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– ARTICLE –

Plant Microfossil and ^{14}C Analysis of Archaeological Features at Coromandel Peninsula, New Zealand: Evidence for regional Māori use of introduced and indigenous plants

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ABSTRACT

The study of Māori agriculture has been limited by lack of evidence in the form of plant remains. Studies using a combined microfossil (pollen, phytolith, and starch) approach have shown promise, although have mostly focused on specific sites. Here we address these limitations by providing a relatively high geographic resolution microfossils and ^{14}C study examining how several sites within a region compared to one another. Using samples from sediments, middens, and coprolites from six sites on Coromandel Peninsula, New Zealand, the results build on previous local studies, showing major landscape disturbance by people, and agricultural activity through the identification of Māori introduced cf. *Colocasia esculenta*, *Cordyline* cf. *fruticosa*, *Dioscorea alata*, and cf. *Ipomoea batatas*. Microfossils of possible gathered wild plants in the coprolites, namely Brassicaceae, *Coriaria*, *Rhopalostylis*, *Rumex*, and *Sonchus*, were also identified, complementing the agricultural record. *Ipomoea batatas* and *Colocasia esculenta* were identified at each of four of the six sites and in each of five of the seven coprolites, which could reflect their generally accepted dominance in Māori agriculture. *Dioscorea alata* starch at only one site is consistent with its status as a marginal crop. Starch of cf. *Solanum tuberosum* at one site reflects adoption of European cropping.

Keywords: Agriculture, Ethnobotany, Polynesia, Cultigens

INTRODUCTION

Based largely on phytogeographic data and early ethnographic accounts, ancestors of the Polynesians introduced a large number (50–72) of plant cultigen species to the Pacific Islands (Whistler 1991; Whistler 2009), with a core of approximately 15 species that formed the staple crops. The number reduced with remoteness, with New Zealand having only six 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* (uwhi, greater yam), *Ipomoea batatas* (kūmara, sweet potato), and *Lagenaria siceraria* (hue, bottle gourd). Gathering of a considerable number of native plants for a variety of uses was also documented by early ethnographers (Anderson 1907; Best 1902; Best 2005; Colenso 1880).

Archaeological excavation and palynological sediment core records from throughout New Zealand document extensive deforestation commencing after Polynesia settlement in AD 1320–1350 (McGlone 1983; McGlone *et al.* 1993; 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 agriculture. 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), Furey (2006), and Gumbley (2021). Despite extensive mapping and detailed descriptions of these features, specific identifications of cultigens are limited. For example, macrobotanical remains have only been found at one site as charred *Ipomoea batatas* tubers found in a crop storage pit at Pouerua in northern New Zealand (Leahy and Nevin 1993; Yen and Head 1993). This paucity is largely a result of generally poor preservation of plant fossil remains.

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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 (Horrocks 2020).

The studies using this combined microfossil approach have mostly been localised (Horrocks, Brown *et al.* in press). A recent exception is a North Island study suggesting the wide geographical extent of Māori cultivation of *Cordyline* cf. *fruticosa* at three archaeological sites, extending from the far north to the central west coast (Horrocks, Bader *et al.* 2022). We considered that a variation of this low-resolution type of study could examine several sites within a more confined region. A series of cultural heritage management-driven investigations at lowland sites around the coast of the mountainous Coromandel Peninsula presented the opportunity to do this.

For this study we selected six Coromandel Peninsula sites, from Thames at the south-western base of the peninsula to Whangamata at the south-eastern base, that showed plant microfossil evidence of Māori agriculture (Gaylard *et al.* 2022; Gumbley 2014; Gumbley *et al.* 2017; Gumbley and Laumea 2019; Hoffman 2012; Jones *et al.* 2021) (Fig. 1). Using a combined microfossil approach (pollen, phytolith, and starch analyses), the aim is to provide a relatively high geographic resolution study of plant microfossils to show how the sites within the region relate to one another and to elsewhere in New Zealand, with respect to Māori agricultural activity and its effect on the landscape after Māori settlement.

STUDY AREA AND SITES

The Coromandel Peninsula on the North Island of New Zealand extends 85 km north from the western end of the Bay of Plenty, forming a natural barrier protecting the Hauraki Gulf and The Firth of Thames in the west from the Pacific Ocean to the east (Wikipedia 2023) (Fig. 1). The peninsula is 40 km wide at its broadest point.

The peninsula is steeply mountainous, and largely covered in forest. The Coromandel and Moehau Ranges form the spine of the peninsula, with the highest point at almost 900 m (Fig. 1). The geology of the peninsula is overwhelmingly volcanogenic. While the peninsula has a steep hinterland, the coastal fringe has fertile soils and a series of large harbours. At over 1900 km^2 the Coromandel Peninsula is larger than most inhabited islands in Polynesia.

A pollen core record of the last *c.* 1800 years from Kauaeranga Valley, in the central base of the peninsula, showed a pattern of deforestation typical of records elsewhere in New Zealand, with an abrupt appearance of *Pteridium* spores and charcoal coincident with a major decrease in forest tree pollen (Byrami *et al.* 2002) (Fig. 1). The AD 1314 ± 12 Kaharoa Tephra (Hogg *et al.* 2003), erupted from the central North Island, was a key stratigraphic marker in this study, with most deforestation occurring after this time.

A recent, macro- and microfossil record from Great Mercury Island, adjacent to Coromandel Peninsula (Fig. 1), compared data from wetland sedimentary deposits indicative of *Colocasia esculenta* and leaf vegetable (including *Sonchus* and *Rorippa* spp.) cultivation with those of Raivavae and Rapa, both subtropical islands in French Polynesia (Prebble *et al.* 2019). Preservation of *C. esculenta* pollen on all islands between AD 1300 and AD 1550 indicated perennial cultivation over multiple growing seasons. Sedimentary charcoal and charred plant remains showed rapid deforestation. Prebble *et al.* (2019) suggested that New Zealand's northern offshore islands were preferred for early horticulture, where initial, brief *C. esculenta* production was supplanted by the more temperate-climate adapted *Ipomoea batatas*, which was subsequently established on a large scale on the mainland after AD 1500. Microfossil analysis in the Great Mercury study did not specifically include analysis of starch and associated material, however 'some [starch] granules of known cultigens (taro and kūmara) were observed and identified' (Prebble *et al.* 2019: 8832) in the pollen preparations.

Our site descriptions, as follows, briefly summarise relevant parts of the formal site reports to which we refer. Complete, detailed descriptions and stratigraphic diagrams are given in those works, which are freely available on the Heritage New Zealand Pouhere Taonga website (www.heritage.org.nz).

Cook's Beach

The Cook's Beach site is located on the central east coast of the peninsula (Fig. 1). The site is situated on a small hill behind the beach and above the tidal Purangi River (Jones *et al.* 2021). The site was excavated in 2020 as part of development which previously involved excavation of sand dunes north of T11/1050 which exposed large areas of horticultural soils (T11/2789) associated with Māori landscape modification. These were dated to the 'first half of the 14th Century, or at the latest within the last 2-decade [sic] of that Century' (Hoffman 2017: 25) with subsequent settlement from AD 1500–1650 after about 100 years of abandonment (Maxwell *et al.* 2017). Settlement at T11/2789 involved short-term encampments adjacent to the cultivations by a small number of people perhaps accessing the range of available resources, including the local obsidian (Hoffman 2017). The excavations at T11/1050 suggested more permanent settlement starting around the time when T11/2789 appeared to have been abandoned and continued alongside the later re-occupation of T11/2789 as late as the 19th century AD.

Two samples (26 and 227) from T11/1050 were col-

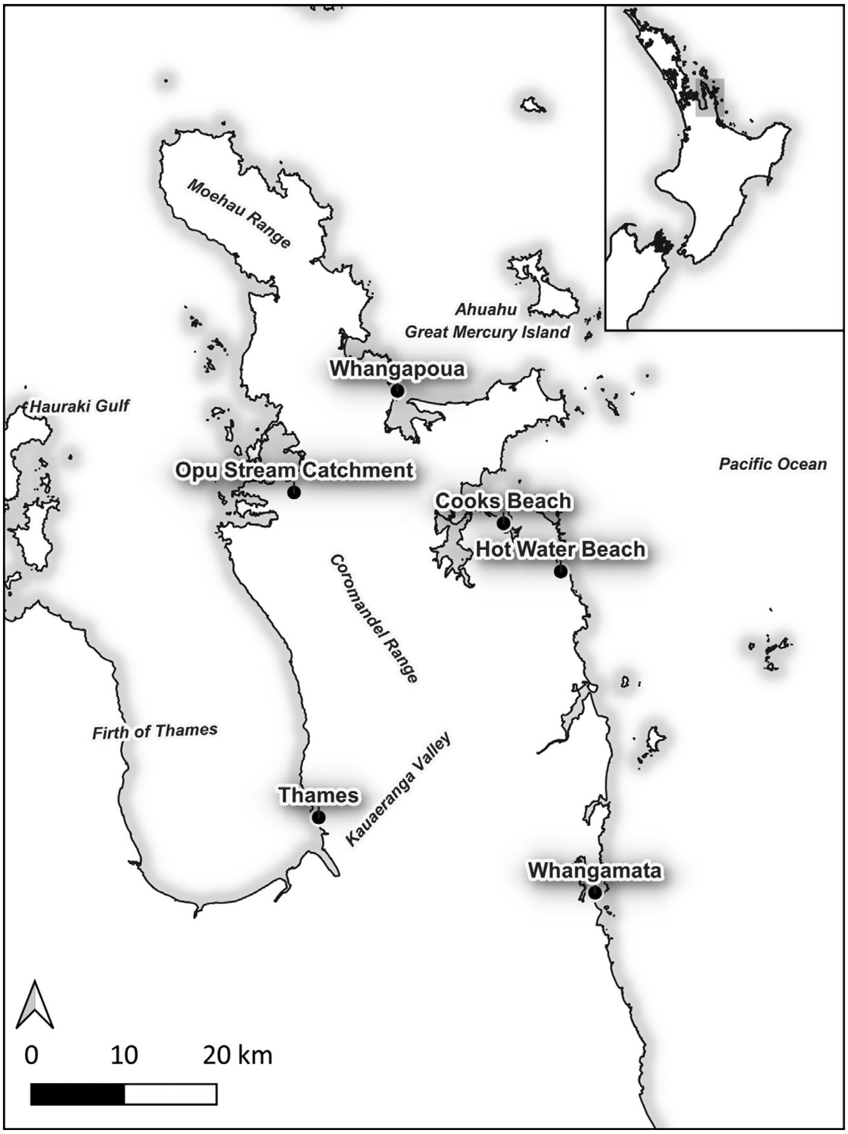

Figure 1. Map of Coromandel Peninsula showing sampling sites. Inset: New Zealand.

lected for plant microfossil analysis. Sample 26 was from immediately above the base of a medium-sized oval rua (pit) found in the flat areas below the main excavation area. No directly datable material was recovered from the feature. Sample 227 was from the fill of a narrow drain associated with a series of postholes. These features were interpreted as a shelter or whare (house) on a bench cut into the hill slope (Jones *et al.* 2021: 69; Fig. 1).

Hot Water Beach

Hot Water Beach is located on the central east coast of the peninsula 8 km south-east of Cook's Beach (Fig. 1). The site (T11/115) is located on consolidated sand dunes at the southern end of Hot Water Beach at the mouth of the Taiwawe Stream. In 1969 Leahy (1974) carried out a 26.5 m^2 investigation of the site where stratigraphy indicated repeated cooking events along with associated midden deposits. The investigation recovered flake stone tools, stone drill points, one-piece moa-bone and shellfish-hooks, adzes of various types, and a range of ornaments. All these items were typical of the early Polynesian Colonisation Phase. Faunal remains were diverse; 13 species of fish, 29 species of birds, a range of rocky shore shellfish, dogs, and fur seals. Radiocarbon dates of shellfish indicated occupation occurred in the late 15th or early 16th century AD.

In 2017, a second archaeological investigation took place in response to the installation of a new toilet block approximately 20 m from the 1969 investigation (Gumbley *et al.* 2017). This part of the site had a single cultural layer. The layer was black, varied in thickness, and included shell midden concentrations in places. Fewer artefacts than in the previous investigation were recovered and included an adze, basalt flakes from adze manufacture, flake stone tools, and moa-bone tabs from one-piece fish-hook manufacture. A range of rocky-shore shellfish were recovered along with cetacean bones. Six radiocarbon assays were carried out: three on charcoal from short-lived tree and shrub species and three on shellfish. The radiocarbon dates from the 2017 investigation suggested that the site was settled in the late 14th century or early 15th century.

Three samples (5, 8, and 11) were collected for plant microfossil analysis in 2017. Samples 5 and 8 were from a midden and sample 11 was a dog coprolite. All samples came from the same cultural layer. The coprolite was similar to other coprolites found in the cultural layers at Whangamata (Allo 1972, Gumbley 2014, Gumbley and Laumea 2019), which were all preserved because they had a large component of crushed bone. These coprolites were all relatively small, generally 10–15 mm across and of a size typical of a small dog like the Polynesian dog (kuri), or perhaps a child. Their composition, size, and close association with the midden deposits indicate they are most likely to have been deposited by dogs.

Opu Stream Catchment

The Opu Stream catchment site is situated in low hills on the southern side of Coromandel Harbour, with T11/50 and T11/51 situated on ridges between 60 and 90 m above sea level in an area known as the Briers Block (Fig. 1). Both T11/50 and T11/51 are typical of the site types found in these hills, *i.e.*, small clusters of rectangular crop storage pits with associated small scale domestic occupation, principally in the form of shell midden and fireplaces but with little evidence for structures (Hoffmann 2012). Three samples, from the fill of the internal drains of three of the storage pits, were collected for plant microfossil analysis.

Six radiocarbon assays were obtained from the pit clusters. Bayesian models of both sets of dates indicated T11/50 was occupied in the late 17th Century AD and T11/51 in the late 16th Century AD (Hoffmann 2012). Again, these ages were generally consistent with radiocarbon dates from earlier excavations on similar sites in the same stream catchment.

Thames

Thames is a small town located at the south-west base of the peninsula founded in the 1860s after gold was discovered (Fig. 1). The site (T12/1412) is located at 703 Pollen Street close to the 1860s foreshore (W. Gumbley, unpubl. data). Most of the area was covered in a series of fill units dating to the middle or late 19th Century.

Immediately east of these fill layers a shell midden was identified in a trench (Gumbley, unpubl. data). The midden layer was 30 cm thick, buried under a 30 cm thick soil and overlying a buried topsoil and subsoil, which, in turn, overlay beach sand. The midden layer included crushed and burnt shell in a brown to black silty matrix that included distinct charcoal pieces. The midden was also proximate to deposits of mid-19th century AD artefacts. One sample was collected for plant microfossil analysis.

Whangamata

Whangamata is a harbour on the east coast of the Coromandel Peninsula (Fig. 1). The archaeological site is located on consolidated sand dunes at the southern side of the harbour mouth and extends over approximately 1.5 ha.

Although recorded as two separate sites (T12/2 and T12/3), this distinction is artificial and reflects an anomaly in the early records. Small-scale investigations occurred in the 1960s, recovering artefacts typical of the early Polynesian Colonisation Phase sites (Jolly 1978; Shawcross 1964). In 1969 Allo (1972) carried out a 28 m^2 investigation of a midden area which included large numbers of rocky shore and estuarine shellfish, low numbers of fish, and seven bird species. The bulk of the remains, framed in terms of meat weight, was mammalian, with at least 17 dogs and at least two fur seals.

The data we use in this study are the result of a series of investigations commencing in 2003, which examined 628 m^2 (Gumbley 2014; Gumbley and Laumea 2019). These investigations occurred at the north-western margin of the site and included examination of cooking and midden areas, along with associated soils apparently modified by cultivation and a single rectangular crop storage pit. Layer 2 and Layer 3 were dominated by evidence for cooking and associated midden deposits, which included abundant evidence for both adze and moa-bone fish-hook manufacture. The two occupation layers were separated by an intermediate unit of soil mixed presumably by cultivation that had affected Layer 3 but not Layer 2. Layer 3 was deposited immediately onto Kaharoa Tephra (AD 1314 ± 12). A diverse range of shellfish, fish, and seals (James-Lee and Gumbley 2012), similar to that found by Allo (1972), was recovered along with the remains of a small cetacean. Sixteen radiocarbon assays were carried out: seven from Layer 2 (seven on marine shell and three on charcoal from short-lived shrubs and small trees) and six from Layer 3 (two on fish bone, one on marine shell, and three on charcoal from short-lived shrubs and small trees). Bayesian modelling of these assays along with the development of the occupation immediately on Kaharoa Tephra indicated that the site was occupied in the early to mid-14th Century.

Ten samples were selected for plant microfossil analysis. Six were from dog coprolites recovered from Layer 2 and Layer 3. The other four were sediment samples from Layer 2, the soil modified by cultivation, Layer 3, and the soil immediately under the Kaharoa Tephra (Table 1). Although not ascribed a distinct stratigraphic unit number, the soil thought to be modified by cultivation was stratigraphically intermediate between the cooking and midden layers 2 and 3 and was a mixture of Layer 3 and the natural underlying soil, including the Kaharoa Tephra.

Table 1. *Provenance of plant microfossil samples from T12/3. C = dog coprolite, S = sediment.*

Layer 2	Mixed soil	Layer 3	Soil under Kaharoa Tephra
004 C	917 S	219 C	919 S
147 C		711 C	
669 C		735 C	
918 S		983 S	

Whangapoua

Whangapoua is located on the north-east coast of the peninsula (Fig. 1). The site (T60/640) is located within the residential areas at the eastern end of the beach and below the nearby Opera Point Reserve (Gaylard *et al.* 2022). The full extent and complexity of the site is not known as much of it remains under modern development.

One sample was collected for microfossil analysis. The sample is from a small utility trench within the road berm which cut into part of a large shell midden in old dune (Gaylard *et al.* 2022).

METHODS

A total of 21 samples from the six sites were examined for plant microfossils. For all samples except four, the analyses comprised three separate types of extraction: pollen and spores, phytoliths and other biosilicates, and starch and other plant material. The exceptions, due to consulting cost constraints, were Samples 1, 5, and 11 from Opu Stream Catchment, where only starch was analysed, and Sample 919 from Whangamata, where only pollen was analysed. Starch can sometimes be found in pollen preparations, however, as was the case for the latter sample, despite the harsh chemicals and heat used in that treatment.

Samples were prepared for pollen analysis by the standard acetolysis method (Horrocks 2020; Moore *et al.* 1991). For 16 of the 21 samples, at least 150 pollen grains and spores were counted for each sample, and slides were scanned for types not found during the counts. The exceptions are from Whangamata, where pollen sparseness resulted in lower counts. Microscopic fragments of charcoal extracted with the pollen were qualitatively noted as present in all pollen samples. Maximum charcoal fragment size was no greater than the mesh size of the sieve used in preparation, *i.e.*, 130 µm. Quantitative charcoal assessment, which is very time consuming, was not used in this study due to consulting cost constraints, and to the potential unreliability of such assessments in dryland, *in situ* archaeological soil/sediment samples such as ours. As in our case, *macro*scopic particles of charcoal are often seen by the naked eye in such samples, and if these relatively large particles are fragmented during the preparation process and before or at the sieving stage, they can result in very high concentrations of microscopic fragments compared to those samples representing similar environments where this has by chance not occurred. Quantitative charcoal assessment is especially useful for microfossil sediment cores from wetlands, where accumulated in washed sediments hold records of progressive change in fire frequency and intensity, and vegetation composition, over long time periods. Our samples do not come from such environments and were recovered to address questions about the local environment at the time of site occupation.

Samples were prepared for phytolith analysis by density separation (Horrocks 2020; Piperno 2006). A sum of least 150 phytoliths was counted for each sample, and slides were scanned for types not found during the counts. Other biosilicates, in this case fragments of aquatic indicators (diatoms and sponge spicules), were not included in the sum. Samples were prepared for analysis of starch and other remains by density separation and presence/absence qualitatively noted (Horrocks 2020, Pearsall 2015).

Identification of pollen, phytoliths, starch, and xylem was aided using a modern reference collection of specimens of species cultivated by Polynesians. The collection is housed at Microfossil Research Ltd., Auckland. Photomicrographs of microfossils were taken with a Canon EOS 600D camera mounted on a Nikon 400E microscope.

RESULTS

Radiocarbon

Radiocarbon age determinations for the contexts of the samples recovered from the sites are shown in Table 2. The dates, which included both terrestrial and marine, were calibrated using the ShCal20 and Marine20 curves with OxCal 4.4 (Bronk Ramsey 2009). The charcoal dates are all from short-lived species. The dates range from the early 14th Century AD at Whangamata (T12/3) and Hot Water Beach (T11/115) through to 18th Century AD at the later parts of the sequence at Cooks Beach (T10/1050).

Microfossils

Pollen and phytolith graphical diagrams are shown in Figures 2–6 and microfossil photomicrographs are shown in Figures 9–10. All pollen samples contained microscopic fragments of charcoal (up to the 130 µm sieve mesh size), reflecting fire activity and burning of plant material at the sites, corresponding to elevated levels of macroscopic charcoal found in the same substrates.

Cook's Beach

The Cook's Beach pollen assemblages were dominated by *Cyathea* and *Pteridium* spores (Fig. 2A). *Sonchus/Taraxacum* type pollen and Anthocerotopsida spores were also present.

The phytolith assemblages were dominated by tree/shrub phytoliths, mostly spherical verrucose type (Fig. 2B).

Table 2. *Radiocarbon age determinations from Coromandel Peninsula.*

Site/sample	**Material**	**Sample no.**	**^{14}C BP**	**CalAD**	**δ^{13}C (‰)**
Cook's Beach **T11/1050 (227)**	charcoal *Coriaria* sp.	Wk52925	282 ± 18	1642–1665 1σ 1518–1798 2σ	
Hot Water Beach **T11/115**	charcoal *Pseudopanax* sp.	Wk46822	637 ± 18	1324–1396 1σ 1316–1405 2σ	
	marine shell *Turbo smaragdus*	Wk46823	959 ± 17	1337–1455 1σ 1290–1518 2σ	
	charcoal *Pseudopanax aboreus/Myrsine salicina/Dodonaea viscosa*	Wk46824	421 ± 18	1458–1608 1σ 1452–1619 2σ	
	marine shell *Turbo smaragdus*	Wk46825	998 ± 17	1316–1430 1σ 1265–1488 2σ	2.7 ± 0.30
	charcoal *Olearia* sp.	Wk46826	444 ± 18	1450–1487 1σ 144 – 1612 2σ	
	marine shell *Turbo smaragdus*	Wk46827	954 ± 16	1340–1456 1σ 1291–1520 2σ	2.5 ± 0.30
Opu Stream Catchment **T11/51**	charcoal *Coprosma* sp./*Kunzea ericoides*	Wk33864	388 ± 29	1464–1623 1σ 1459–1628 2σ	−28.9 ± 0.20
	charcoal *Kunzea ericoides*	Wk33865	416 ± 30	1458–1615 1σ 1450–1625 2σ	−26.2 ± 0.20
	seeds *Elaeocarpus dentatus*	Wk33869	336 ± 26	1511–1641 1σ 1502–1651 2σ	−25 ± 0.20
Whangamata T12/3					
T12/3 Layer 2	marine shell *Austrovenus stutchburyi*	Wk21693	1025 ± 33	1295–1416 1σ 1230–1475 2σ	0.5 ± 0.20
T12/3 Layer 2	marine shell *Paphies australis*	Wk21694	931 ± 32	1345–1480 1σ 1294 – 1555 2σ	1.3 ± 0.20
T12/3 Layer 3	fishbone *Chrysophrys auratus* gelatin	Wk33698	981 ± 25	1325–1442 1σ 1274–1503 2σ	
T12/3 Layer 3	fishbone *Chrysophrys auratus* gelatin	Wk33849	1038 ± 25	1289–1406 1σ 1225–1460 2σ	
T12/3 Layer 3	charcoal *Dodonaea viscosa/ Leucopogon fasciculatus/Carpodetus serratus/ Melicytus ramifloris*	Wk33850	635 ± 28	1322–1400 1σ 1305–1411 2σ	−27.8 ± 0.20
T12/3 Layer 2	marine shell Turbo smaragdus	Wk46204	996 ± 16	1319–1429 1σ 1266–1491 2σ	2.3 ± 0.25
T12/3 Layer 3	marine shell *Austrovenus stutchburyi*	Wk46205	1040 ± 15	1287–1403 1σ 1226–1456 2σ	−1.5 ± 0.25
T12/3 Layer 3	charcoal *Leptospermum scoparium*	Wk46206	338 ± 20	1511–1639 1σ 1505–1647 2σ	
T12/3 Layer 3	charcoal *Coprosma* sp.	Wk46207	638 ± 19	1324–1396 1σ 1315–1406 2σ	
T12/3 Layer 2	charcoal *Dodonaea viscosa*	Wk46208	634 ± 17	1324–1397 1σ 1317–1405 2σ	
T12/3 Layer 2	charcoal *Coprosma australis*	Wk46209	667 ± 18	1312–1393 1σ 1299–1396 2σ	
T12/3 Layer 2	marine shell *Austrovenus stutchburyi*	Wk46210	1009 ± 15	1307–1419 1σ 1255–1480 2σ	−0.2 ± 0.35
T12/3 Layer 2	charcoal *Myrsine salicina*	Wk46211	674 ± 18	1304–1391 1σ 1297–1395 2σ	
T12/3 Layer 2	marine shell *Austrovenus stutchburyi*	Wk46212	961 ± 16	1335–1452 1σ 1291–1517 2σ	−0.2 ± 0.25
T12/3 Layer 2	marine shell *Austrovenus stutchburyi*	Wk46213	985 ± 15	1325–1436 1σ 1276–1496 2σ	−0.7 ± 0.25
T12/3	marine shell *Paphies australis*	Wk46214	960 ± 15	1336–1455 1σ 1290–1514 2σ	0.8 ± 0.25
Whangapoua (T10/640)	marine shell *Paphies australis*	Wk52736	760 ± 22	1498–1636 1σ 1440–1700 2σ	0.4 ± 0.30

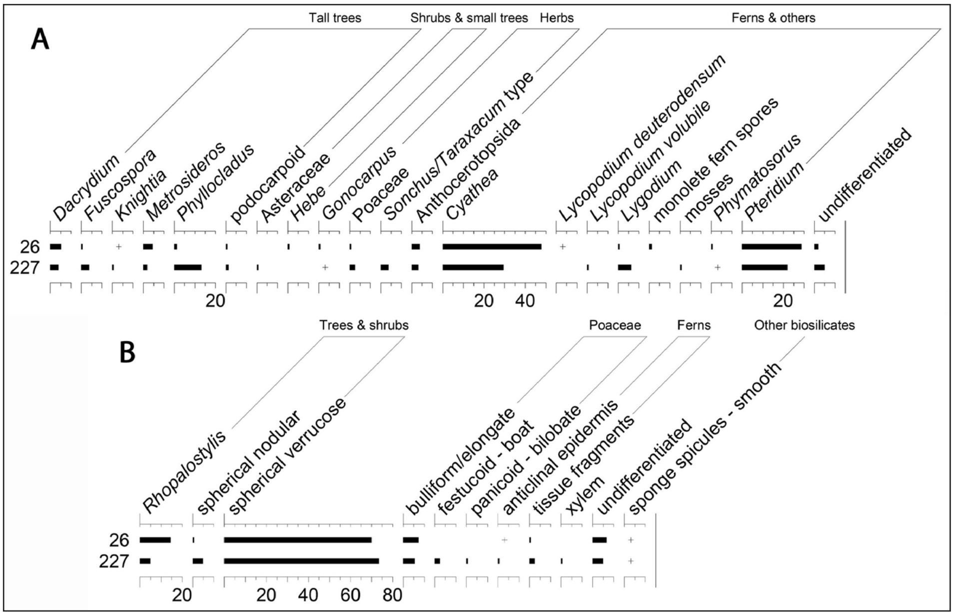

Figure 2. Pollen (A) and phytolith (B) percentage diagrams from Cook's Beach (+ = found after count).

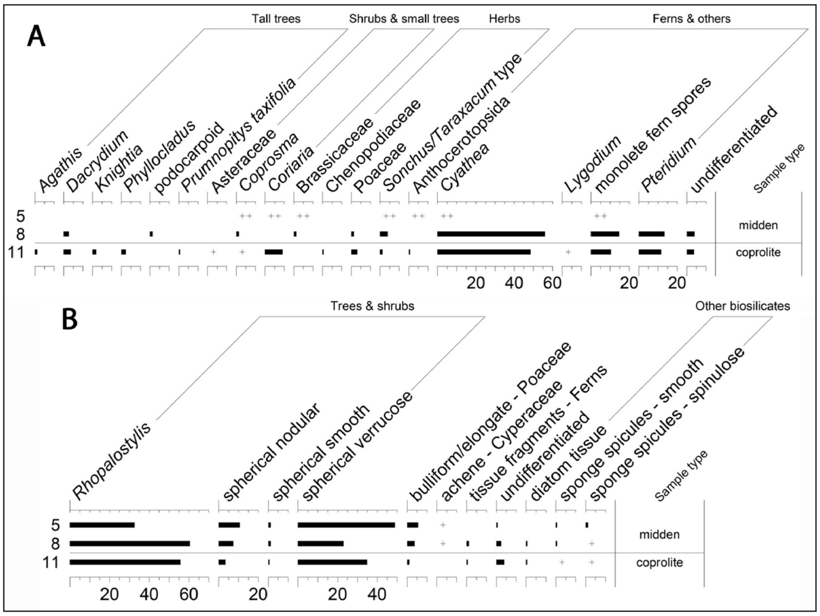

Figure 3. Pollen (A) and phytolith (B) percentage diagrams from Hot Water Beach (+ = found after count, ++ = present. Other biosilicates excluded from sum).

Rhopalostylis sapida phytoliths recorded an unusually relatively large amount in sample 26.

Starch and associated material from three Māori-introduced cultigens were identified at this site, present in both samples. The first type comprised individual starch grains of the tuberous root of cf. *Ipomoea batatas* (Table 3; Fig. 7A–H). Fragments of xylem cells, also consistent with the root of this species, were identified (Fig. 7I, J). The second type of starch comprised fragments of amyloplasts of the corm of cf. *Colocasia esculenta* (Fig. 8A, B). The remaining type comprised individual starch grains of the tuber of cf. *Dioscorea alata* (Fig. 8C).

Hot Water Beach

Midden sample 5 contained insufficient pollen and spores for meaningful counting. The pollen assemblages of the other midden sample and the coprolite sample were dominated by *Cyathea* spores (Fig. 3A). *Pteridium* and Anthocerotopsida spores, and ferns with monolete spores

Table 3. *Plant microfossils of cf. cultigens and possible gathered plant taxa from Coromandel Peninsula.*

Site/Sample no.	Sample type	Brassicaceae	*Colocasia esculenta*	*Coriaria* sp.	*Cordyline fruticosa*	*Dioscorea alata*	*Ipomoea batatas*	*Rhopalostylis sapida*	*Rumex* sp.	*Solanum tuberosum*	*Sonchus kirkii*
Cooks Beach											
26	soil		starch			starch	starch, xylem				
227	soil		starch			starch	starch, xylem				
Maxwell et al. (2017)											
	obsidian						starch				
Hot Water Beach											
5	midden	pollen									
8	midden	pollen									
11	coprolite		starch	pollen	pollen		starch, xylem				
Opu Stream Catchment											
11	soil						starch, xylem				
Thames											
	midden									starch	
Whangamata											
004	coprolite						starch	pollen			
147	coprolite				pollen						
219	coprolite		starch		pollen		starch				
669	coprolite		starch				starch		pollen		
711	coprolite		starch								
735	coprolite		starch				starch				
917	soil		starch				starch, xylem				
918	soil						starch				pollen
919	soil		starch								
Whangapoua											
	midden		starch								

were also represented. Pollen types noted included *Sonchus*/*Taraxacum* type in all three samples, Brassicaceae in both midden samples, and *Cordyline* cf. *fruticosa*, and an unusually moderate to large amount of *Coriaria* sp. in the coprolite sample (Table 3; Fig. 9A–D).

The phytolith assemblages were dominated by trees and shrubs (Fig. 3B). The tree and shrub types comprised mostly *Rhopalostylis sapida* and spherical verrucose phytoliths.

Starch and associated material from two Māori-introduced cultigens were identified at this site, present in the coprolite sample. The first type comprised individual starch grains of the tuberous root of cf. *Ipomoea batatas* (Table 3). Fragments of xylem cells, similarly consistent with the root of this species, were also identified (Fig. 7I, J). The second type of starch comprised fragments of amyloplasts of the corm of cf. *Colocasia esculenta*.

Opu Stream Catchment

Of the three samples analysed at the Opu Catchment site (1, 5, and 11, for starch only), starch and associated material from one Māori-introduced cultigen were identified. This type comprised individual starch grains of the tuberous root of cf. *Ipomoea batatas*, found in Sample 11 (Table 3). Fragments of xylem cells, similarly consistent with the root of this species, were also identified.

Thames

The Thames pollen assemblage was dominated by *Pteridium* and *Cyathea* spores, and *Sonchus*/*Taraxacum* type pollen (Fig. 4A). Anthocerotopsida spores also featured.

The phytolith assemblage was dominated by tree and shrub phytoliths, mostly spherical verrucose type (Fig. 4B). Other biosilicates, in this case sponge spicule fragments, prominently featured.

Starch and associated material from one introduced cultigen were identified in the sample. This type comprised individual starch grains of the tuber of European introduced cf. *Solanum tuberosum* (potato) (Table 3; Fig. 8D).

Whangamata

The Whangamata pollen assemblages were variably dominated by *Pteridium* and *Cyathea* spores and ferns with monolete spores (Fig. 5A). Other pollen types noted included *Rhopalostylis sapida*, *Rumex* sp., and *Sonchus*/*Taraxacum* type, which showed unusually moderate to large amounts (Table 3; Fig. 9A, E, F).

The phytolith assemblages were variably dominated by several tree and shrub phytolith types, notably *Rhopalostylis sapida*, spherical verrucose, and spherical nodular (Fig. 5B). Sponge spicule fragments, prominently featured in two of the coprolite samples.

Starch and associated material from two Māori introduced cultigens was identified at this site, present in some of the coprolite samples and one of the soil samples. The first type comprised individual starch grains of the tuberous root of cf. *Ipomoea batatas* (Table 3). Fragments of xylem cells, similarly consistent with the root of this species, were also identified. The second type of starch comprised fragments of amyloplasts of the corm of cf. *Colocasia esculenta*.

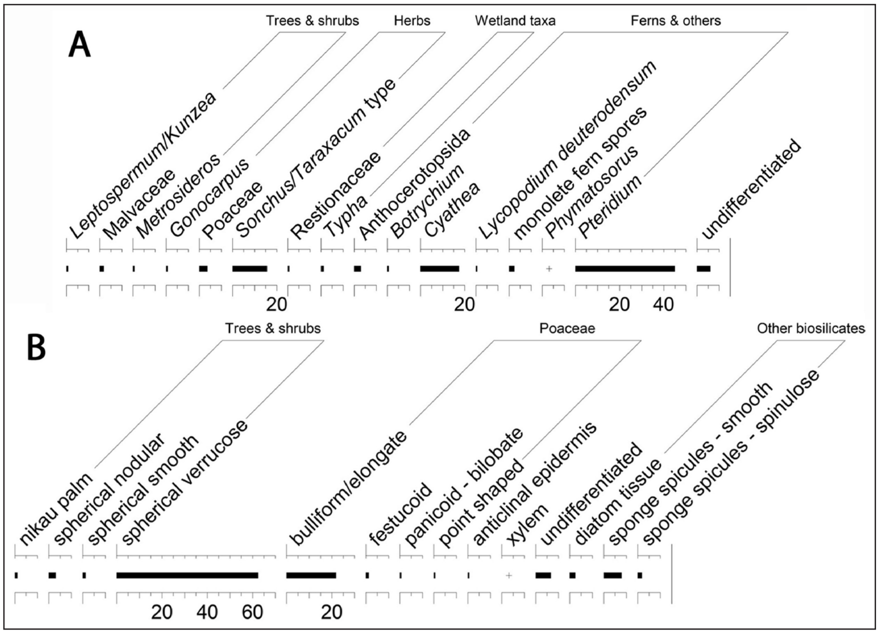

Figure 4. Pollen (A) and phytolith (B) percentage diagrams from Thames (+ = found after count. Other biosilicates excluded from sum).

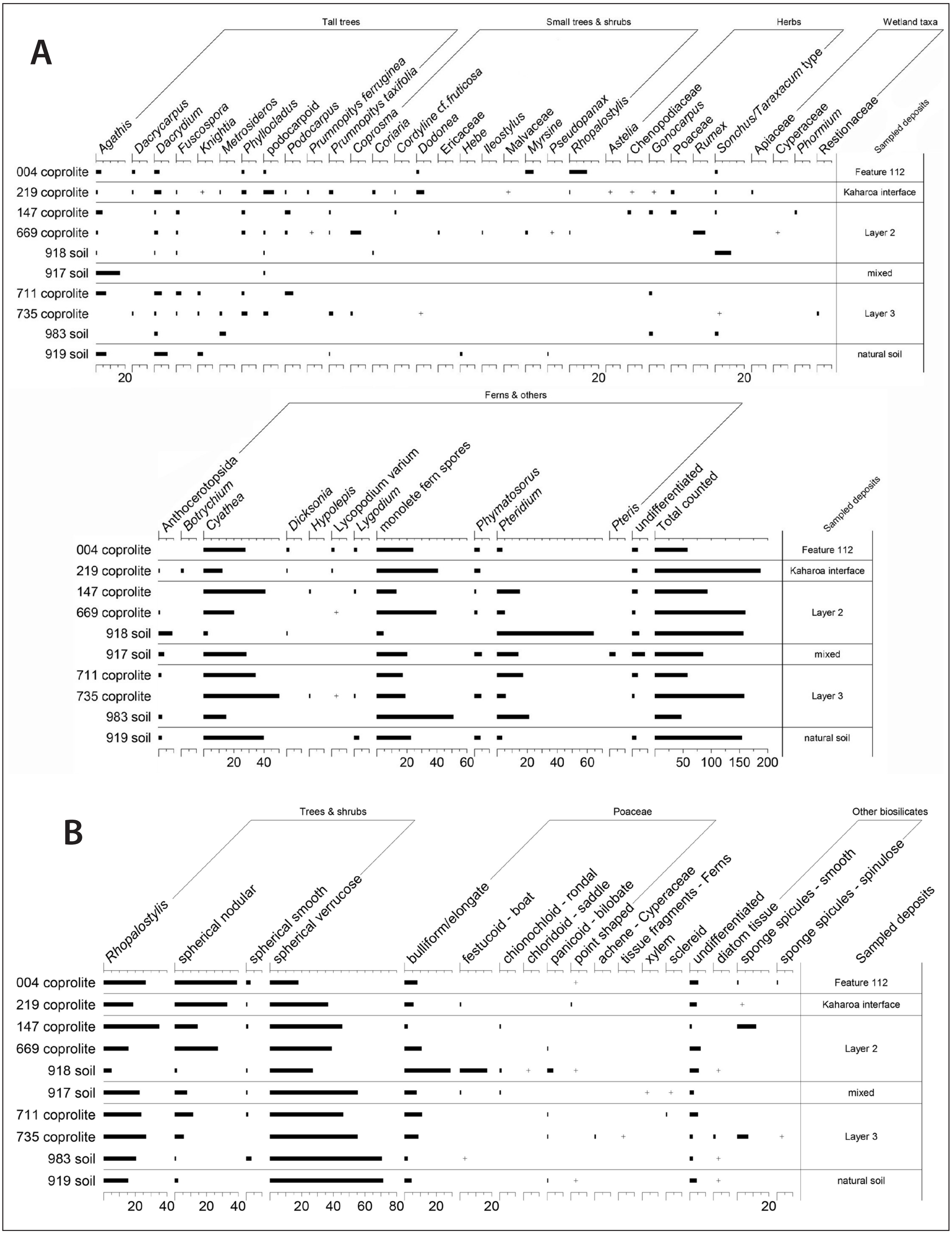

Figure 5. Pollen (A) and phytolith (B) percentage diagrams from Whangamata (+ = found after count. Other biosilicates excluded from sum).

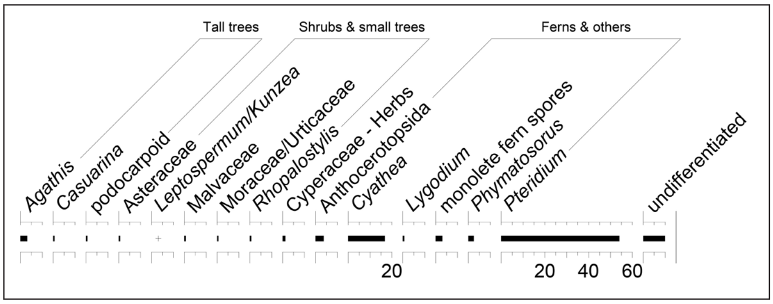

Figure 6. Pollen percentage diagram from Whangapoua (+ = found after count).

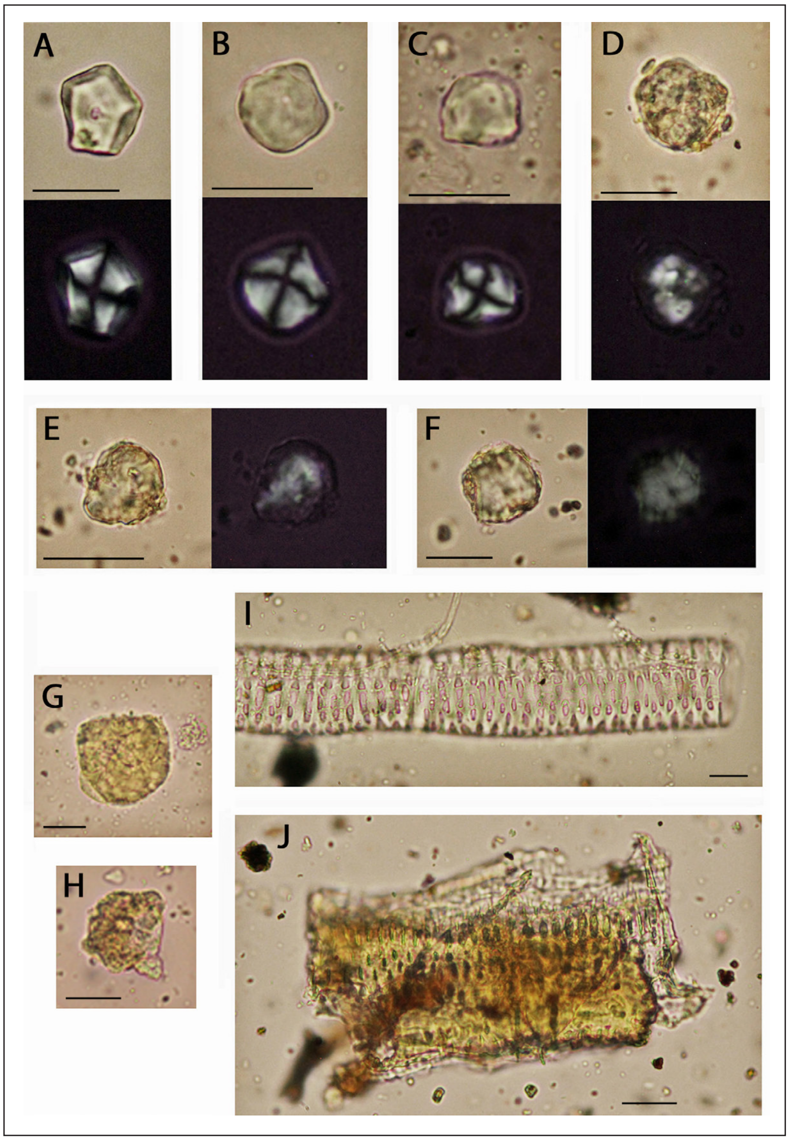

Figure 7. Fossil starch (A–H) and xylem (I, J) of cf. *Ipomoea batatas* from Coromandel Peninsula. Sample numbers in brackets; mounted in glycerol jelly; G-J 400×, remainder 600×; black background: cross-polarized light; scale bars: 20 µm. A (669), B (227), C (11-Hot Water Beach), D (26), E (26), F (227) starch grains in various states of preservation, from well-preserved to highly decomposed. The grains show progressive discoloration (from normal opaque gray to shades of yellow/brown), and loss of shape and of the Maltese cross. G (735) and H (26) have lost all visibility under cross-polarized light, with the latter also showing an expanded vacuole and disintegration. Central vacuole visible in all grains, as a white or black dot; facets retained in most. I (26) and J (227) show well preserved and degraded xylem tissue, respectively. Pits are characteristically slit-like, with many on J narrowed or lost.

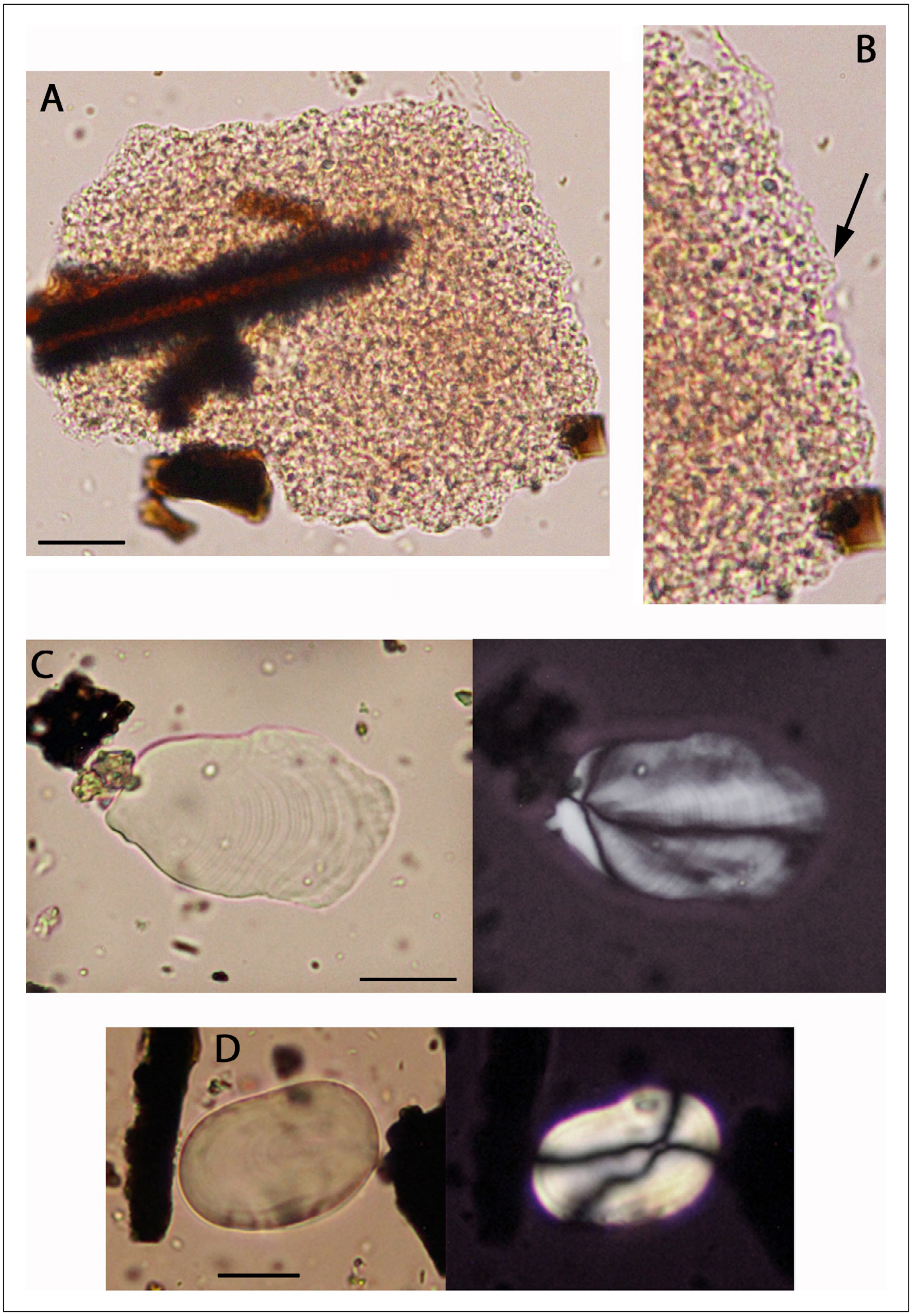

Figure 8. Fossil starch of cf. *Colocasia esculenta*, cf. *Dioscorea esculenta*, and cf. *Solanum tuberosum* from Coromandel Peninsula. Sample numbers/name in brackets; mounted in glycerol jelly; A 600×, B 1000×, remainder 400×; scale bars: 20 µm. A (919) degraded, discolored cf. *Colocasia esculenta* corm amyloplast, with characteristic densely packed, sharply angular, tiny (≤ 4 µm) starch grains (100s), and the central vacuole apparent as a dark gray/black dot. Partly obscured by detritus; B right side of A at higher magnification, with a group of grains readily apparent along edge (arrow); C (227) starch grain of cf. *Dioscorea alata*, showing characteristic elongated, ovoid, often flattened shape, and pronounced growth rings. Maltese cross and characteristic eccentric hila shown in cross-polarised light; D (Thames sample) starch grain of cf. *Solanum tuberosum*, showing characteristic spherical ovate to elongated shape. Maltese cross and characteristic eccentric hila shown in cross-polarized light.

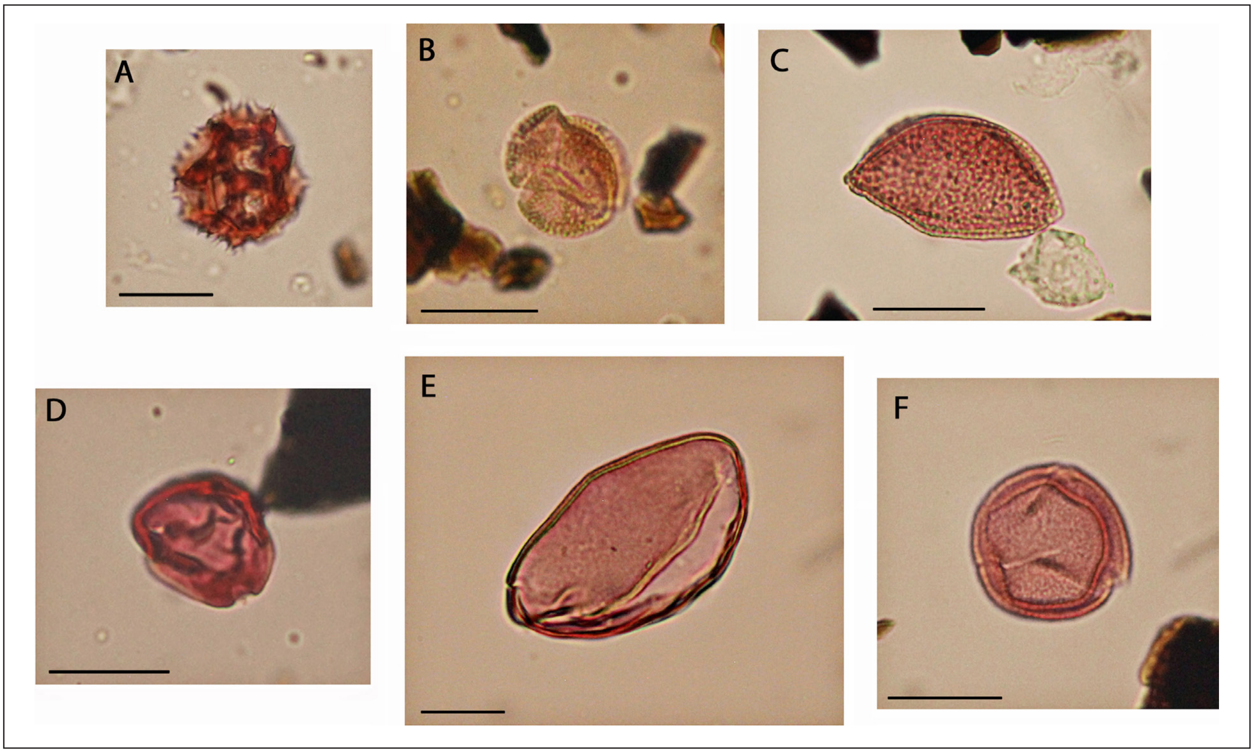

Figure 9. Fossil pollen from Coromandel Peninsula. Sample numbers in brackets; mounted in glycerol jelly, stained with basic fuchsin; C, E 400×, remainder 600×; scale bars: 20 µm. A (919) *Sonchus/Taraxacum* type; B (8) Brassicaceae; C (147) *Cordyline* cf. *fruticosa*; D (11) *Coriaria* sp.; E (004) *Rhopalostylis sapida*; F (669) *Rumex* sp.

Whangapoua

The Whangapoua pollen assemblage was dominated by *Pteridium* and *Cyathea* spores (Fig. 6). Anthocerotopsida were also identified.

A type of Australian native tree pollen, namely *Casuarina*, was also identified (Fig. 6). This type has long-distance pollen transport in air currents and can occur as a trace in New Zealand pollen spectra.

The phytolith separation yielded insufficient phytoliths for meaningful counting. Instead, the separation comprised almost entirely apparent microscopic volcanic glass shards.

Starch from one Māori introduced cultigen was identified at this site. This type comprised fragments of amyloplasts of the corm of cf. *Colocasia esculenta* (Table 3).

DISCUSSION

Evidence for site occupation and forest clearance

Radiocarbon dates from Whangamata (T12/3) and Hot Water Beach (T11/115) are the earliest sites in this study, with both Layers 2 and 3 from T12/3 virtually indistinguishable and similar to the earlier dates from T11/115 (Table 2). Dates for the 15th Century AD from Hot Water Beach also suggest that occupation occurred then. Dates from the kumara storage pits at Opu Stream (T11/51) and the midden at Whangapoua (T11/640) indicate occupation in the 16th century or possibly early 17th Century. As noted earlier, the date from the shelter or whare at Cook's Beach (T11/1050) indicated the mid-17th Century AD, which was part of a sequence of occupation there that spanned over 400 years prior to European arrival. The early European artifacts associated with the Thames midden, with our addition of *Solanum tuberosum* starch, clearly show it is modern.

The *Pteridium*, *Cyathea*, Anthocerotpsida, and monolete fern spores, and *Sonchus/Taraxacum* type pollen, coincident with the charcoal and a paucity of pollen of forest trees in the samples, reflect a majorly disturbed landscape largely cleared of forest by people (Figs 2–6). *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, and subsequently Europeans (McGlone 1983). It can form tall, dense stands over extensive areas, and its rhizome was commonly harvested as a food by Māori (Best 1902). *Cyathea* tree ferns commonly colonise gullies in *Pteridium* fernland (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 (Large and Braggins 1991). *Sonchus* (puha) is native to New Zealand, while *Taraxa-*

cum includes European introduced *Taraxacum officinale* (dandelion). *Sonchus*/*Taraxacum*-type 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 (Anderson 1907; Best 1902; Colenso 1880; Crowe 1997). The Anthocerotposida spores also reflect landscape disturbance; this plant division comprises small inconspicuous plants that colonise freshly exposed soils (Wilmshurst *et al.* 1999).

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 very small or negligible amounts of tree and shrub pollen (Figs 2–5). 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.

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 and 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 fragments of diatoms and sponge spicules, reflect the local coastal environments (Fig. 3B-6B). The abundant glass shards found in the Whangamata phytolith extraction is presumably airfall tephra from Mayor Island and central North Island eruptions deposited on the Coromandel Peninsula during the Late Quaternary (Hogg and McCraw 1983; Houghton *et al.* 1992).

Evidence for agriculture

Descriptions and photomicrographs of reference starch, xylem, or pollen of the cultigens *Colocasia esculenta*, *Cordyline fruticosa*, *Dioscorea alata*, *Ipomoea batatas*, and *Solanum tuberosum* starch are given in the works of Cranwell (1953, 1962), Horrocks, Bader *et al.* (2022), Horrocks, Brown *et al.* (in press), Horrocks *et al.* (2012a), Horrocks *et al.* (2012b), Horrocks *et al.* (2007), Horrocks *et al.* (2008), Horrocks and Weisler (2006), Loy *et al.* (1992), Reichert (1913), Seidemann (1966), and the Australasian Pollen and Spore Atlas (apsa.anu.edu.au/).

The four introduced starch-rich species identified by their starch grain morphology in this study are readily differentiated from the starch of the native *Pteridium esculentum*, which added a starch rich rhizome to Māori diet. Descriptions and photomicrography of starch grains and xylem tracheid cells of this plant are found in Horrocks *et al.* (2004).

Colocasia esculenta starch was identified in 10 of the 21 samples, at four of the six sites, and in five of the seven coprolites, one from Hot Water Beach and four from Whangamata (Table 3). This cultigen is native to Southeast Asia and was introduced by ancient people throughout the Pacific Islands (Whistler 2009). The corm and shoot of *Colocasia esculenta* were cooked and eaten (Best 1902; Crowe 1997). *Colocasia esculenta* corm amyloplasts, containing hundreds of densely packed starch grains, are ovate, up to approximately 185 µm in diameter, with very thin enclosing double membranes (Fig. 8A, B). Starch grains are spherical, appearing sharply angular, and mostly <4 µm 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 <4 µm grain size is near the limits of light microscopy, so grains are best identified in archaeological samples as groups, *i.e.*, amyloplasts or fragments thereof. In archaeological soils and sediments, *C. esculenta* amyloplasts are commonly fragmented and without visible membrane tissue, as shown in this case.

Despite their tiny size, reasonably clear photomicrographic images of *Colocasia esculenta* starch grains can be provided when working with stone tools or other types of archaeological samples preserved in permanently dry environments such as caves (Loy *et al.* 1992). The limitation of light microscopy in relation to this tiny size, and of depth of focus, can present problems for photomicrography when working with soils or sediments. It can be a major challenge to obtain clear focus on, and high magnification of, a large mass of these densely packed grains extracted from soils/sediments, especially if the grains are degraded. The effects are increased when the mass is more three-dimensional, and decreased when it is flatter, *i.e.*, more two-dimensional. The microscope and therefore photograph can show only one focal plane at any point while focusing through the object. Exacerbating this effect, depth of field becomes shallower with increasing magnification. Increasing the magnification from 400x or 600x to 1000x using oil immersion does not necessarily produce clearer images. In this study, we were able to show a few *Colocasia esculenta* starch grains at the edge of a dense mass that were easier to distinguish than most of those within the mass (Fig. 8A, B). Focus stacking software, where images of the same object at different focal planes are merged to show all the object in focus, does not necessarily work well for a large dense mass of tiny grains because each image represents a thin section across the mass, with different grains in different positions and focus for each image, so merging the images attempts to overlay different grains together. Applying pressure to the cover slip of the slide can show more of a mass in the same focal plane and can dislodge small clumps or individual grains but doing this can squash and disfigure the starch grains, which of course is not how they naturally appear.

Lack of accompanying *Colocasia esculenta* pollen in this study is not surprising. To date this pollen has been found at only three New Zealand sites (Handley *et al.* 2020; Horrocks and Brown *et al.* in press; Prebble *et al.* 2019). As *Colocasia esculenta* is entomophilous it produces little pollen and has particularly poor preservation and a proneness to acetolysis damage, resulting in rare fossil reporting (Nusaifa Beevi 2009).

Cordyline cf. *fruticosa* pollen was found in three of the seven coprolite samples, one from Hot Water Beach and two from Whangamata (Table 3; Fig. 9C). The native range of *C. fruticosa* is probably the broad area between the Himalayas and northern Australia (Whistler 2009). Apart from Fiji, Tonga, and Samoa, where the manner and timing of introduction is uncertain, *C. fruticosa* is an ancient introduction throughout Polynesia except for Easter Island and the Tuamotu Islands. The leaves were widely used for clothing, temporary house thatching, and food wrappings for cooking. Secondarily, the root and trunk were cooked and eaten (Best 1902; Crowe 1997; Whistler 2009). The works of Cranwell (1953, 1962) show how *C. fruitcosa* pollen can be readily differentiated from that of New Zealand's native *Cordyline* species.

Dioscorea alata starch was found at one of the sites, in both samples from Cook's Beach (Table 3; Fig. 8C). It is native to Southeast Asia and introduced throughout Polynesia (Whistler 2009). The tuber was cooked and eaten. Starch grains are elongated ovate, up to approximately 55 µm long (a few can reach 70 µm), often appear flattened, and have generally highly visible growth rings, and an eccentric hilum (Fig. 8C). The fossil grains in this case are reasonably well preserved, clearly showing the so-called 'Maltese cross' in cross-polarized light. In a pre-contact New Zealand context, this type of starch grain is readily differentiated from starch grains of the other two Māori introduced starch-rich cultigens, namely *Colocasia esculenta* and *Ipomoea batatas.* In a post-contact context, the starch grains of *D. alata* could be confused with those of European introduced *Solanum tuberosum* (potato), which have a similar, but not identical, morphology (Fig. 8D).

Ipomoea batatas micro-remains were identified in 11 of the 21 samples, at four of the six sites, and in five of the seven coprolites, all from Whangamata (Table 3). This cultigen is native to Peru or Ecuador (Rouillier *et al.* 2013). Its introduction to Polynesia is generally considered to be the result of Polynesian contact with South America (Green 2005; Hather and Kirch 1991; Kirch *et al.* 2017; Whistler 2009; Yen 1974). The tuberous root of *I. batatas* was cooked and eaten. *Ipomoea batatas* root starch grains are spherical to sub-spherical, often bell-shaped, up to approximately 25 µm in diameter with many much smaller, with a vacuole appearing as a small dot at the central hilum (Fig. 7A–H). The vacuole can sometimes be fissured. Nearly all grains have one domed surface and up to six flattened pressure facets. In a pre-contact New Zealand context, this type of starch grain is readily differentiated from starch grains of the other two Māori introduced starch-rich cultigens, namely *Colocasia esculenta* and *Dioscorea alata*.

Identifying *Ipomoea batatas* starch in New Zealand can be complicated by the presence of two other, probably indigenous, *Ipomoea* species, namely *I. pes-caprae* and *I. cairica*. Neither of these vines have pronounced starch storage organs and therefore produce little starch. Both can be ruled out in this case because the former is restricted to the Northland region (Cooper 1967, de Lange 2012) and 'most literature regards Tiritirimatangi Island as the actual southern limit' of *I. cairica* (de Lang 2023). The island is 25 km north of our northernmost *I. batatas* site in the Opu Stream Catchment. In addition, we can find no published reports of this species on Coromandel Peninsula nor any of utilisation by early Māori. In a post-contact context, the starch grains of *Ipomoea batatas* could be confused with those of European introduced *Zea mays* (maize), which have a similar, but not identical, morphology. Root xylem vessel elements of *I. batatas* are tubular, joined end to end, up to 75 µm across, with walls up to 4 µm thick, and have slit-like pits 6–16 µm wide (Fig. 7I, J). Although some other plants can have similar xylem cells, finding this xylem type with the starch grains supports the starch evidence for *I. batatas*. The starch showed highly variable preservation. Decay of this species' starch grains involves progressive loss of the Maltese cross and fading of visibility in cross-polarised light, discoloration, expansion, distortion, and disintegration (Horrocks *et al.* 2007; Horrocks *et al.* 2012a; Horrocks *et al.* 2012b). In Horrocks' experience, the discoloration generally appears in shades of yellow/brown in non-basaltic soils, as in this case, and in shades of amber/brown in basaltic soils. Workers new to ancient starch research could easily not recognise and thus overlook degraded grains.

Lack of accompanying *Ipomoea batatas* pollen in this study is not unexpected as this pollen type is very rarely found in the Pacific region. Although mostly propagated by the tuberous root, it can flower, but being entomophilous little pollen is produced and the pollen seems to be sensitive to acetolysis and is poorly preserved. Nonetheless, this pollen type can be unequivocally differentiated from pollen of both *I. cairica* and *I. pes-caprae*, even in fragments, thus in New Zealand it can be assuredly assigned to *I. batatas* (Moar 1993). Identification of *Ipomoea batatas* pollen in the wider Pacific region (Cummings 1998; Selling 1947) is potentially complicated by the presence of more indigenous *Ipomoea* species.

Solanum tuberosum, starch grains of which were identified in the Thames midden sample, was introduced to New Zealand accompanying European contact in the late 18th century (Table 3). This cultigen was first domesticated in the area of Peru and Bolivia, from a species in the *S. brevicaule* complex, which is native to the Andes region (Spooner *et al.* 2005). Starch grains are spherical ovate to elongated, up to approximately 70 µm in diameter (a few can reach 90 µm) and have an eccentric hilum Reichert (1913) reported that grains of a small number of varieties can grow larger than 100 µm. Larger grains are often irregularly shaped. The fossil grains in this case are well preserved, clearly showing the Maltese cross in cross-polarised light (Fig. 8D). This type of starch grain is readily differentiated from starch grains of two of the three other Māori-introduced starch rich cultigens, *i.e.*, *Colocasia esculenta* and *Ipomoea batatas.* The starch grains of *S. tuberosum* could be confused with those of the other Māori-introduced cultigen, *Dioscorea alata*, which have a similar, but not identical, morphology. Comparison reveals the latter's generally highly visible growth rings, a feature not seen or at least relatively faintly in *S. tuberosum*.

All seven dog coprolites in this study, from the Hot Water Beach and Whangamata sites, contained cultigen microfossils (Table 3). This presence is presumably a result of intentional ingestion with food intake, although inadvertent ingestion during sniffing activity close to the ground cannot be ruled out. The microscopic fragments of charcoal reflect either ingestion of fire-cooked food or burning of plant material in the area, or a combination of both.

Evidence for gathering of wild plants

Descriptions and photomicrographs of pollen of the possible gathered taxa Brassicaceae, *Coriaria* sp., *Rhopalostylis sapida*, *Rumex* sp., and *Sonchus kirkii* are given in the works of Cranwell (1953) and Moar (1993). Microfossil types in the coprolites possibly from gathering of native plants by people include the small amounts of pollen of Brassicaceae and *Rumex* sp., and the unusually relatively moderate to large amounts of pollen of *Coriaria* sp., *Rhopalostylis sapida*, and *Sonchus kirkii* (Table 3; Fig. 9A, B, D–F). Although the Brassicaceae and *Rumex* sp. pollen types were found in relatively small amounts, they rarely feature at all in New Zealand pollen spectra. 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 1902). Similarly, pollen of *Rumex flexuosus* could reflect use of the inner shoots and roots of this medicinal plant by local people (Adams 1945; Collier 1959). The petals and petal juice of *Coriaria* sp. were widely used as a food by Māori at least up until the end of the 19th Century (Crowe 1997). The *Rhopalostylis sapida* pollen could be from food prepared by people. The immature flower, before its sheath opens, and the immature green berries were eaten by Māori (Crowe 1997; Esler 1974). The extreme under-representation of *R. sapida* pollen in New Zealand pollen spectra adds weight to this suggestion (Macphail and McQueen 1983). The leaves and shoots of *S. kirkii* were commonly cooked and eaten by Māori (Colenso 1880, Best 1902, Anderson 1907, Crowe 1997). Descriptions and photomicrographs of reference pollen of these New Zealand native taxa are provided in the works of Cranwell (1953) and Moar (1993). Pollen of some of these possibly gathered taxa was previously identified in the Great Mercury Island study (Prebble *et al.* 2019).

A possible animal addition to the plant material in Māori food ingested by dogs is suggested by the larger amounts of sponge spicules in two of the Whangamata coprolite samples (Fig. 5B). These larger amounts could reflect dogs ingesting seafood.

CONCLUSIONS

The evidence of forest clearance and landscape disturbance in this study is consistent with the pollen core record from Kauaeranga Valley and from records elsewhere in New Zealand (Figs 1, 3–7). The results show that much of the Coromandel Peninsula's coastline underwent considerable forest clearance by fire following Polynesian settlement, with a sharp decline in forest pollen and influx of *Pteridium* spores, charcoal, and other palynomorph indicators of disturbance (Byrami *et al.* 2002; McGlone 1983; McGlone *et al.* 1993; Prebble *et al.* 2019).

Our microfossil dating is primarily by stratigraphic association with the excavated cultural deposits, which subjects interpretation to site-specific taphonomic histories. In the absence of direct recovery and dating of charred remnants of the harvested elements, however, this stratigraphic interpretation is the best available evidence for both presence and absence of cultigens (Anderson and Petchey 2020).

The discovery of micro-remains of four specific Māori-introduced crops, namely *Colocasia esculenta*, *Cordyline* cf. *fruticosa*, *Dioscorea alata*, and *Ipomoea batatas*, three of which were identified at more than one site, provides insight into Māori agriculture, suggesting mixed cropping across the region (Table 3). Our results from Hot Water Beach and Whangamatā support Prebble *et al.*'s (2019) argument that cultivation of *Colocasia esculenta* in New Zealand was accompanied by *Ipomoea batatas* during the colonisation phase of settlement or soon after. Prebble *et al.*'s (2019) suggestion for offshore island locations as the original staging post for agricultural introduction is based on evidence from a single New Zealand location, Great Mercury Island (Fig. 1), and from a comparative perspective with other Polynesian islands. However, these islands are much smaller than the New Zealand mainland. The North Island, including the Coromandel Peninsula, could have offered an extensive, diverse range of micro-habitats suitable for a wide range of cultigens matching offshore locations and perhaps with more reliable climatic conditions (see also Barber 2020; Prebble *et al.* 2020). Documenting the changing patterns of horticultural practice throughout the sequence of Māori settlement therefore relies on a greater number of regional studies capturing the diverse responses (see *e.g.*, Gumbley 2021) and more reliable control of the chronologies (Anderson and Petchey 2020; Bunbury *et al.* 2022).

Starch and xylem of *Colocasia esculenta* and *Ipomoea batatas* in some of the dog coprolites reflect overlapping of human and dog diets, with dogs being fed and scavenging food scraps (Table 3). As well as cultigen microfossils, those of possible gathered wild plants found in the coprolites, namely Brassicaceae, *Coriaria* sp., *Rhopalostylis sapida*, *Rumex* sp., and *Sonchus kirkii*, complement the agricultural record. The presence of cultigen and other possible subsistence taxa in all coprolites shows the value of coprolites, both human and their commensals, in studies of human plant subsistence, with the search narrowed to diet.

Micro-remains of *Colocasia esculenta* and *Ipomoea batatas* at each of four of the six sites and in five of the seven coprolites could reflect their generally accepted dominance in Māori agriculture, with the latter considered the most extensively grown cultigen (Furey 2006, Gumbley 2021) (Table 3). By comparison, *Dioscorea alata* starch at only one site is consistent with its status as a relatively uncommon and marginal Māori crop (Colenso 1880). *Solanum tuberosum* starch at another site reflects adoption of European cropping.

Given the highly variable production and preservation of different plant tissues, especially in archaeological contexts, this study highlights the value of a combined microfossil approach for the study of agriculture and wild plant gathering. The approach in this case provides a regional record of four of the six cultigens Māori introduced to New Zealand, and four possible wild subsistence plant taxa (Table 3).

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References

Adams, O. 1945. *Maori Medicinal Plants*. Auckland Botanical Society Bulletin 2. Auckland: Craig, Lineham, Duplicatists.

Allo, J. 1972. The Whangamata Wharf site (N49/2): Excavations of a Coromandel coastal midden. *Records of the Auckland Institute and Museum,* 9: 61–79.

Andersen, J.C. 1907. *Maori Life in Ao-tea*. Christchurch: Whitcombe and Tombs Ltd.

Anderson, A., & Petchy, F. 2020. The transfer of kūmara (*Ipomoea batatas*) from East to South Polynesia and its dispersal in New Zealand. *Journal of the Polynesian Society,* 129(4): 351–82.

Barber, I.G. 2004. Crops on the border: the growth of archaeological knowledge of Polynesian cultivation in New Zealand, In L. Furey & S.J. Holdaway (eds.) *Change Through Time: 50 Years of New Zealand Archaeology*. Auckland: New Zealand Archaeological Association Monograph 26, pp. 169–92.

Barber, I. 2020. Further wet-taro evidence from Polynesia's southernmost Neolithic production margins. *Proceedings of the National Academy of Sciences* 117(3): 1257–1258.

Best, E. 1902. Food products of Tuhoeland. *Transactions of the New Zealand Institute,* 35: 45–11.

Best, E. 2005. *Forest lore of the Maori*. Wellington: Te Papa Press.

Bronk Ramsey, C. 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon,* 51(1): 337–60.

Bunbury, M., Petchey, F., & Bickler, S.H. 2022. A new chronology for the settlement of Aotearoa (New Zealand) by Māori and the role of the Little Ice Age in demographic developments. *Proceedings of the National Academy of Sciences*, 119: e2207609119.

Byrami, M., Ogden, J., Horrocks, M., Deng, Y., Shane, P. & Palmer, J. 2002. A palynological study of Polynesian and European effects on vegetation in Coromandel, New Zealand, showing the variability between four records from a single swamp. *Journal of the Royal Society of New Zealand,* 32(3): 507–31.

Colenso, W. 1880. Vegetable food of the ancient New Zealanders before Cook's visit. *Transactions of the New Zealand Institute,* 13: 3–38.

Collier, N. 1959. Comments upon some forms of medical treatment prescribed by the Maori. *Historical Review,* 7: 79–80.

Cooper, R.C. 1967. *Ipomoea pes-caprae* (Convolvulaceae) on Ninety Mile Beach, New Zealand. *Records of the Auckland Institute and Museum* 6: 171–174.

Cranwell, L.M. 1953. *New Zealand Pollen Studies: The Monocotyledons*. Cambridge: Bulletin of the Auckland Institute and Museum No. 3.

Cranwell, L.M. 1962. Endemism and isolation in the Three Kings Islands, New Zealand–with notes on pollen and spore types of the endemics. *Records of the Auckland Institute and Museum,* 5: 215–32.

Crowe, A. 1997. *A Field Guide to the Native Edible Plants of New Zealand.* Auckland, Godwit Publishing.

Cummings, L.S. 1998. A review of recent pollen and phytolith studies from various contexts on Easter Island, In: C.M. Stevenson, G. Lee & F.J. Morin (eds.) *Easter Island in Pacific Context, South Seas Symposium*. Proceedings of the Fourth International Conference on Easter Island and East Polynesia. University of New Mexico, Albuquerque, 5–10 August 1997. Bearsville: The Easter Island Foundation, and Los Osos: Cloud Mountain Press, pp. 100–106.

de Lange, P. 2012. Beach morning glory (*Ipomoea pes-caprae* subsp. *brasiliensis*) in beach drift on Ripiro Beach, Omamari Stream Mouth, Northland. *Wellington Botanical Society Bulletin,* 54: 37–41.

de Lange, P. 2023. Ipomoea cairica Fact Sheet (content continuously updated). New Zealand Plant Conservation Network. https://www.nzpcn.org.nz/flora/species/ipomoea-cairica/ (site accessed January 2023)

Esler, A.E. 1974. The nikau palm. *New Zealand's Nature Heritage,* 2: 532–34.

Furey, L. 2006. *Maori Gardening: An Archaeological Perspective.*

Wellington: Department of Conservation.

Gaylard, D., Judge, C., Low, J. & Harding, L. 2022. Chorus Ultra-Fast Broadband Installation–Whangapoua, Coromandel: Final Archaeological Monitoring and Investigation Report. Auckland: Clough & Associates Ltd.

Green R.C. 2005. Sweet potato transfers in Polynesian prehistory, In: C. Ballard, P. Brown, R.M. Bourke & T. Harwood (eds.) *The Sweet Potato in Oceania: A Reappraisal*. Sydney: University of Sydney Oceania Monograph 56, pp. 71–84.

Gumbley, W. 2014. The Cabana Site (T/12/3), Whangamata: Results of the 2007 Investigation. Hamilton: W. Gumbley Ltd.

Gumbley, W. 2021. The Waikato Horticultural Complex: An Archaeological Reconstruction of a Polynesian Horticultural System. PhD thesis, Anthropology, Australian National University.

Gumbley, W. & M. Laumea. 2019. T/12–The Cabana Site, Whangamata, New Zealand: Results of the 2016 Investigation. Hamilton: W. Gumbley Ltd.

Gumbley, W., M. Laumea & M. Sutton. 2017. Hot Water Beach: Archaeological Report for Site T11/115. Hamilton: W. Gumbley Ltd.

Handley, S.J., Swales, A., Horrocks, M., Gibbs, Carter, M., Ovenden, R. & Stead, J. 2020. Historic and contemporary anthropogenic effects on granulometry and species composition detected from sediment cores and death assemblages, Nelson Bays, Aotearoa-New Zealand. *Continental Shelf Research,* http://dx.doi.org/10.1016/j.csr.2020.104147.

Hather, J., & P.V. Kirch. 1991. Prehistoric sweet potato (*Ipomoea batatas*) from Mangaia Island, central Polynesia. *Antiquity,* 65(249): 887–93.

Hoffmann, A. 2012. *Archaeological investigation of prehistoric horticultural sites T12/653–655, Kaupeka Stream, Whangamata Harbour, Coromandel Peninsula*. Report to Matariki Forests Ltd.

Hoffmann, A. 2017. *Investigation of archaeological site T11/2789, Cooks Beach (Pukaki), Mercury Bay: Final report.* Report to Longreach Developments Ltd and Heritage New Zealand.

Hogg, A.G., Higham, T.F.G., Lowe, D.J., Palmer, J.G., Reimer, P.J. & Newnham, R.M. 2003. A wiggle-match date for the settlement of New Zealand. *Antiquity,* 77(295): 116–25.

Hogg, A. G., McCraw, J. D. 1983. Late Quaternary tephras of Coromandel Peninsula, North Island, New Zealand: a mixed peralkaline and calcalkaline tephra sequence. *New Zealand Journal of Geology and Geophysics* 26: 163–187.

Horrocks, M. 2020. Recovering plant microfossils from archaeological and other paleoenvironmental deposits: A practical guide developed from Pacific Region experience. *Asian Perspectives,* 59(1): 186–208.

Horrocks, M., Bader, H.-D., Simmons, A. & Adamson, J. 2022. Pollen and phytolith analyses of archaeological features from North Island, New Zealand, reveal large scale landscape disturbance and cultivation of Polynesian introduced *Cordyline* cf. *fruticosa* (ti). *Journal of Island and Coastal Archaeology*, http://dx.doi.org/10.1080/15564894.2022.2129883.

Horrocks, M., A. Brown, J. Brown & Presswell, B. In press. A plant and parasite record of a midden on Auckland Isthmus, New Zealand, reveals large scale landscape disturbance, Māori introduced cultigens, and helminthiasis. *Asian Perspectives*.

Horrocks, M., Baisden, W.T., Flenley, J., Feek, D., González Nualart, L., Haoa-Cardinali, S. & Edmunds Gorman, T. 2012a. Fossil plant remains at Rano Raraku, Easter Island's statue quarry: Evidence for past elevated lake level and ancient Polynesian agriculture. *Journal of Paleolimnology,* 48(4): 767–83.

Horrocks, M., W. T. Baisden, M. K. Nieuwoudt, J. Flenley, D. Feek, L. González Nualart, S. Haoa-Cardinali, and T. Edmunds Gorman. 2012b. Microfossils of Polynesian cultigens in lake sediment cores from Rano Kau, Easter Island. *Journal of Paleolimnology,* 47(2): 185–204.

Horrocks, M., Campbell, M. & Gumbley, W. 2007. A short note on starch and xylem of *Ipomoea batatas* (sweet potato) in archaeological deposits from northern New Zealand. *Journal of Archaeological Science,* 34(9): 1441–8.

Horrocks, M., A. Brown, J. Brown, and B. Presswell. In press. A plant and parasite record of a midden on Auckland Isthmus, New Zealand, reveals large scale landscape disturbance, Māori introduced cultigens, and helminthiasis. *Asian Perspectives*.

Horrocks, M., Irwin, G.J., Jones, M. D. & Sutton, D.G. 2004. Starch grains and xylem cells of sweet potato (*Ipomoea batatas*) and bracken (*Pteridium esculentum*) in archaeological deposits from northern North Island, New Zealand. *Journal of Archaeological Science,* 31(3): 251–8.

Horrocks, M., Smith, I.W.G., Nichol, S.L., Shane, P.A. & Jackman, G. 2008. Field survey, sedimentology and plant microfossil analysis of sediment cores from possible cultivation sites at Tolaga Bay, eastern North Island, New Zealand. *Journal of the Royal Society of New Zealand,* 38: 131–47.

Horrocks, M. & Weisler, M.I. 2006. A short note on starch and xylem of *Colocasia esculenta* (taro) in archaeological deposits from Pitcairn Island, southeast Polynesia. *Journal of Archaeological Science,* 33(9): 1189–93.

Houghton B. F., Weaver, S. D., Wilson, C. J. N., Lanphere, M. A. 1992. Evolution of a Quaternary peralkaline volcano: Mayor Island, New Zealand. *Journal of Volcanology and Geothermal Research* 51: 217–236.

James-Lee, T. & Gumbley, W. 2012. Patterns of faunal resource use at an early prehistoric settlement at Whangamata on the Coromandel Peninsula, North Island, New Zealand. *Journal of Pacific Archaeology,* 3(2): 33–51.

Jolly, R.W.G. 1978. The East or Cabana Lodge site, Whangamata. *New Zealand Archaeological Association Newsletter,* 21(4): 135–7.

Jones, B., Bickler, S., Larsen, B., Roth, K., Gaylard, D. & Clough, R. 2021. *Stage 2B, 4 and 5 Earthworks, 720 Purangi Road, Cooks Beach (Pukaki), Coromandel. Final Report of Archaeological Investigations*. Auckland: Clough & Associates Monograph Series no. 23.

Kirch P.V., Hather J.G. & Horrocks, M. 2017. Archaeobotanical assemblages from Tangatatau Rockshelter, In: P.V. Kirch (ed.) *Tangatatau Rockshelter: The Evolution of an Eastern Polynesian Socio-ecosystem*. Los Angeles: Cotsen Institute of Archaeology Press, pp. 157–73.

Kondo, R., Childs, C. & Atkinson, I. 1994. *Opal Phytoliths of New Zealand*. Lincoln: Manaaki Whenua Press.

Large, M.F., Braggins, J.E. 1991. Spore atlas of New Zealand ferns and fern allies. *New Zealand Journal of Botany Supplement*.

Leahy, A. 1974. Excavations at Hot Water Beach (N44/69), Coromandel Peninsula. *Records of the Auckland Institute and Museum,* 11: 23–76.

Leahy, A. & Nevin, D. 1993. Excavations at Site P5/228, In: D.G. Sutton (ed.) *The Archaeology of the Peripheral Pa at Pouerua, Northland, New Zealand*. Auckland: Auckland University Press, pp. 27–55.

Loy, T. H., Spriggs, M. & Wickler, S. 1992. Direct evidence for human use of plants 28,000 years ago: starch residues on stone artefacts from the northern Solomon Islands. *Antiquity,* 66(253): 898–912.

Macphail, M. K. & McQueen, D.R. 1983. The value of New Zealand pollen and spores as indicators of Cenozoic vegetation and climates. *Tuatara,* 26(2): 37–59.

Maxwell, J.J., McCoy, M.D., Tromp, M., Hoffmann, A. & Barber, I. 2017. The difficult place of deserted coasts in archaeology: New archaeological research on Cooks Beach (Pukaki), Coromandel Peninsula, New Zealand. *The Journal of Island and Coastal Archaeology,* 13(1): 1–20.

McGlone, M.S. 1983. Polynesian deforestation of New Zealand: A preliminary synthesis. *Archaeology in Oceania,* 18(1): 11–25.

McGlone, M.S., Salinger, M.J. & Moar, M.T. 1993. Paleovegetation studies of New Zealand's climate since the Last Glacial Maximum, In: H.E. Wright Jr., J.E. Kutzbach, T. Webb III, W.F. Ruddiman, S.-P.F. Alayne & P.J. Bartlein (eds.) *Global Climates since the Last Glacial Maximum*. Minneapolis: University of Minnesota Press, pp. 294–317.

McWethy, D.B., Whitlock, C., Wilmshurst, J.M., McGlone, M.S., Fromont, M., Xun, L., Dieffenbacher-Krall, A., Hobbs, W.O., Fritz, S.C. & Cook, E.R. 2010. Rapid landscape transformation in South Island, New Zealand, following initial Polynesian settlement. *Proceedings of the National Academy of Sciences,* 107(50): 21343–8.

Moar, N. T. 1993. *Pollen Grains of New Zealand Dicotyledonous Plants*. Lincoln: Manaaki Whenua Press.

Moore, P.D., Webb, J.A. & Collinson, M.E. 1991. *Pollen Analysis,* 2nd edn. London: Blackwell Scientific.

Nusaifa Beevi, P. 2009. Biosystematic Studies in Taro (Colocasia esculenta (L.) Schott.). PhD thesis, Botany, University of Kerala.

Pearsall, D.M. 2015. *Paleoethnobotany: A Handbook of Procedures.* Walnut Creek: Left Coast Press.

Piperno, D.R. 2006. *Phytoliths: A Comprehensive Guide for Archaeologists and Paleoecologists*. Lanham: Altamira Press.

Prebble, M., Anderson, A.J., Augustinus, P., Emmitt, J., Fallon, S.J., Furey, L.L., Holdaway, S.J., Jorgensen, A., Ladefoged, T.N., Matthews, P.J., Meyer, J.Y., Phillipps, R., Wallace, R. & Porch, N. 2019. Early tropical crop production in marginal subtropical and temperate Polynesia. *Proceedings of the National Academy of Sciences,* 116(18): 8824–33.

Prebble, M., Anderson, A.J., Augustinus, P., Emmitt, J., Fallon, S.J., Furey, L.L., Holdaway, S.J., Jorgensen, A., Ladefoged, T.N., Matthews, P.J., Meyer, J.Y., Phillipps, R., Wallace, R. & Porch, N. 2020. Reply to Barber: Marginal evidence for taro production in northern New Zealand between 1200 and 1500 CE. *Proceedings of the National Academy of Sciences,* 117(3): 1259–60.

Reichert, E.T. 1913. *The Differentiation and Specificity of Starches in Relation to Genera, Species, etc*. Washington: Carnegie Institution of Washington.

Rouillier, C., Duputié, A., Wennekes, P., Benoit, L., Fernández Bringas, V. M., Rossel, G., Tay, D., McKey, D., Lebot, V., Joly, S. 2013. Disentangling the Origins of Cultivated Sweet Potato (*Ipomoea batatas* (L.) Lam.). *PLoS ONE,* 8(5): e62707.

Seidemann, J. 1966 *Stärke-atlas*. Berlin: Paul Parey.

Selling, O. H. 1947. *Studies in Hawaiian Pollen Statistics, Pt. II*. Honolulu: Bernice P. Bishop Museum Special Publication 38.

Shawcross, W. 1964. Stone flake industries in New Zealand. *Journal of the Polynesian Society,* 73: 7–25.

Spooner, D.M, McLean, K., Ramsay, G., Waugh, R., & Bryan, G.J. 2005. A single domestication for potato based on multilocus amplified fragment length polymorphism genotyping. *Proceedings of the National Academy of Sciences,* 102(41): 14694–9.

Walter, R., Buckley, H., Jacomb, C. & Matisoo-Smith, E. 2017 Mass migration and the Polynesian settlement of New Zealand. *Journal of World Prehistory,* 30(4): 351–76.

Wardle, P. 2002. *Vegetation of New Zealand*. Caldwell: The Blackburn Press.

Whistler, W.A. 1991. Polynesian plant introductions, In: P.A. Cox & S.A. Banack (eds.) *Islands, Plants, and Polynesians: An Introduction to Polynesian Ethnobotany: Proceedings of a Symposium*. Portland: Dioscorides Press, pp. 41–66.

Whistler, W.A. 2009. Plants of the Canoe People: An Ethnobotanical Voyage through Polynesia. Lawa: National Tropical Botanical Garden.

Wikipedia (2022) https://en.wikipedia.org/wiki/Coromandel_Peninsula [accessed 3 February, 2023].

Wilmshurst, J.M., Eden, D.E. & Froggatt, P.C. 1999. Late Holocene forest disturbance in Gisborne, New Zealand: A comparison of terrestrial and marine pollen records. New Zealand Journal of Botany, 37(9): 523–40.

Yen, D.E. 1974. *The Sweet Potato and Oceania: An Essay in Ethnobotany*. Honolulu: Bernice P. Bishop Museum Bulletin 236.

Yen, D. & Head, J. 1993. Kumara remains in Pit O at P5/228, In: D.G. Sutton (ed.) *The Archaeology of the Peripheral Pa at Pouerua, Northland, New Zealand*. Auckland: Auckland University Press, pp. 27–55.