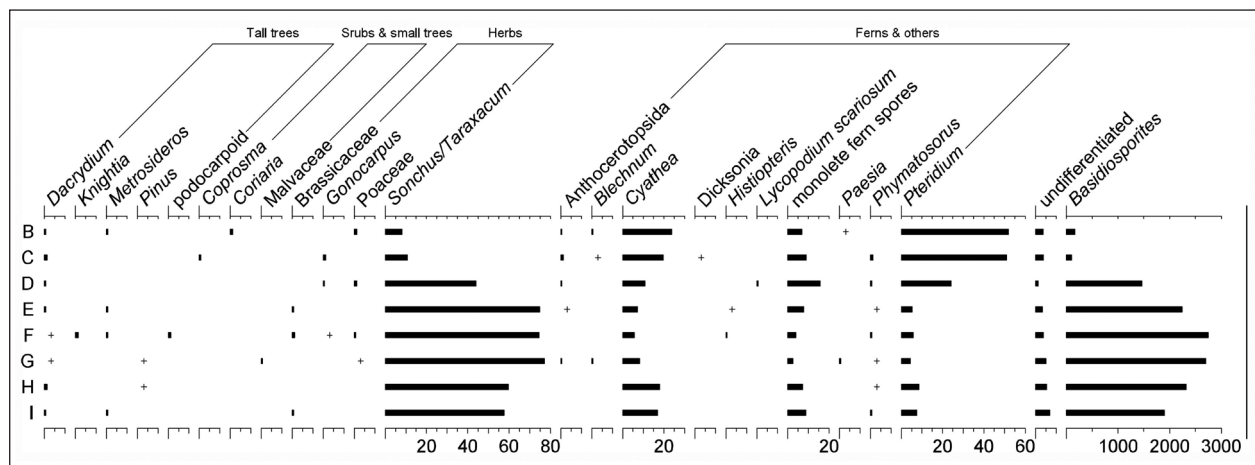


Figure 7. Pollen and spore percentage diagram Feature 1876, Pohokura (*Basidiosporites* not included in sum, + = found after count).

### Other dryland features and wetland areas (discrete samples)

The pollen assemblages were variably dominated by *Cyathea* and *Pteridium* spores (Fig. 9). Poaceae pollen recorded high values in Samples 4 and 2070. *Typha* pollen and moderate amounts of Cyperaceae pollen and *Blechnum* spores was observed in the wetland samples (A and L). A trace of European introduced *Pinus* pollen was found in each of Samples 4 and 1657.

The phytolith assemblages were variably dominated by tree and shrub phytoliths, mostly *Rhopalostylis* (Fig. 10). Considerable amounts of Poaceae rondel phytoliths were found in about half the samples, with the highest amounts in Samples 4 and 2070. Other biosilicates, in this case fragmented diatoms and sponge spicules, were observed in small amounts in several samples.

Two types of starch were identified in the samples. The first type, found in Samples 2100 and Area L, comprised individual grains and remains of amyloplasts consistent



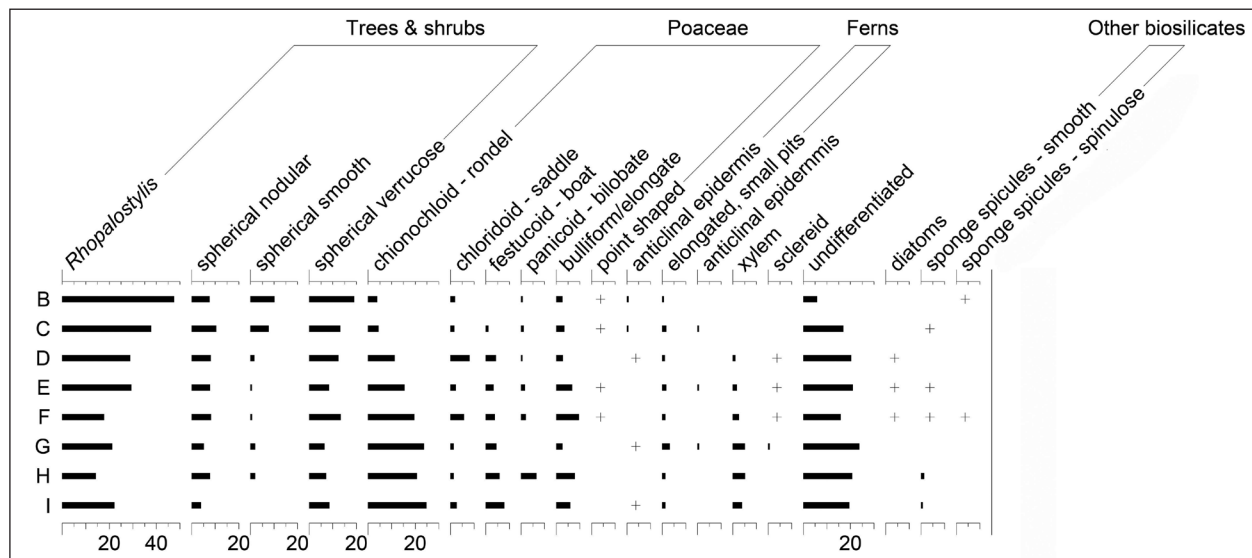


Figure 8. Phytolith percentage diagram of Feature 1876, Pohokura (Other biosilicates not included in sum, + = found after count, ++ = present).

with the tuberous root of cf. *Ipomoea batatas* (Table 2; Fig. 10, Fig. 11F-I). The second type, found in eight samples, comprised amyloplast remains consistent with the corm of *Colocasia esculenta* (Table 2; Fig. 11J, K; Fig. 12A). Also consistent with the latter species, storage idioblast (an isolated cell differing from neighbouring tissues) remains containing long thin raphides (a type of calcium oxalate crystal) were found in the two wetland area samples (Table 2; Fig. 12B).

Two types of helminth egg were identified in this study. The first type, found in sample 1929, is attributable to *Ascaris lumbricoides* (Table 2; Fig. 10, Fig. 12C). Depending on their stage of fertility, *A. lumbricoides* eggs are 45–90 µm long, with a thick shell and external mammillated layer. The other egg type, found in the same sample and Sample 480, is attributable to *Toxocara canis* (Table 2; Fig. 10, Fig. 12 D, E). These eggs are 75–90 µm in diameter, with a characteristic thick wall and pitted surface.

## DISCUSSION

### Evidence for site occupation, vegetation, and forest clearance

Māori settlement at Pohokura/Waipapa was related to topography, with most features located on ridgetops and knolls, and the gentle slopes on their upper edges (Gibb 2011). Pre-contact Māori pit and fireplace features were mostly situated on the ridge top and north-east corner of Area A and in Areas T, E, and D (Fig. 1, Table 1). These four areas are all located above the Waipapa Stream and the more recent swamp that formed there. Fire-cracked/hangi stones were recovered from generally throughout the analysed pit fills, indicating that site occupation continued

throughout the period of pit fill deposition.

The radiocarbon dates indicate the earliest Māori settlement at Pohokura/Waipapa as 1395–1455 AD, with further pre-contact activity ranging through to the 17th and 18th centuries (Gibb 2011) (Table 1). Six periods of settlement are interpreted from the assembled data stretching from prehistory up until the mid-20th century. This is based on <sup>14</sup>C dates, relative dating of inter-cutting features, spatial pattern, feature type and dimensions, and the comparison of depositional histories of soil accumulation within large archaeological features. The first is an early pre-contact period dating to the early to mid-15th century AD (Area T), followed by a middle pre-contact period dating from the 16th to early 17th century AD (Areas A, D, and T), then a late pre-contact/early contact period from the 1760s to 1832 AD. The final three periods are post-contact.

The *Pteridium*, *Cyathea*, Anthocerotopsida, and monolete fern spores, and pollen of *Coriaria* and *Sonchus/Taraxacum*, coincident with the charcoal and a paucity of pollen of forest trees in the samples, reflect a highly disturbed landscape largely cleared of forest by people (Fig. 4–9). *Pteridium* is an invasive, indigenous ground fern with widely dispersed spores, common in New Zealand pollen spectra since human settlement and almost always associated with large-scale, repeated burning of forest by early Māori (McGlone 1983), and subsequently Europeans. It can form tall, dense stands over extensive areas, and its rhizome was commonly harvested as a food by Māori (Best 1976). *Cyathea* tree ferns and *Coriaria* shrubs/small trees commonly colonise bracken fernland, with the former preferring gullies (Wardle 2002). Monolete spores, bean-shaped and difficult to differentiate, are produced by many of New Zealand's numerous native species of ground ferns and often reflect forest disturbance. *Sonchus*

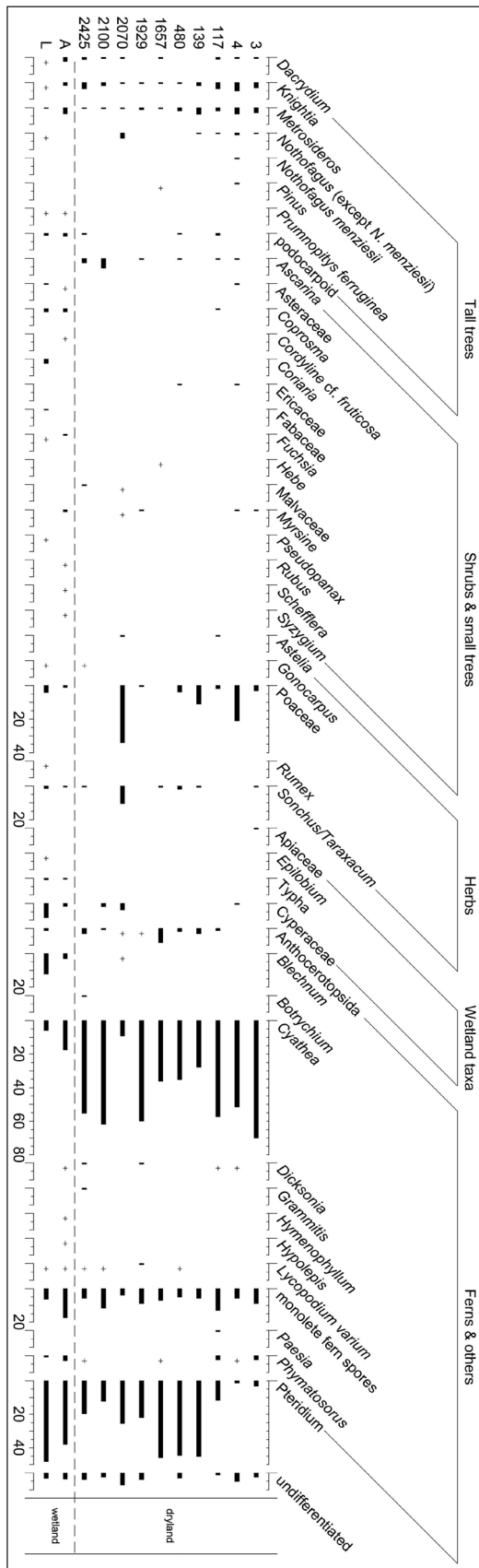


Figure 9. Pollen and spore percentage diagram of dryland features and wetland areas, Pohokura (+ = found after count).

(puha) is native to New Zealand, while *Taraxacum* includes European introduced *Taraxacum officinale* (dandelion). *Sonchus/Taraxacum* largely comprises a small number of invasive herbaceous species following disturbance and pollen of the two genera can be difficult to differentiate. Leaves and shoots of *Sonchus/Taraxacum* were cooked and eaten by Māori (Andersen 1907; Best 1976; Colenso 1880; Crowe 1997). The Anthocerotopsida spores also reflect landscape disturbance; this plant division comprises small inconspicuous plants that colonise freshly exposed soils (Wilmshurst *et al.* 1999).

The traces of pollen of European exotics, namely *Pinus* trees and the invasive herbaceous weed *Plantago lanceolata*, throughout the full depth of the wetland sediment core indicates that different aged material has been mixed in the profile due to erosion, bioturbation, or mechanical disturbance, also evidenced by the sandy nature of the peat (Fig. 4). The increase in pollen of the wetland taxa *Typha* and *Cyperaceae* in the upper section of the profile suggests that the wetland developed mainly as a result of human disturbance of the local landscape, with increased hill slope erosion restricting stream flows. The large increase in *Poaceae* pollen in the upper section reflects increased farming of European introduced pasture grasses in the region. Traces of *Pinus* pollen in a few of the other samples could also be a result of mixing of different aged material.

The large amounts of tree phytoliths in some of the samples in this study, notably *Rhopalostylis sapida* (from the fronds) and spherical nodular and verrucose types, could seem at odds with the generally small or negligible amounts of tree and shrub pollen (Figures 4–9). This difference can be explained by the tree and shrub phytoliths likely in large part reflecting the pre-settlement forest (Kondo *et al.* 1994). Phytoliths, being non-organic, can accumulate in substrates for much longer than pollen and spores, due to their generally greater resistance to decay. Another explanation could be that the large phytolith amounts are in part from burned tree material in the samples, especially where some of the tree and shrub phytoliths could be from wood and *R. sapida* fronds used as cooking fuel.

*Rhopalostylis sapida* phytolith type is one of the few types that can be identified to species level in the New Zealand phytolith flora. In the North Island *R. sapida* is found in coastal and adjacent lowlands, and in abundance only near coasts, often persisting after forest clearance (Macphail & McQueen 1983). The spherical verrucose type of phytolith is generally from the wood, twigs, and leaves of several native trees, namely *Beilschmiedia tawa*, *Knightia excelsa*, and *Metrosideros* spp. (Kondo *et al.* 1994). Little is yet known about the taxa that produce spherical nodular phytoliths. Other biosilicates identified in some samples, in this case diatoms and sponge spicules, reflect the regional coastal or local wetland environments (Figures 5–8).

The *Dactylanthus* pollen in Sample 113 is rare in pollen spectra and is from a highly unusual plant—New Zealand’s

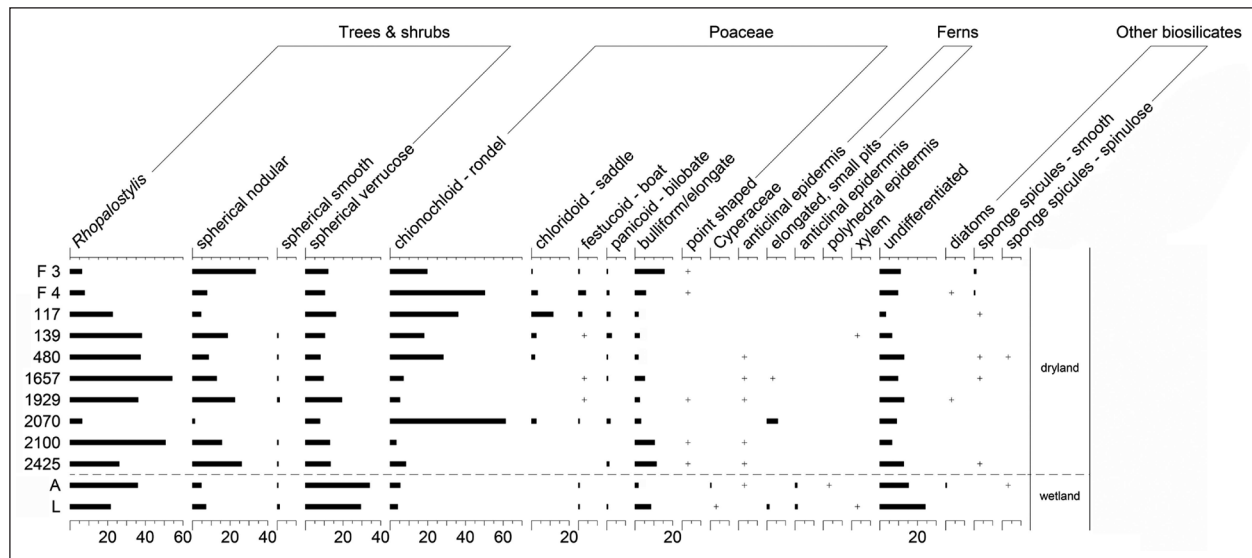


Figure 10. Phytolith percentage diagram of dryland features and wetland areas, Pohokura (Other biosilicates not included in sum, + = found after count, ++ = present).

only fully parasitic flowering plant (Fig. 8). *Dactylanthus* has no green leaves or roots of its own and grows as a root-like stem attached to the root of a host tree (Ecroyd 1996). Many species of trees may be hosts. In response, the host root moulds into the shape of a fluted wooden rose, which gives the plant its previous common name of wood rose. It is through this placenta-like attachment that *dactylanthus* draws its nutrients. The Māori name for this plant, ‘pua o te reinga’ (flower of the underworld), alludes to the way its flowers emerge from below ground. It is pollinated by the short-tailed bat. *Dactylanthus* is currently in serious decline and classified as endangered.

The large amounts of *Sonchus/Taraxacum* type pollen in the Feature 1876 pit (up to almost 80%) are very unusual in New Zealand pollen spectra (Fig. 7, Fig. 11A). Possible explanations for the abundance of this pollen type in the pit are that it was used for cooking (*Sonchus* shoots), or to dump food or garden waste, or perhaps there is human or dog faecal material involved. Further evidence that the pit is associated with human food remains is the Brassicaceae pollen in several samples (Fig. 7, Fig. 11C). If the Brassicaceae pollen was a result of gathering by people, it could be from *Rorippa palustris* (poniu, marsh cress), the cooked leaves of which were eaten by Māori (Best 1976). In a previous microfossil study, Māori dog (kuri) coprolites from Bay of Plenty showed similarly large amounts of *Sonchus/Taraxacum* pollen and also small amounts of Brassicaceae pollen, a result of scavenging or being fed meal scraps (Irwin et al. 2004).

Another unusual result from the Feature 2 pit is the very high concentrations of spores of a type of fungus (fungi are not plants) (Fig. 6, Fig. 11A). Fungal spores are extracted with pollen and often noticed on the prepared slides, usually in small concentrations. The spores in this

case are most like those of the *Basidiosporites* Elsik 1968 (Macphail & Stevenson 2004). This saprophytic (obtaining nourishment from dissolved organic material, including dung) taxon has a small thin-walled ovoid spore with a simple apical pore. This evidence of high saprophytic activity is a result of decay of organic material, supporting the pollen evidence that the pit is associated with human food remains. The similarity of the up-profile spore concentration curve with that of the *Sonchus/Taraxacum* pollen suggests that the two are related.

### Botanical evidence for horticulture

The food plants cf. *Colocasia esculenta*, *Cordyline* cf. *fruticosa*, and cf. *Ipomoea batatas*, are part of the group of introduced species cultivated by Māori. Almost all the plant species identified as introduced to Polynesia by early colonisers are native to various regions within the broad area from Africa to Melanesia (Whistler 2009). The native range of *C. esculenta* is Southeast Asia, and that of *C. fruticosa* is probably ‘between the Himalayas and northern Australia’ (Whistler 2009:98). *Ipomoea batatas* is one of the few exceptions. This species originated in South America, its introduction to the Pacific a result of Polynesian contact (Hather & Kirch 1991).

Descriptions and photomicrographs of modern reference pollen, and starch and associated material of *Colocasia esculenta*, *Cordyline fruticosa*, and *Ipomoea batatas* are given in the works of Barber & Higham (2021), Horrocks, Dodd et al. 2024, Horrocks et al. (2004, 2007, 2012a, 2012b, 2022, 2023a, 2023b, 2023c), Horrocks & Weisler (2006), Loy et al. (1992), Reichert (1913), Seidemann (1966), and the Australasian Pollen and Spore Atlas (apsa.anu.edu.au/). Details of the macro- as well as micro-remain finds of these

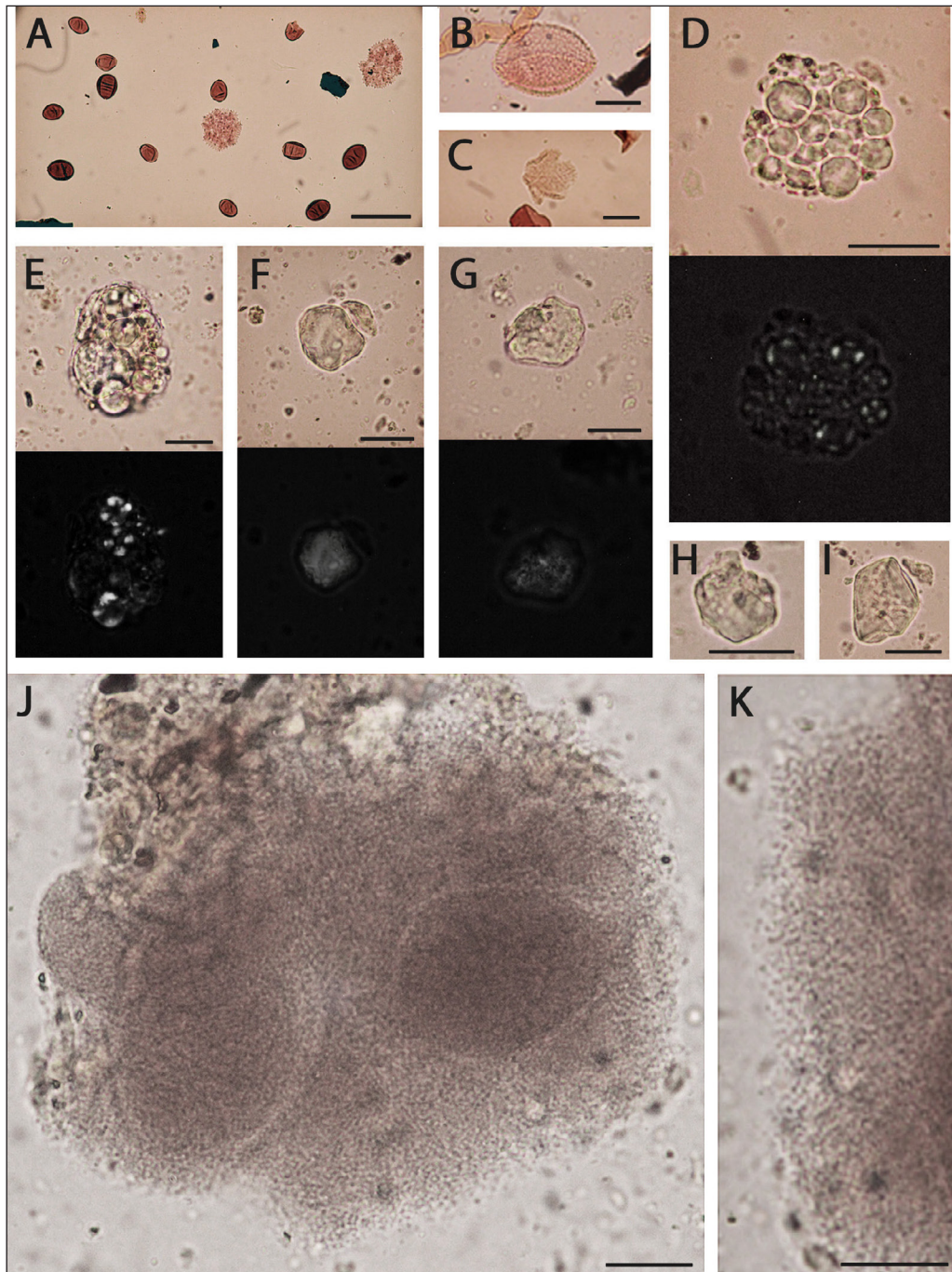


Figure 11. Selected plant microfossils from Pohokura. Sample labels in brackets; mounted in glycerol jelly; A 400 $\times$ , remainder 600 $\times$ ; black background: cross-polarized light; scale bars: 20  $\mu\text{m}$ . A (1929) two *Sonchus/Taraxacum* pollen grains among densely concentrated cf. *Basidiosporites* sp. spores. B (30 cm) *Cordyline* cf. *fruticosa* pollen grain, showing characteristic thick walled, granular, double layered exine, finely beaded in cross-section. C (1876) damaged Brassicaceae pollen grain. D, E (Area L, 117, respectively) clumps of cf. *Ipomoea batatas* starch grains, showing central Maltese cross in cross-polarised light (cf. Figure 13A). F–I (2100) degraded cf. *Ipomoea batatas* starch grains showing surficial roughening, discoloration (from normal smooth and opaque grey to shades of yellow/amber/brown starting at the edges) and reduced visibility in cross-polarised light. Characteristic pressure facets and ‘vacuoles’ visible in some grains, the latter seen as an approximately central white or dark grey/black dot. J, K (Area L), cf. *Colocasia esculenta* corm amyloplast remains showing characteristic densely packed, sharply angular, tiny ( $\leq 4 \mu\text{m}$ ) starch grains (hundreds-thousands), and the central vacuole seen as a dark grey/black dot giving an overall grainy appearance (cf. Figure 13B). Cell wall and/or amyloplast membrane shapes visible as thin curved lines. K shows lower edge of J in higher magnification to better show these tiny grains.

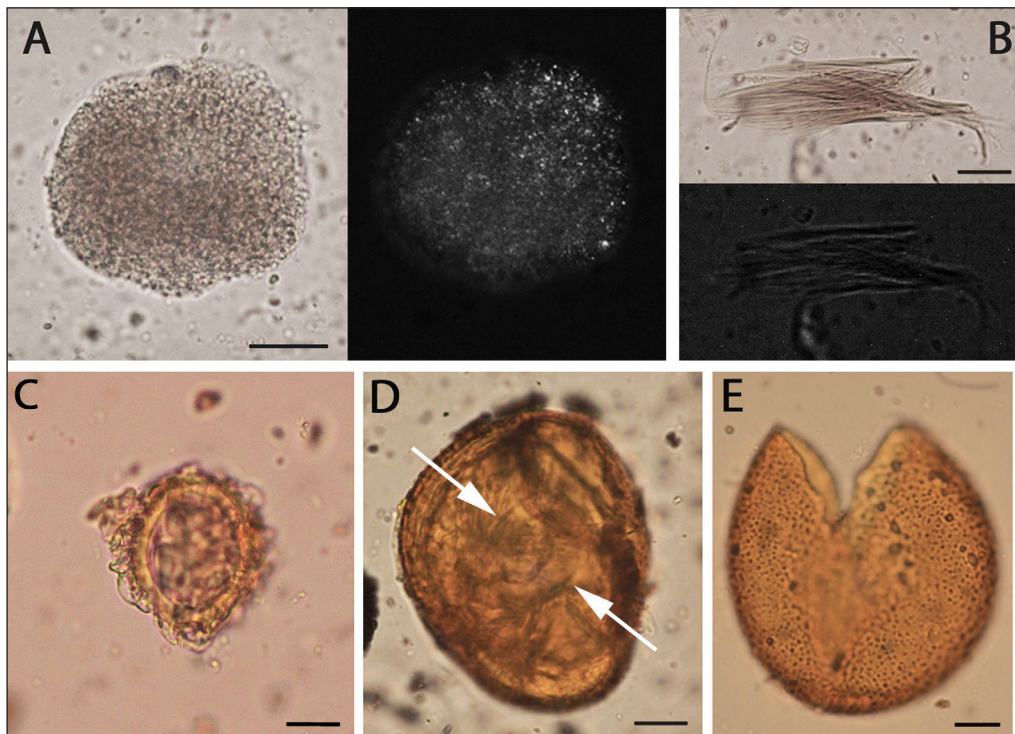


Figure 12. Selected plant and parasite microfossils from Pohokura. Sample labels in brackets; mounted in glycerol jelly; 600 $\times$ ; black background: cross-polarized light; scale bars: 20  $\mu\text{m}$ . A (Area L) cf. *Colocasia esculenta* amyloplast with Maltese crosses visible in cross-polarised light. The enclosing membrane is not preserved. B cf. *Colocasia esculenta* idioblast remains comprising densely clumped ‘whisker’ raphides, with faint visibility preserved in cross-polarised light (cf. Fig. 13C). C (1929) *Ascaris lumbricoides* egg, showing characteristic external mammillated layer, somewhat abraded in this example. D, E (1929) *Toxocara canis* eggs, showing characteristic thick shell and pitted surface. D has a coiled larva inside, visible in optical section (arrows).

species elsewhere in New Zealand and Polynesia are given in the works of Horrocks *et al.* (2022, 2023a). As ancient starch analysis is a relatively recent microfossil technique (cf. pollen and phytoliths) with new methods still developing (e.g., Horrocks *et al.* 2023c), we take a cautious approach with identification.

The identification of fossil starch in this study is based on starch grain morphology. All other Māori-introduced starch-rich cultigens can be ruled out on this basis. New Zealand has at least two native Araceae (to which *Colocasia esculenta* belongs) species (*Lemna* sp., species disputed, and *Wolffia australiana*). These are very small, free-floating, aquatic duckweed plants without specialized starch storage organs (Moore & Edgar 1976). Although New Zealand has several endemic species of the family to which *Cordyline fruticosa* belongs (Asparagaceae), the works of Cranwell (1953, 1962) and Horrocks *et al.* (2022) show that *C. fruticosa* pollen can be differentiated from those species’ pollen.

*Colocasia esculenta* corm amyloplasts, containing up to hundreds-thousands of densely packed starch grains, are ovate, up to approximately 185  $\mu\text{m}$  in diameter, with very thin enclosing double membranes (Fig. 11J–K, Fig. 12A, Fig. 13B). Starch grains are spherical, appearing sharply angular,

and mostly <4  $\mu\text{m}$  in diameter. The central vacuole often appears as a dark gray/black dot. This type of starch grain is relatively tiny, allowing ready differentiation from starch grains of all other starch cultigens introduced to the Pacific Islands. This generally <4  $\mu\text{m}$  grain size is near the limits of light microscopy, so grains are best identified in archaeological samples as groups, i.e., masses and amyloplasts or fragments thereof. In archaeological soils and sediments, *C. esculenta* amyloplasts are commonly fragmented and without visible membrane tissue. Occasionally though, cell wall and/or membrane outlines can be seen in starch masses as thin curved lines (Fig. 11J, Fig. 13B).

*Colocasia esculenta* produces several types of raphide idioblasts, based on length and thickness of the enclosed raphides (Loy *et al.* 1992; Sunell & Healy 1979). The idioblast remains preserved in this case, found in the two wetland area samples along with *C. esculenta* starch, comprised bundles of long thin ‘whisker’ raphides (Loy *et al.* 1992) with the cell walls/membranes apparently not preserved (Fig. 12B, Fig. 13C).

Starch grains of the tuberous root of *Ipomoea batatas* are spherical to sub-spherical, often bell-shaped, up to approximately 25  $\mu\text{m}$  in diameter with some larger and

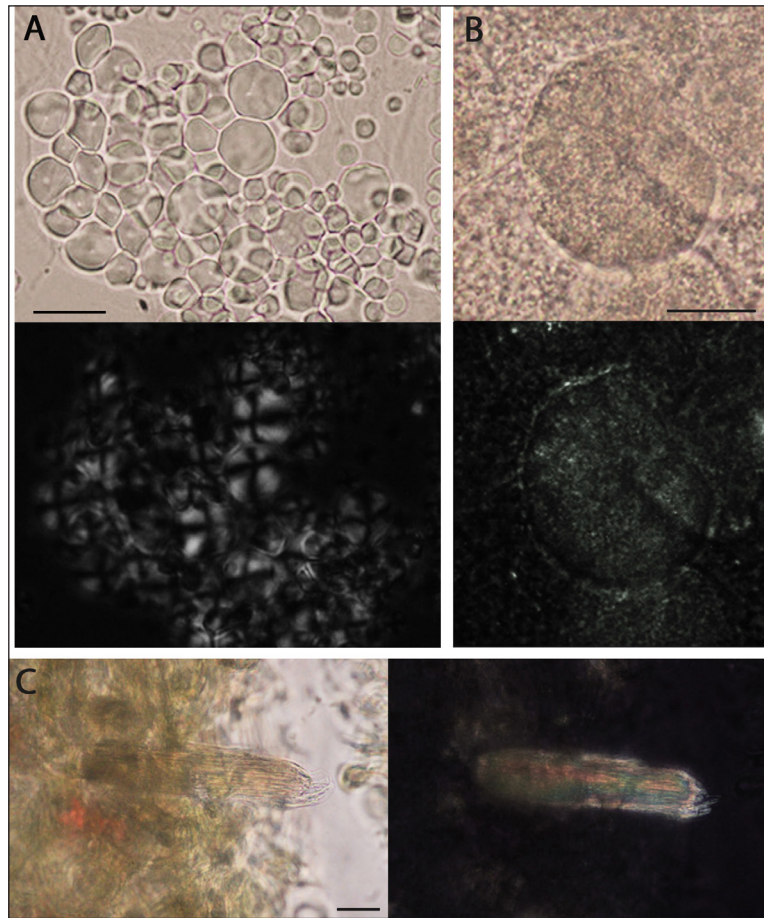


Figure 13. Modern reference *Ipomoea batatas* and *Colocasia esculenta* material. Mounted in glycerol jelly; 600 $\times$ ; black background: cross-polarized light; scale bars: 20  $\mu\text{m}$ . A Starch grains of *I. batatas* tuberous root, showing characteristic facets, central 'vacuole', and central Maltese cross in cross-polarised light. B *C. esculenta* corm amyloplast, with characteristic densely packed, tiny ( $\leq 4 \mu\text{m}$ ), sharply angular starch grains (hundreds-thousands), and the central vacuole seen as a dark gray/black dot giving an overall grainy appearance. Tiny Maltese crosses visible in cross-polarised light. C *C. esculenta* leaf parenchyma with idioblast inclusion, the latter showing densely packed raphides and high visibility and pleochroism (different colours when viewed at different angles) in cross-polarised light.

many much smaller, with the vacuole (appearing as a white or dark grey/black dot in fossil grains, depending on the degree of decay) at the central to slightly eccentric hilum (Fig. 11D–I, Fig. 13A). The vacuole can sometimes be fissured. Many grains have one domed surface and up to six flattened pressure facets.

Although there are two possible indigenous New Zealand *Ipomoea* species, these can generally also be ruled out; the southern limit of *I. pes-caprae* (Cooper 1967, de Lange 2012) and *I. cairica* (de Lange 2023), is Northland and Tiritirimatangi Island, Auckland, respectively, well north of Taranaki. In addition, we can find no published reports of utilisation of these species by early Māori. Several starch yielding indigenous plants utilised by early Māori, namely *Calystegia sepum*, *Corynocarpus laevigatus* (karaka), *Microtis* spp., *Pteridium esculentum*, and *Typha orientalis* (raupo), can generally also be ruled out on starch grain

morphological basis (Barber & Higham 2021: S3 Table; Horrocks *et al.* 2004).

Starch grain decay involves progressive loss of visibility in cross-polarised light, (the so-called black 'Maltese' or extinction cross), discoloration, grain and vacuole expansion, distortion, and disintegration (Horrocks *et al.* 2007, 2023a, 2023b; Horrocks & Thomas 2022; Horrocks & Weisler 2006) (Fig. 11F–I). These effects potentially make identification difficult, and such remains can be overlooked by the novice microfossil analyst. Using Fourier Transform InfraRed spectroscopy, several previous microfossil studies, from the Society Islands, Rapa Nui (Easter Island), and Vanuatu, have shown that degraded starch grains that are discoloured and have lost shape and the Maltese cross, can be positively identified as starch (Horrocks *et al.* 2012b, 2014; Kahn *et al.* 2014). Similar results were obtained with SEM imaging and chemical analysis of degraded cf. *Colo-*

*casia esculenta* starch and cf. *C. esculenta* calcium oxalate crystals, respectively, in a Marquesas Islands study (Horrocks *et al.* 2023c).

Table 2 shows that *Colocasia esculenta* starch remains were identified in considerably more samples than *Ipomoea batatas* (13 vs three), suggesting that the sampled areas were associated more with *C. esculenta* cultivation or processing. Sampling preferences and differential preservation could also be factors explaining this difference.

## Helminth eggs

Descriptions and photomicrographs of modern reference eggs of *Toxocara canis* can be found in the works of Saari *et al.* (2018), and an illustration at <https://www.medical-labs.net/ascaris-lumbricoides-egg-1726/> provides a comprehensive range of images of the variable morphology of *A. lumbricoides* eggs. *Ascaris lumbricoides*, the 'large roundworm' of humans, is a soil-transmitted helminth, having a single host and direct life cycle. Fertilised eggs become infective in the soil, and when ingested, the larva hatches then penetrates the wall of the intestine and enters the blood stream from where it is carried to the lungs. The larvae are coughed up and swallowed thereby reaching the intestine where they develop into sexually reproducing adults. The female produces eggs (up to 200,000 eggs per day for its lifetime, 12–18 months) which are voided with the faeces, thus reaching the soil to start the cycle again (Dold & Holland 2011). Ascariasis is usually asymptomatic but may cause acute inflammatory reaction during the migration process. Heavy infections can block the intestines and may slow growth, or even be fatal in children (Dold & Holland 2011). A second species of *Ascaris*, *A. suum*, has very similar eggs that are easily confused with those of *A. lumbricoides*. However, *A. suum* is a parasite of pigs, which were not present in the pre-European era (King 2019) so that our identification of the human *Ascaris* can be confident.

At the time of writing, to our knowledge *Ascaris lumbricoides* eggs have not previously been firmly reported in pre-European archaeological contexts in New Zealand, nor in wider Oceania. Andrews (1979) reported finding this species' eggs in New Zealand human coprolites, dated to 150–200 BP, but pre-European origin is not definitive since the timing is very close to first contact (Ferreira & Araújo 2014). Although the *A. lumbricoides* egg type identified in the present study is from Feature 1929 which is not directly <sup>14</sup>C dated, based on location within Area T the feature falls within 'Prehistoric Phase 2: 1480–1720 AD' (Gibb 2011:157). The feature is thus deemed to be pre-contact (Table 2). Supporting evidence is that no coincident European pollen types were present (Fig. 9). Reports of *Ascaris lumbricoides* in archaeological contexts are common from the Northern hemisphere. However, there are far fewer accounts from the Southern Hemisphere, with a handful of reports from South America and Africa (see Leles *et al.* 2010). This is

likely to be due more to lack of research than a true picture of historical distribution.

*Toxocara canis* is a nematode parasite of dogs and other canids. It inhabits the small intestine of the definitive host, and is usually asymptomatic, except in the case of massive infection in pups, which may be fatal. Eggs are deposited in the faeces of the dog and the worm develops within the egg, and once embryonated becomes infectious. Dogs are infected when they ingest embryonated eggs from contaminated soil, or the worm larvae are directly acquired by a pup trans-placentally. In young dogs the larvae hatch out and migrate to the lungs where they are coughed up and swallowed, bringing them again to the intestine where they mature to adulthood. In dogs over three months old the larval worm either remains in the gut to mature and produce eggs for dispersal or enters the bloodstream and migrates to any organ of the body, where it will encyst in the tissues (Harris-Linton 2001).

Toxocariasis is a zoonotic disease, usually acquired by children ingesting eggs from soil. Infective larvae hatch in the intestine, but the juvenile stages do not mature. Instead, they wander throughout the body for months or up to several years, damaging where they settle, and causing blindness or death in the case of ocular or neurological infections.

There is widespread evidence of dogs in the archaeological record across New Zealand, summarised in the work of Greig and Rawlence (2021). Their Māori roles included food source, food scavenger, bird hunter, clothing source, and companion (*e.g.*, Greig *et al.* 2018; Greig & Walter 2021; Kramer *et al.* 2022; Pillay 2020; 2022). Previous dog helminth discoveries in New Zealand comprise coprolites from Bay of Plenty (*Toxocara canis* and *Capillaria cf. hepatica*) (Irwin *et al.* 2004), an Auckland midden (*Dipylidium caninum*) (Horrocks, Brown *et al.* 2023), stone garden systems at Palliser Bay (*T. canis* and *D. caninum*) (Horrocks, Dodd *et al.* 2024), and a Māori village at Shag River Mouth (*T. canis*) (Horrocks, Presswell & Smith 2024). Eggs of *T. canis* are not common in archaeological studies worldwide but have been found at a Lapita site in Bismarck Archipelago (Horrocks, Summerhayes & Presswell 2024), in canid coprolites in Paris (11th to 16th centuries) (Bouchet 1995), and in Brittany (300,000–500,000 years ago) (Bouchet *et al.* 2003) and Peru (700–1476 AD) (Richardson *et al.* 2012).

## CONCLUSIONS

The plant microfossil evidence in this study of large-scale landscape disturbance by people is consistent with pollen sediment core records from the Taranaki region and throughout New Zealand, which document widespread deforestation of lowland New Zealand by early Māori (*e.g.*, Anderson 2013).

The site demonstrates the widespread evidence of premodern Māori occupation in this region of Taranaki.

For example, several 1000 features within 5 ha suggest that population and settlement patterns could have been very different from ethnographic observations.

The large amounts of *Rhopalostylis* frond and Poaceae leaf phytoliths in many of the samples in this study could reflect activities such as weaving and thatching.

The similarity of the up-profile concentration curve of the *Basidiosporites* fungal spores with that of the *Sonchus/Taraxacum* pollen in the pit Feature TC/1876 suggests that the two are linked.

The discovery of micro-remains of three specific Māori introduced crops, namely *cf. Colocasia esculenta*, *Cordyline cf. fruticosa*, and *cf. Ipomoea batatas*, is consistent with previous archaeological microfossil studies of New Zealand sites in that these are the most frequently found (see Anderson & Petchey 2020). The study provides insight into local Māori horticulture, suggesting that mixed cropping was the norm across the Taranaki region.

Given the highly variable production and preservation of different plant and animal tissues, especially in archaeological contexts, the study highlights the value of a combined plant microfossil approach for determining human activity (see *e.g.*, Anderson and Petchey 2020). The evidence from Pohokura (Q19/54) points to a well-established horticulture practice of a range of introduced Polynesian crops from the 1600s AD onwards in coastal Taranaki up to European arrival, although it is likely this process started earlier. The addition of parasitological analysis, in this case identifying *Ascaris lumbricoides* and *Toxocara canis*, parasites that could have adversely affected people and their dogs, extends the combined approach for Oceania to the realm of helminthiasis.

The use of the archaeological samples obtained from infrastructure and private developments to elucidate the known spatial and temporal context of the crops identified and track ancient parasites demonstrates the importance of the heritage management framework in New Zealand (Bickler 2018).

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