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– ARTICLE –

Plant Microfossils and Parasites from Palliser Bay Stone Garden Systems, New Zealand, Reveal Māori Translocations and Helminthiasis

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ABSTRACT

The study of Māori agriculture, including almost all the numerous Māori stone garden sites recorded in both the North and South Islands, has been hindered by lack of evidence in the form of plant remains. Here we address this with pollen, phytolith, and starch analyses of 22 archaeological soil samples across a 14 km range, with an additional sample from 11 km distant, from Palliser Bay in the southern North Island. Results show evidence of premodern Māori translocations, comprising cf. *Ipomoea batatas*, cf. *Colocasia esculenta*, and *Cordyline* cf. *fruticosa*, to date the southernmost New Zealand report for the latter two. The presence of cf. *I. batatas* and cf. *C. esculenta* starch remains in relatively large amounts in almost all samples and small amounts in fewer samples, respectively, suggests that the latter was more of a minor crop in Palliser Bay. Samples also contained eggs of *Dipylidium caninum* and *Toxocara canis*, parasites of the introduced kurī dog (*Canis familiaris*), which could have adversely affected local people and their dogs. The plant evidence supports the view that the southern extent of Māori cultivation of introduced warmer climate crops in temperate New Zealand was variably, progressively limited by length of growing season requirements.

Keywords: Agriculture, Ethnobotany, Cultigens, Introductions, Polynesia

INTRODUCTION

A series of projects requiring archaeological monitoring in eastern Palliser Bay in far southern North Island presented an opportunity to address the paucity of plant macro-remains by microfossil analysis of substrate samples across several local archaeological sites (Dodd 2020; in prep. a, b, c) (Fig. 1). The original site mapping and excavations, carried out in the 1970s, are detailed in the work of Leach and Leach (1979). The obvious characteristic feature of these sites is abundant stone structures. There are scores of these recorded Māori 'horticultural complexes' in New Zealand, from the far northern North Island to Banks Peninsula in the central South Island (Furey 2006). The structures are thought to be agriculturally related, but determining whether different structures were used for growing cultivars, the result of stone clearance, or as types of boundary markers can be difficult.

Early colonisers introduced a large number (70+) of plant cultigen species to the Pacific Islands (Whistler 2009). The number reduced with remoteness, 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* (uwhi, greater yam), *Ipomoea batatas* (kūmara, sweet potato), and *Lagenaria siceraria* (hue, bottle gourd) (Best 1976).

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. Examples are crop storage pits, ditches/drains, stone structures, terraces, borrow pits, and 'made' or modified soils (Barber 2004; Barber and Higham 2021; Furey 2006; Gumbley 2021). Despite

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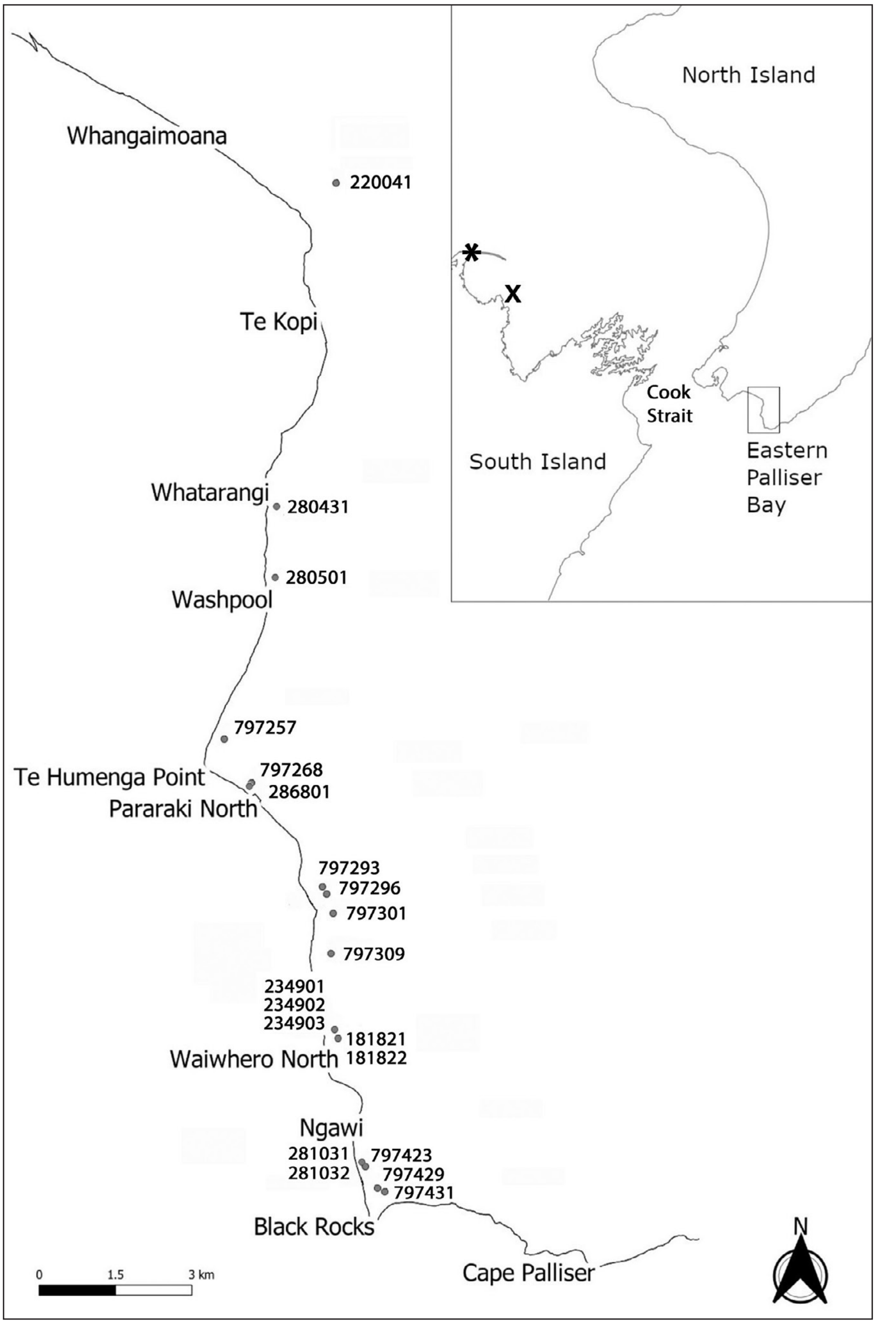

Figure 1. Maps of Eastern Palliser Bay and lower North/upper South Islands showing site locations (∗ = Golden Bay archaeological site, × = Nelson Bays off-shore core site).

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 far northern North Island (Leahy and Nevin 1993; Yen and 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, the addition of other plant microfossil types, notably phytoliths and starch grains, have enabled identification of specific crop species at archaeological sites (Barber and Higham 2021; Horrocks *et al.* 2020, 2022, 2023a, 2024a; Prebble *et al.* 2019).

There have been few botanical studies of stone garden systems in New Zealand, and these are microfossil analyses restricted to two areas in the northern North Island:

South Auckland and inland Bay of Islands. These studies identified starch grains and xylem cells of *Ipomoea batatas* and *Colocasia esculenta*, and a possible leaf phytolith of *Lagenaria siceraria* (Horrocks 2004; Horrocks and Lawlor 2006).

Using a combined plant microfossil approach (pollen, phytolith, and starch analyses), the aim of this study is to build on the previous Palliser Bay archaeological study by identifying direct agricultural evidence in the form of botanical remains (Leach and Leach 1979) and address the difficulties of dating the gardening practices around Palliser Bay (*e.g.*, Anderson and Petchey 2020). As well as potentially shedding light on stone structure function, a southern extension of knowledge is also of interest because New Zealand's long, narrow latitudinal shape is assumed to have progressively limited cultivation because of cooler temperature and reduced growing season (Barber 2004). The study is augmented by parasitological analysis.

STUDY AREA AND SITES

Palliser Bay is at the southern end of the North Island of New Zealand, southeast of Wellington (Fig. 1). It runs for 40 km along the Cook Strait coast from Turakirae Head at the southern end of the Remutaka Ranges to Cape Palliser, the North Island's southernmost point. Inland from the bay is the plain of the Ruamahanga River, which has its outflow in the bay. This river flows through Lake Wairarapa, 10 km from the coast.

The eastern Palliser Bay coastline was the subject of a large-scale recording project by the University of Otago from 1969 to 1972 (Leach 1981; Leach and Leach 1979) (Fig. 1). The project, referred to as the 'Wairarapa Archaeological Research Programme' (WARP), has been acknowledged as the first major regional archaeological research programme in New Zealand (McFadgen 2003). The investigated areas comprised numerous stone rows, mounds, pits, and house floors, thought in part to reflect pre-contact Māori horticultural systems. These features were mapped, and excavations were carried out at several sites including Whangaimoana, Washpool, Te Humenga, Pararaki, Waiwhero, and Black Rocks (Fig. 1). The research considerably advanced the knowledge about Māori gardening and early occupation of Palliser Bay. A diverse range of faunal, lithic, and artefactual remains were detailed in the results, but no macrofossil remains of any of the crop species were recovered in the excavations.

The archaeological monitoring that provided the samples for microfossil analyses was carried out to satisfy the conditions of Heritage New Zealand archaeological authorities related to private and civil works in Eastern Palliser Bay. These included a replacement of power pole infrastructure between Te Humenga Point and Cape Palliser, construction of a cell tower at Whangaimoana, and two private developments at Waiwhero involving the preparation of building sites and boundary fence construction. Individually, the archaeological sites from which samples have been obtained is compiled below.

Aerial site photography and section diagrams are shown in Figures 2–5. S28/9 (Whangaimoana) comprises an extensive occupation of Pleistocene river terraces along 1.4 km of the Whangaimoana Stream in the Moikau Valley (Fig. 1, 2A). This location has five consecutive river terraces with evidence of stone rows, mounds, pits, and house floors covering approximately 14 ha. It was this site that was the subject of the 1972 excavations which uncovered the Moikau house (Prickett 1979). The sample for microfossil analysis used in the present study (220041) was obtained from a darkened soil horizon below the topsoil on the highest terrace, Moikau V, adjacent to the present-day road.

S28/50 is in the Washpool area, which covers 9.7 ha of the coastal platform from Shag Rock south to the bank of the Makotukutuku River, and features include stone walls (Fig. 1, 2B). The soil sample used in the present study (280501) is from one of the walls.

S28/66 (Te Humenga) covers 9.3 ha of stone rows either side of the Cape Palliser Road on uplifted marine terraces (Fig. 1, 2C, 4A). Shell middens and burials are present on the lower marine terraces and have been recorded separately as S28/65 and S28/67. One sample for microfossil analysis (797257) was obtained from a buried section of stone row feature at the northern end of the Te Humenga horticultural site.

S28/68 (North Pararaki) also covers 9.3 ha of stone rows either side of the Cape Palliser Road on uplifted marine terraces (Figs 1, 2D, 4B). Shell middens and burials are present on the lower marine terraces and have been recorded separately as S28/28, S28/69, and S28/70. One sample for microfossil analysis (797268) was obtained from a buried soil horizon in the central part of the site on Leach's 'middle terrace' near to 'excavation C' on the inland side of the Cape Palliser Road (Leach 1979).

S28/77 (North Kawakawa) is part of a complex including a hilltop pā (S28/76), 7.3 ha of stone rows (S28/77), and shell middens and ovens on the lower lying land adjacent to the coast (S28/79 and S28/80), and stone rows (Fig. 1, 3A; 4C, D). This site provided two samples for microfossil analysis (797293 and 797296). The former was from the central one of the three stone rows sectioned by Leach (1979: 149–151), and the latter from a small hāngi feature on the inland side of the Cape Palliser Road, near the toe of the spur leading up to the pā.

S28/82 (South Kawakawa) is a cluster of three pits or depressions on the south side of the Kawakawa Stream (Fig. 1, 3A, 4E). One sample for microfossil analysis (797301) was recovered from a buried soil approximately 30 m to the southwest.

S28/91 (South Kawakawa) comprises 1.3 ha of stone rows on one of several gravel fans emanating from a series of smaller streams south of the Kawakawa Stream (Fig. 1, 3B). The site is located at the base of the coastal hills and has a centrally located pit with a raised rim. This site pro-

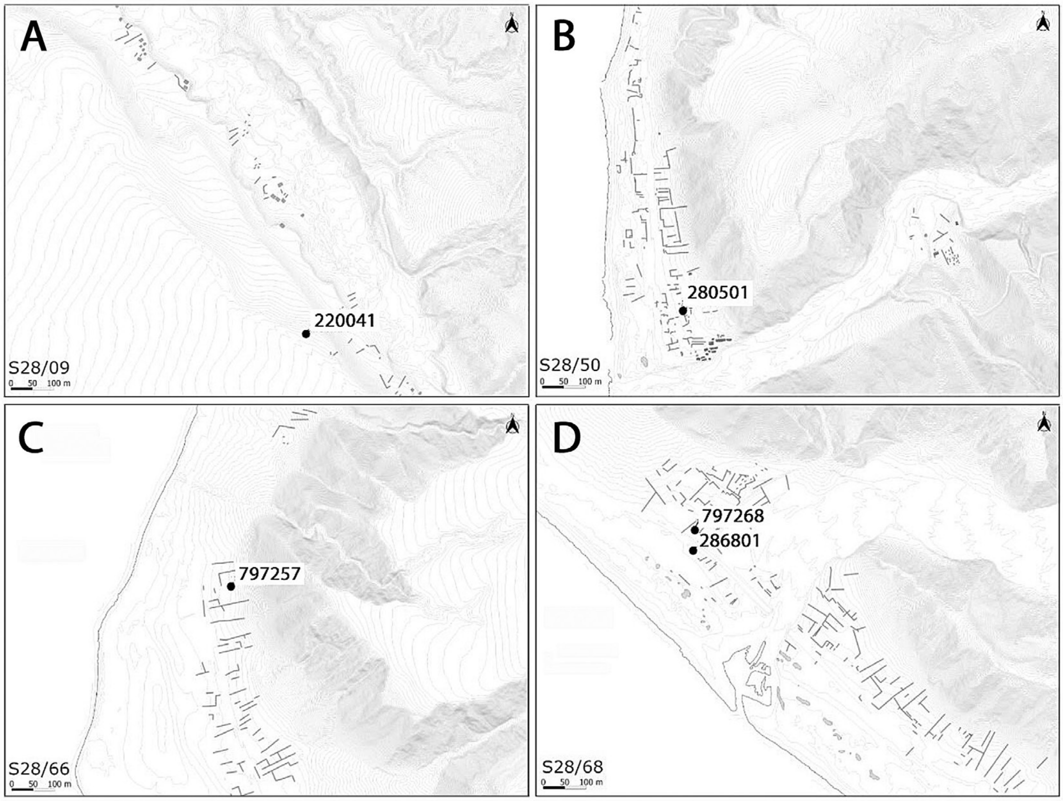

Figure 2. Site plans showing sample locations, with stone structures outlined (see also Fig. 3).

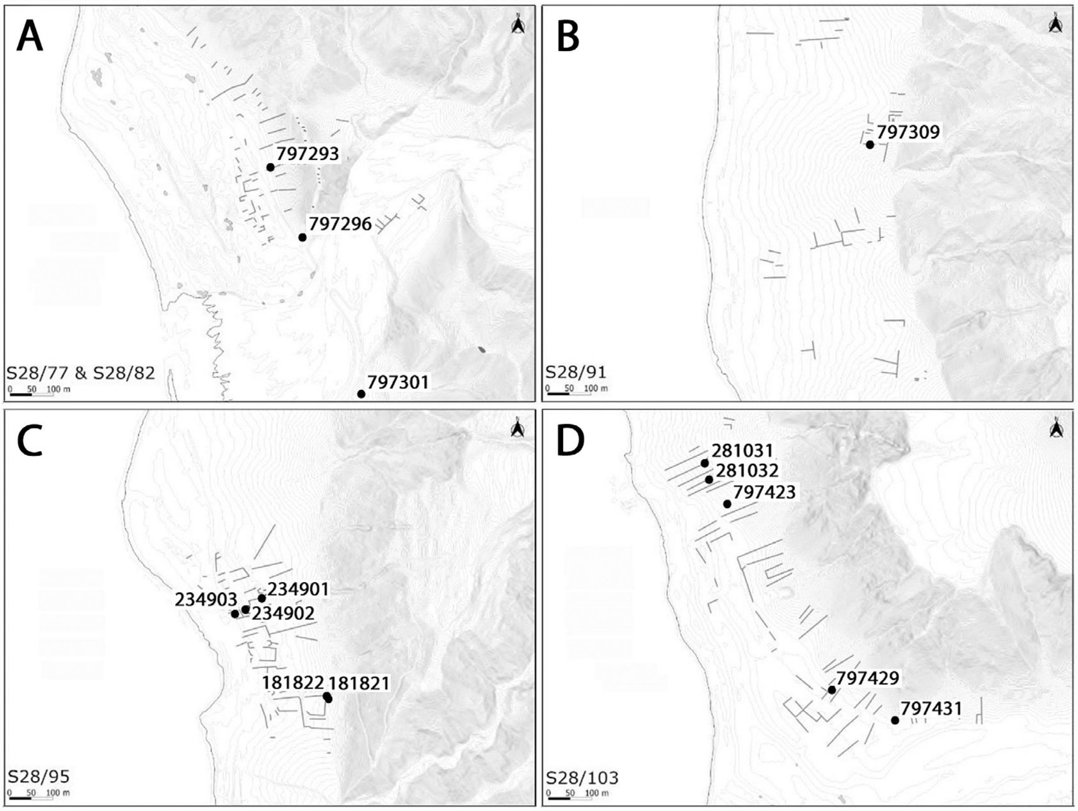

Figure 3. Site plans showing sample locations, with stone structures outlined (see also Fig. 2).

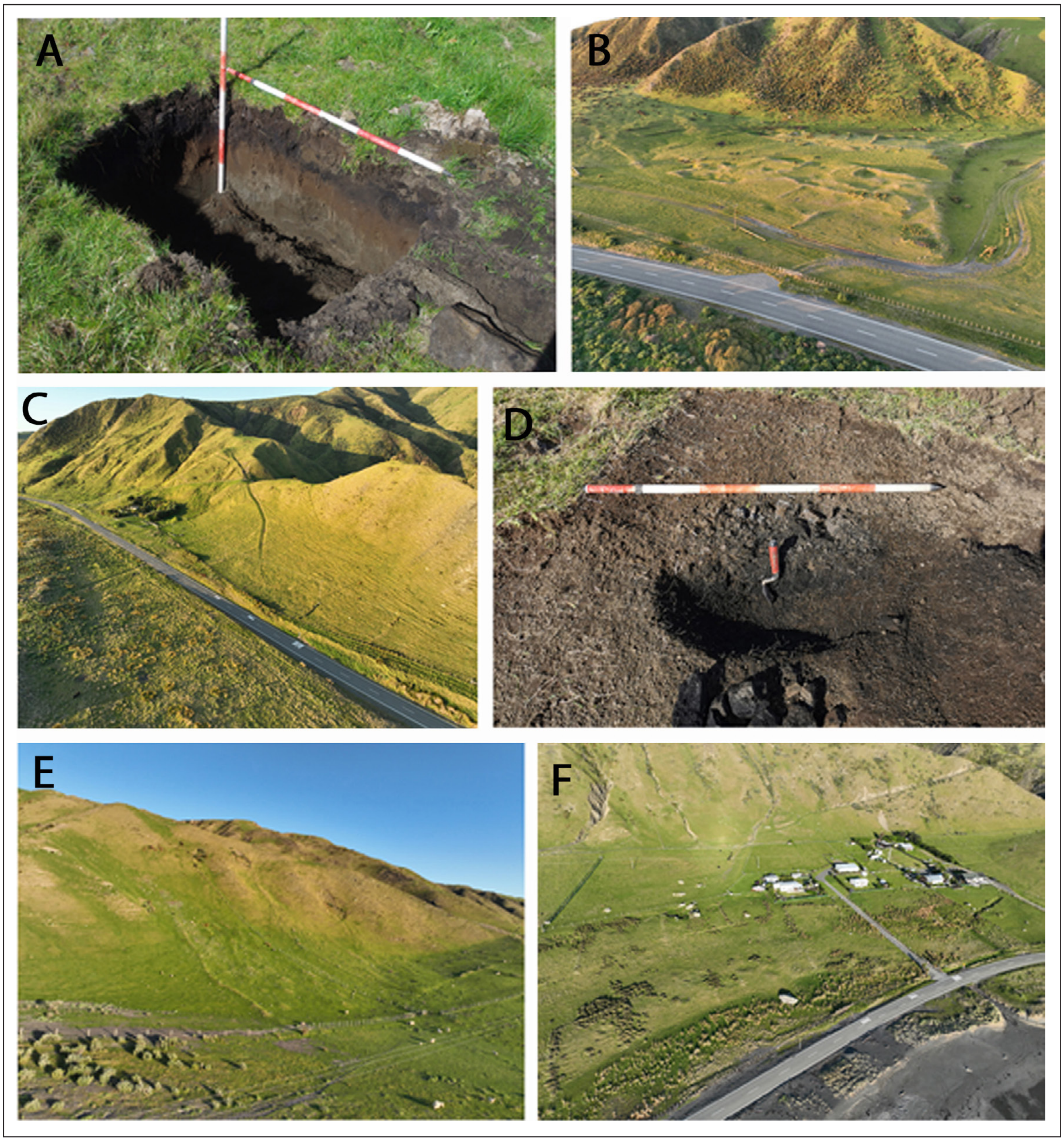

Figure 4. Aerial footage and soil profiles of sample sites (see also Fig. 5). A soil profile at Te Humenga sample site 797293 (A. Dodd, 7/10/2022). B drone footage of the stone rows at North Pararaki S28/68 (A. Dodd, 16/10/2022). C drone footage of the hilltop pā and stone rows at North Kawakawa S28/77 (A. Dodd, 16/10/2022). D oven Feature (797296) at North Kawakawa (D. Carley, 17/10/2022). E drone footage of the stone rows at South Kawakawa S28/91 (A. Dodd, 16/10/2022). F drone footage of the stone rows at the southern end of North Waiwhero S28/95 (A.Dodd, 16/10/2022).

vided one sample for microfossil analysis (797309), taken from a stone row on the seaward side of the farm fence.

S28/95 (North Waiwhero) extends over 10 ha of raised marine terraces on the north side of the Waiwhero Stream, a little north of Ngawī township (Fig. 1, 3C; 5A, B). The site provided two samples for microfossil analysis (181821 and 181822), one each from a paleo soil and a buried stone row, respectively, on a residential section near the southern end of the site.

S28/103 (the 'Black Rocks' horticultural site) provided three samples for microfossil analysis (797423, 797429, and 797431) (Fig. 1, 3D, 5D). The visible stone rows for this site cover 18 ha. The rows extend a considerable distance up the adjacent slope, and either side of a one-kilometre-long stretch of Cape Palliser Road. Shell middens, referred to as the Black Rocks site have been recorded under a separate number S28/104.

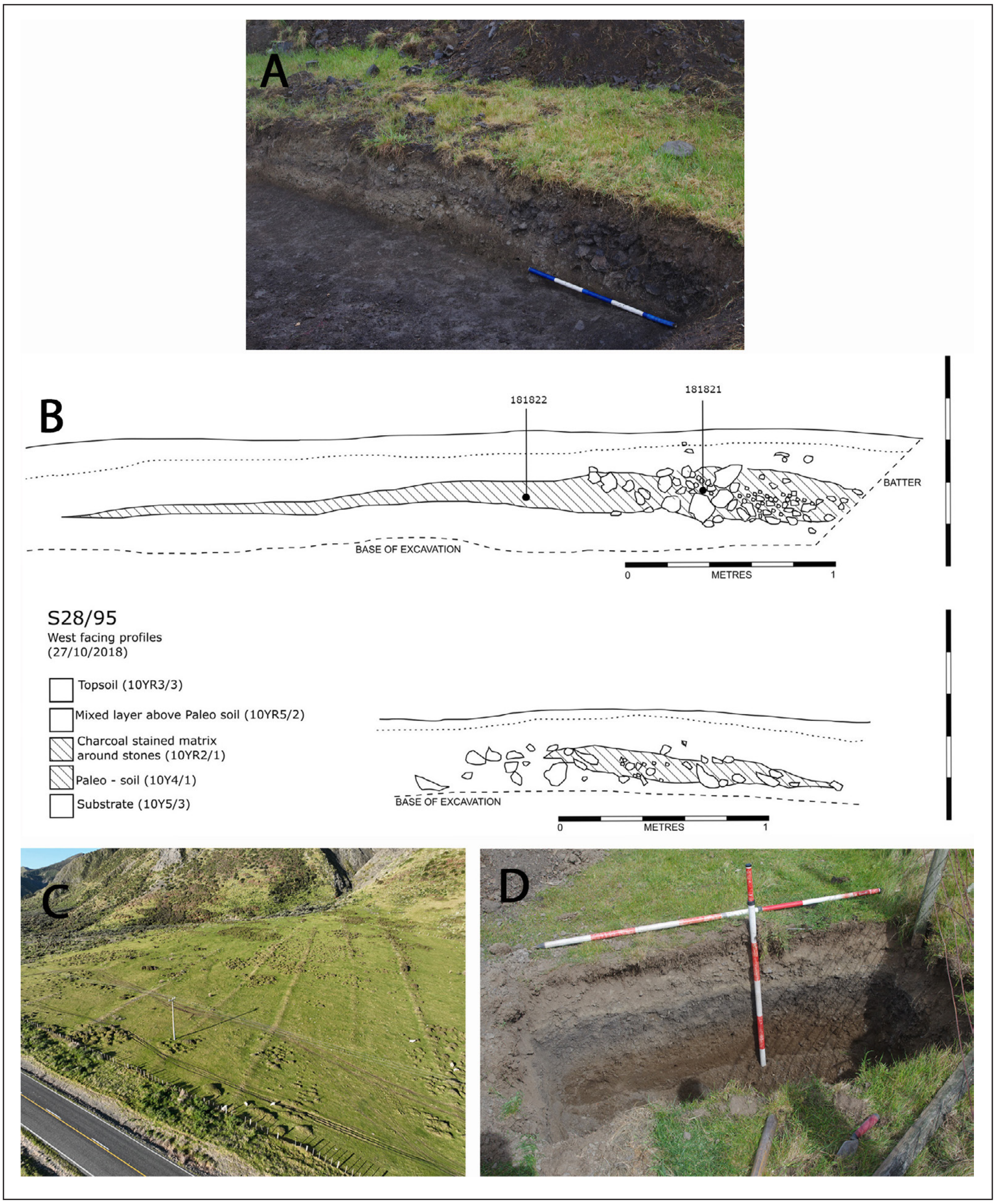

Figure 5. Aerial footage and soil profiles of sample sites (see also Fig. 4). A soil profile at Waiwhero sample sites 181821 and 181822 (A. Dodd, 27/10/2018). B drawing of soil profile at Waiwhero showing sample locations (reproduced from Dodd 2021). C drone footage of the stone rows at the northern end of the Black Rocks horticultural site S28/103 (A. Dodd, 16/10/2022). D soil profile at Black Rocks sample site 797423 (A. Dodd, 10/11/2022).

METHODS

Sampling

A total of 22 archaeological samples from Palliser Bay was analysed for plant microfossils and helminth parasite eggs to provide a record of past vegetation, environments, and human activity. Fifteen samples were analysed for pollen, phytoliths, and starch, and the remainder for starch only.

Of the 15 samples that received the three different microfossil analyses, nine were taken from a series of excavations for power pole replacement which occurred in late 2022 under Heritage New Zealand authority 2022–735. These were discrete excavations in areas along an existing alignment, so all had been excavated in the past. The pole replacement holes, however, were larger than the previous excavation, allowing inspection and sampling of the adjacent soil profile, undisturbed by modern excavations. One of the holes (797431) was positioned directly in a stone row, with backfill from the earlier excavation containing the same large stones as the row. Mechanical disturbance of this profile was identified during sampling.

The remaining six samples receiving the three microfossil analyses were taken during archaeological monitoring of unrelated earthworks. Two samples were obtained while monitoring earthworks for the preparation of foundations for a house and garage at Waiwhero under Heritage New Zealand authority 2018-182 (Dodd 2021). Another was obtained while monitoring earthworks for installation of a cell tower site at Whangaimoana under Heritage New Zealand authority 2022-004 (Dodd in prep. a), and three samples were obtained during archaeological monitoring of the construction of a boundary fence across part of the Waiwhero horticultural site (Dodd in prep. b).

In 2005, a preliminary, starch only analysis of six soil samples from the Leach and Leach (1979) Palliser Bay excavations was carried out by Horrocks. These samples carried the Te Papa Registration numbers AR000090, AR000098 (two samples), AR000100, AR000101, AR000102, and AR000106. Five samples (AR000090 = 280501, AR000098 = 281031 and 281032, AR000102 = 286801, and AR000106 = 280431) yielded convincing remains of starch and associated material (and parasite eggs) and are included in the present study.

Three radiocarbon samples were obtained for the project, two from site S28/79 Sample 797297 including one from marine shell and another from twig charcoal. The third sample was obtained from twig charcoal from Wk-56904 (WEB 013).

Plant microfossils

Identification of plant microfossils 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 cultigen microfossils and modern reference specimens were taken with a Canon EOS 600D camera mounted on a Nikon 400E microscope. 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 150 pollen grains and spores was counted for each sample, and the slides were scanned for types not found during the 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, macroscopic particles of charcoal are often seen by the naked eye in such samples. 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.

Phytoliths and other biosilicates

Samples were prepared for phytolith analysis by density separation (Horrocks 2020; Piperno 2006). A sum of at least 150 phytoliths was counted for each sample, and the slides were scanned for types not found during the counts.

Starch and associated material, and helminth eggs

Samples were prepared for combined starch and helminth analysis by density separation (1.7–1.8 specific gravity) with sodium polytungstate (David and Linquist 1982; Horrocks 2020), and presence/absence noted. Precaution was taken to avoid modern starch grain contamination (Crowther *et al.* 2014, Ma *et al.* 2017).

RESULTS

Radiocarbon dates

The three new radiocarbon dates are shown in Table 1 and Figure 6. Calibration of the dates was undertaken utilising OxCal 4.4 (Bronk Ramsey 2009), using ShCal20 for terrestrial samples and Marine20 with a Delta R value of -154 ± 38 for marine samples (Hogg *et al.* 2020). Two dates from S28/79 (Wk56547 797296A and Wk56548 797296B) were obtained from the same hāngi/oven context from short-lived *Dacrycarpus dacrydioides* charcoal fragments and *Paphies* sp. marine shell. The date from the charcoal sample provided a broad range when calibrated, 1650–1800 AD at 1σ, but closer examination of the calibration suggested it was multimodal, with two separate peaks around 1650–1670 AD and 1780–1800 AD at 1σ. The shell sample provided a date for 1500–1660 AD at 1σ, which is quite broad, but even at 2σ does not overlap with the later 18th century AD peak suggested by the charcoal date. As a result, it seems that the sample from S28/79 most likely dates from 1650–1670 AD. The date from S28/95 (Wk56904) returned a calibrated date range of around 1450–1490 AD

Table 1. *Radiocarbon dates from Palliser Bay: New dates from project (Wk56547, Wk56548, and WK56904) and previously reported dates discussed in the text (Leach* et al. *2022). Dates are reported using modern CRA and calibrated using ShCal20 and Marine20 with Delta R −154 ± 34.*

Lab ID	NZAA site no. & sample code	Material	CRA/error (yr BP)	1σ calibrated range (yr AD)	2σ calibrated range (yr AD)
Wk56547	S28/79 797296A	*Dacrycarpus dacrydioides* twig charcoal	256 ± 15	1650–1800	1640–1800
Wk56548	S28/79 797296B	*Paphies* sp. marine shell	757 ± 18	1500–1660	1440–1720
Wk56904	S28/95 234902	*Hebe* sp. short-lived charcoal	438 ± 13	1450–1490	1450–1620
Previously reported (Leach *et al.* 2022)					
NZ1310	S28/66	short-lived charcoal	784 ± 70	1219–1381	1159–1394
NZ1311	S28/68	"	676 ± 86	1292–1397	1226–1441
NZ1312	S28/68	"	737 ± 86	1230–1391	1181–1419
NZ1313	S28/68	"	712 ± 86	1277–1394	1211–1433
NZ1315	S28/77	"	693 ± 86	1285–1395	1221–1435
NZ1316	S28/95	"	484 ± 72	1408–1615	1329–1631
NZ1317	S28/104	"	566 ± 86	1319–1455	1281–1622

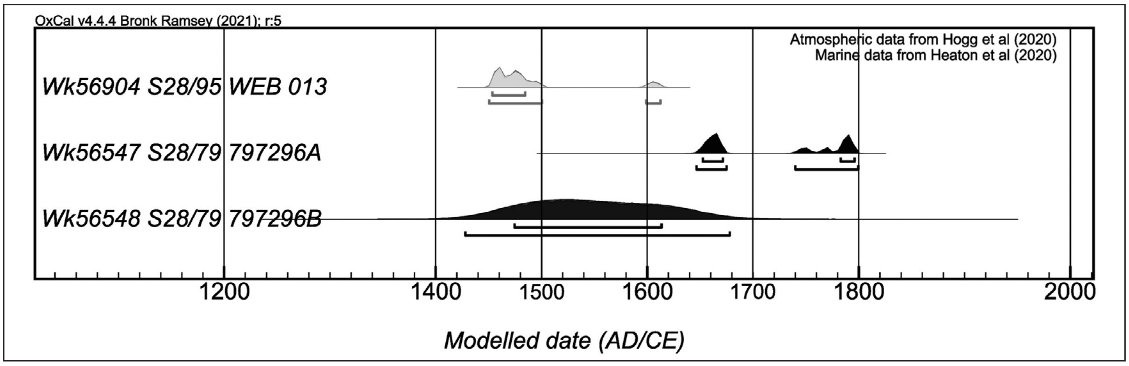

Figure 6. Radiocarbon dates from Palliser Bay project (calibrated using OxCal 4.4).

at 1σ, although at the 2σ there was a possibility of the date range extending to a peak around 1600 AD.

Pollen and spores

All samples contained microscopic fragments of charred plant material, reflecting fire activity by people in the region. The pollen and spore assemblages were generally similar, and variably dominated by *Pteridium esculentum* (bracken) spores and Poaceae (grass) pollen (Fig. 7). *Sonchus*/*Taraxacum* and *Coriaria* spp. (tutu) pollen and Anthocerotopsida (hornwort) spores were also observed in the samples. Cyperaceae pollen records a noticeably higher frequency in Samples 234902 and 234903. Pollen of Māori introduced *Cordyline* cf. *fruticosa* (tī pore) was found in Sample 234901 (Fig. 8A).

Small amounts or traces of pollen of European introduced plants were found in four samples (Fig. 7). These types comprised *Pinus* (pine trees) in the four samples, and the invasive herbs *Plantago lanceolata* (narrow-leaved plantain) and *Rumex* spp. (dock) in one sample. The coincident Ericaceae, Caryophyllaceae, and *Geranium* pollen in two of these samples could also be from exotic species. Although *Sonchus* and *Taraxacum* are native to New Zealand, in a modern context the latter in this case could include European introduced *Taraxacum officinale* (dandelion) for these four samples.

Phytoliths

All samples except 797309 contained sufficient phytoliths for meaningful counting. The phytolith assemblages were generally similar, and variably dominated by Poaceae leaf and fern frond phytoliths (Fig. 9). Other biosilicates observed in this study comprised small amounts or traces of fragments of sponge spicules.

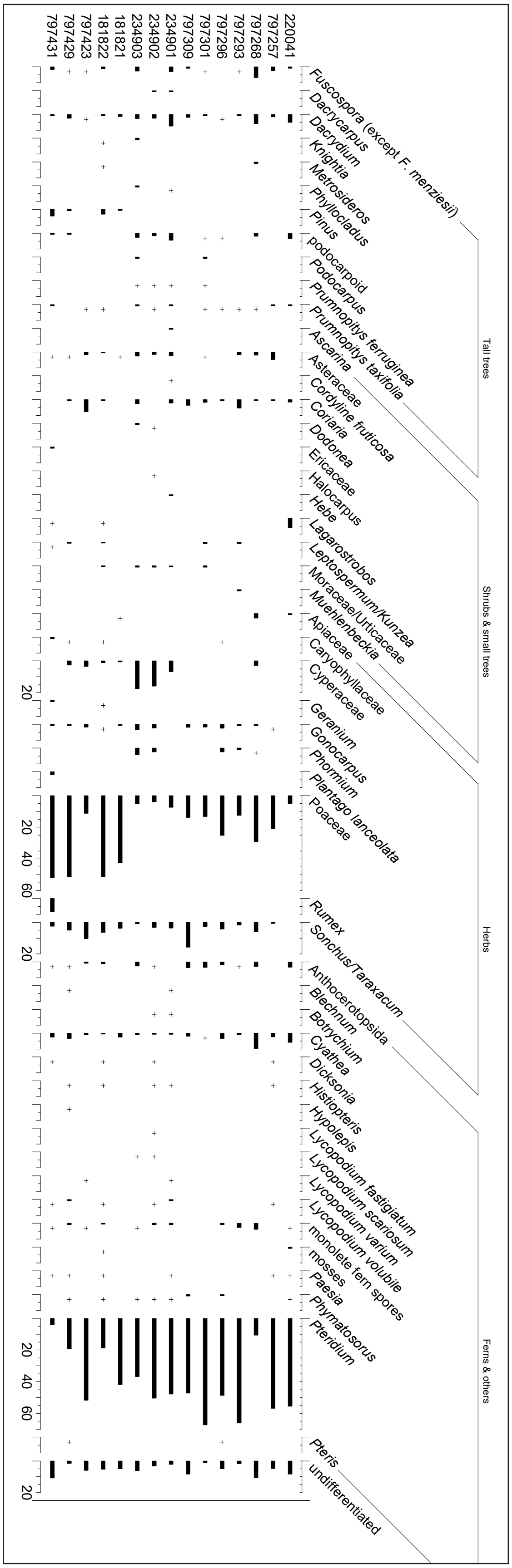

Figure 7. Pollen percentage diagram from Palliser Bay (+ = found after count).

Starch and associated material

This extraction showed all samples except one containing abundant fine microscopic fragments of mineral particles and relatively little plant material. The exception, Sample 797431, conversely showed very little mineral material and a relatively large amount of plant material, especially root hair material.

Two types of starch were identified in this study. Diagnostic features are outlined in detail in the Discussion. The first type, identified in generally large amounts in 18 samples, comprised mostly degraded individual starch grains (scores per sample, 20 × 40 mm coverslip) consistent with the tuberous roots of Māori introduced *Ipomoea batatas* (Table 2, Fig. 10A–R). A few relatively well-preserved grains were found in some samples. In addition, entire and fragmented xylem cells (vessel elements) consistent with this species were found in most of the samples (Table 2; Fig. 10S, 11A–D). Xylem is a type of tracheary tissue. The xylem ranged from reasonable well-preserved to very degraded.

The other type of starch, identified in relatively small amounts in 11 samples, comprised reasonable well preserved amyloplasts and degraded fragments thereof (13 in Sample 281031, 1–3 per remaining samples, 20 × 40 mm coverslip) consistent with the corms of Māori introduced cf. *Colocasia esculenta* (Table 2; Fig. 12A, B). Amyloplasts are sub-cellular units that synthesise and store starch grains. In addition, fragmented, degraded xylem cells consistent with this species were found in two of the samples (Table 2; Fig. 12C, D).

Helminth eggs

Two types of helminth egg were found in this study. The first type, found in Sample 797296, comprised an entire oval egg packet. The packet presents the distinctive appearance of those belonging to *Dipylidium caninum* (Table 2, Fig. 12E). The eggs are slightly smaller than expected for this cestode, which we assume to be a factor in preservation conditions. The second type, found in nine samples, is attributed to the parasitic nematode *Toxocara canis* (Table 2, Fig. 12F).

DISCUSSION

Evidence for site occupation and forest clearance

Previous archaeological investigations at Palliser Bay produced a range of evidence relating to Māori occupation from the 13th century onwards (Leach *et al.* 2022). Although there remains debate about the interpretation of those associated dates, Leach *et al.* (2022) also pointed to the uneven distribution of dates in their chronology (cf. Anderson and Petchey 2020). This includes a date clustering between 1250 AD and 1450 AD, a set around 1550 AD, and then a large gap of around two centuries. The date from

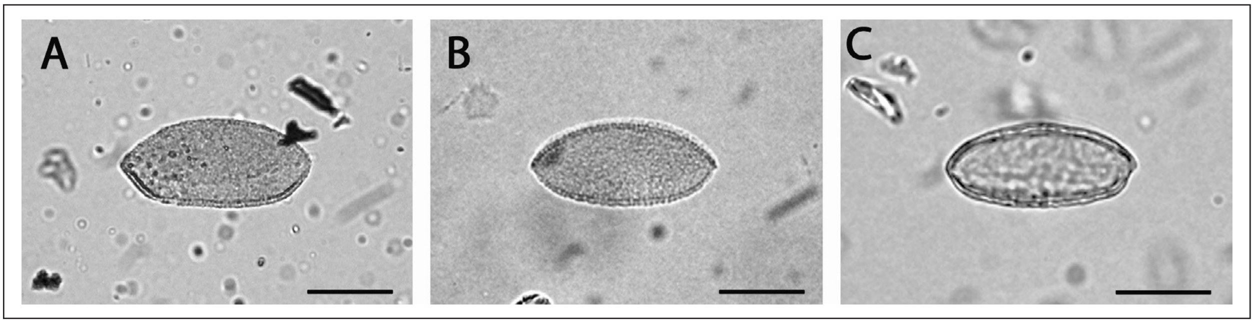

Figure 8. Fossil (234901) and modern reference pollen of *Cordyline fruticosa* and modern reference pollen of *C. australis*. Sample site in brackets; mounted in glycerol jelly; 600×; scale bars: 20 µm. A fossil *C. cf. fruticosa* pollen grain showing characteristic thick walled, granular, double layered exine, with rim finely beaded in cross-section (*cf.* B). B modern reference *C. fruticosa* pollen grain. C modern reference *C. australis* pollen grain showing less granular surface and lack of rim beading in cross-section. See also the Australasian Pollen and Spore Atlas (apsa.anu.edu.au/) and the work of Horrocks *et al.* (2022) for more images of these two species.

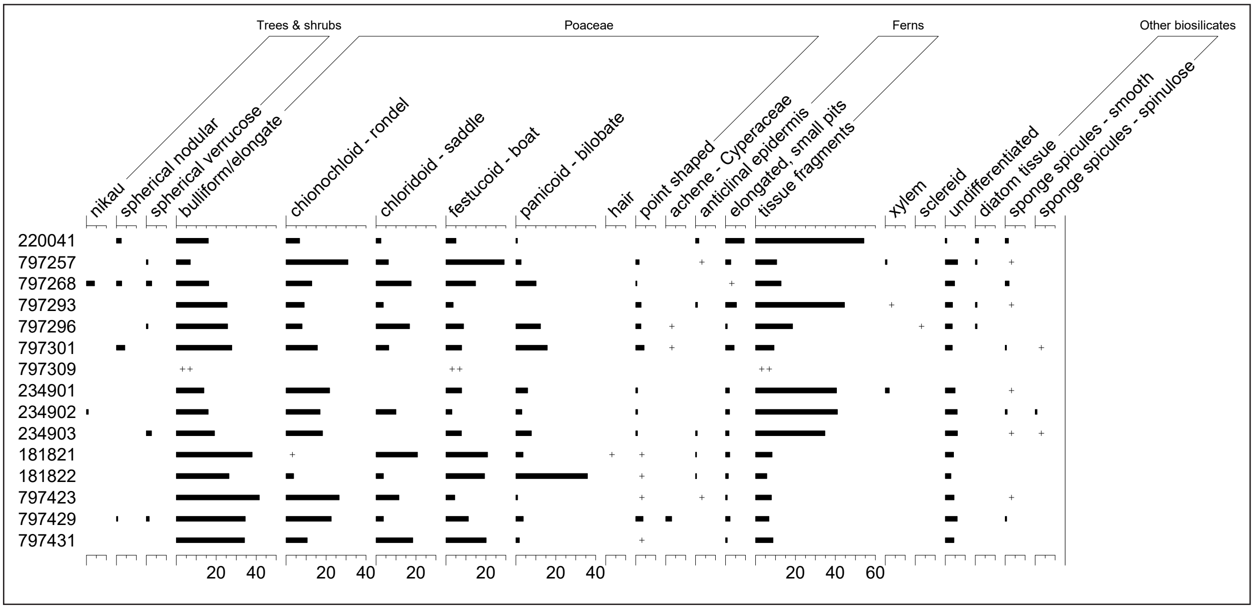

Figure 9. Phytolith percentage diagram from Palliser Bay (Other biosilicates not included in sum, + = found after count, ++ = present).

S28/95 extends the earliest cluster probably to the end of the 15th century and the dates from S28/79 in the mid to late 17th century, in the middle of the previously identified gap. The dates therefore confirm that the area continued to be occupied following the initial occupation in what Leach *et al.* (2022) described as the Early Prehistoric Period into and probably throughout the Late Prehistoric Period. Given the limited number of dates from the testing regime, future archaeological work will probably further fill in the missing parts of the sequence.

Several indigenous pollen and spore types observed in all samples, namely *Pteridium*, Poaceae, *Coriaria*, *Sonchus/Taraxacum*, and Anthocerotopsida, are indicators of landscape disturbance (Fig. 7). Coincident with the charred plant material and a paucity of tall tree pollen, they reflect a majorly disturbed landscape in large part cleared of forest by people. *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. It can form tall, dense stands over extensive areas. *Coriaria* shrubs/small trees commonly colonise bracken fernland (Wardle 2002). Poaceae generally indicate reduced forest canopy. The Anthocerotopsida comprise small inconspicuous plants that commonly colonise freshly disturbed and exposed soils (Wilmshurst *et al.* 1999).

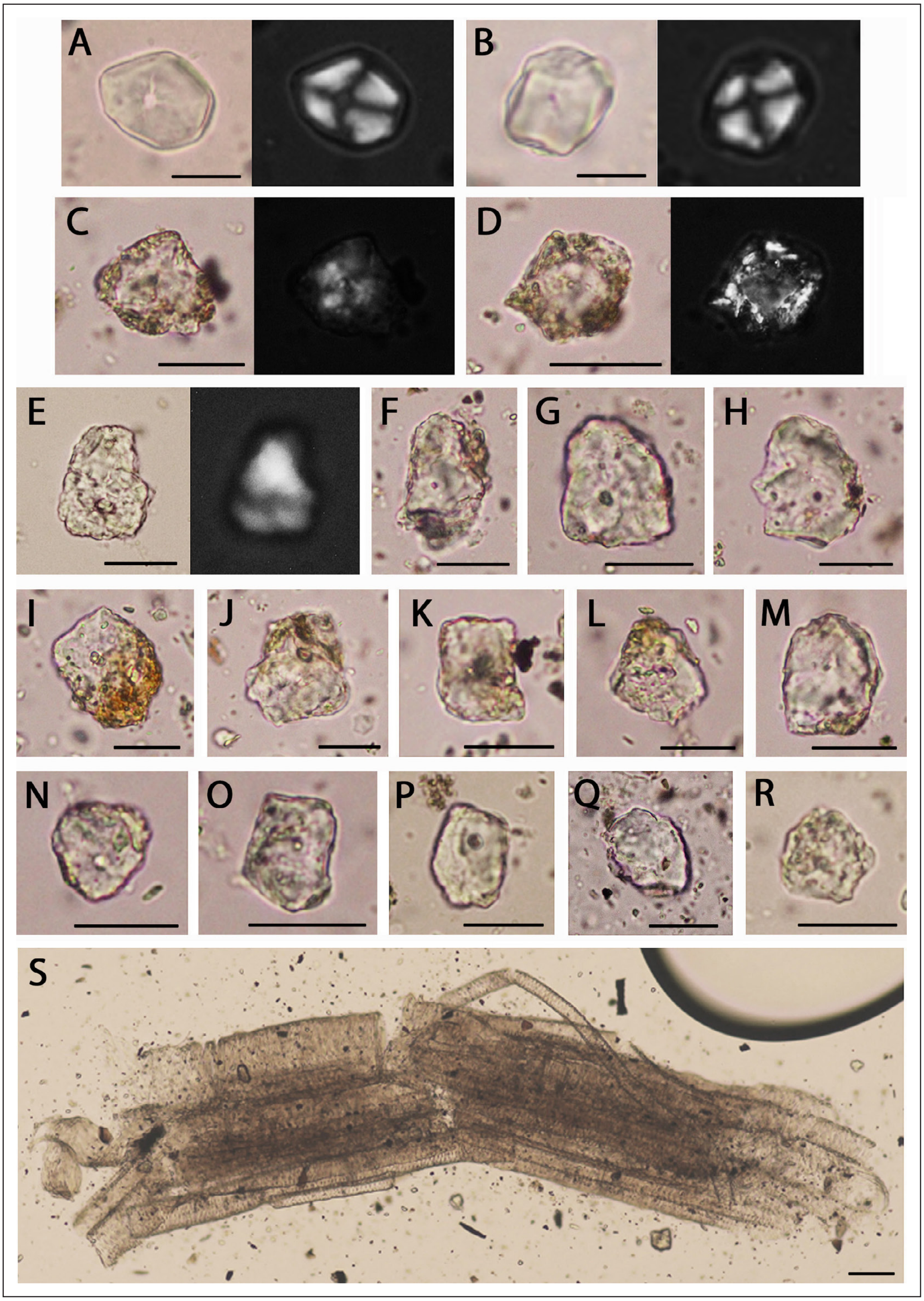

Figure 10. Fossil starch (A-R) and xylem (S) of *cf. Ipomoea batatas* root from Palliser Bay. Sample sites in brackets; mounted in glycerol jelly; 600×; black background: cross-polarised light; scale bars: 20 µm. A (281031), B (286801) well-preserved starch grains, with normal smooth and opaque grey appearance, and Maltese cross highly visible in cross-polarised light. C (797293), D (797423), E (797431), F, G, H (797257), I, J (797268), K (797296), L (797301), M, N, O (797429), P (22004), Q (281103), R (220041) degraded starch grains showing surficial roughening, discoloration (shades of yellow/amber/brown starting at the edges), grain and vacuole (hilum or core) expansion, and distortion (*cf.* Fig. 13A). C–E show partial retention of the Maltese cross in cross-polarised light. Vacuole visible in all grains, as a white or dark grey/black dot; pressure facets retained in most. S (220041) shows large bundle of generally well-preserved xylem vessels, broken in the middle (*cf.* Fig. 13B).

Table 2. *Starch and helminth eggs from Palliser Bay.*

Sample	*Colocasia esculenta*	*Ipomoea batatas*	Helminth eggs
220041		starch, xyelm	
280431			*Toxocara canis*
280501			*Toxocara canis*
797257	starch	starch, xyelm	
797268	starch	starch	
286801	starch, xylem	starch, xylem	
797293	starch	starch	*Toxocara canis*
797296	starch	starch, xylem	*Dipylidium caninum*
797301		starch, xylem	*Toxocara canis*
797309		starch	*Toxocara canis*
234901	starch	starch, xylem	*Toxocara canis*
234902	starch	starch, xylem	*Toxocara canis*
234903	starch	starch, xylem	*Toxocara canis*
181821		starch, xylem	
181822	starch	starch, xylem	
281031	starch, xylem	starch, xylem	
281032	starch	starch, xylem	*Toxocara canis*
797423		starch, xylem	
797429		starch, xylem	
797431		starch, xylem	

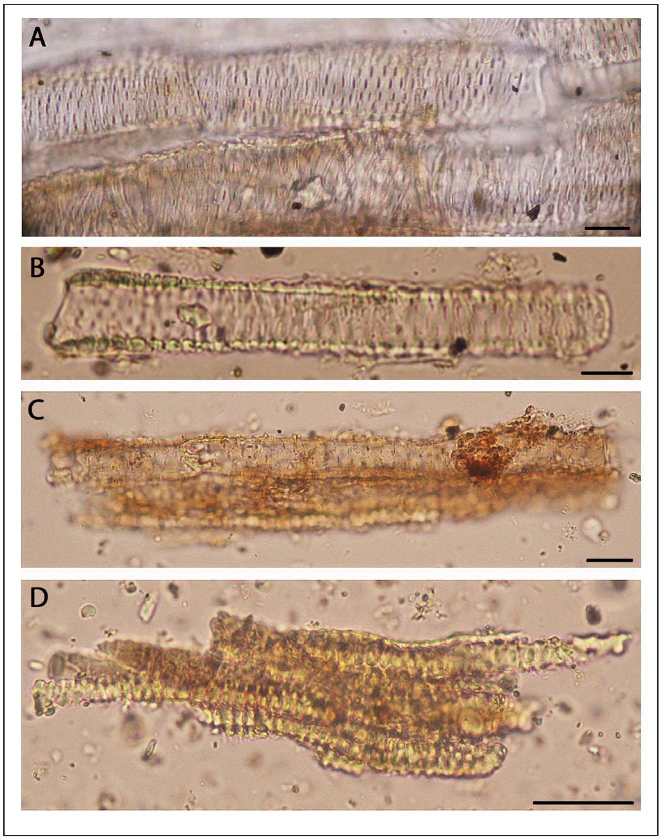

Figure 11. Fossil xylem vessel elements of *cf*. *Ipomoea batatas* root from Palliser Bay (cf. Fig. 13B). Sample sites in brackets; mounted in glycerol jelly; 600×; scale bars: 20 µm. A–C (220041), D (181822) xylem vessels showing characteristic thick walls with slit like pits, and progressive stages of decay, from well preserved with normal colouring of opaque grey (A) to shades of yellow/amber/brown, and pit distortion and loss (B–D) (cf. Fig. 13B).

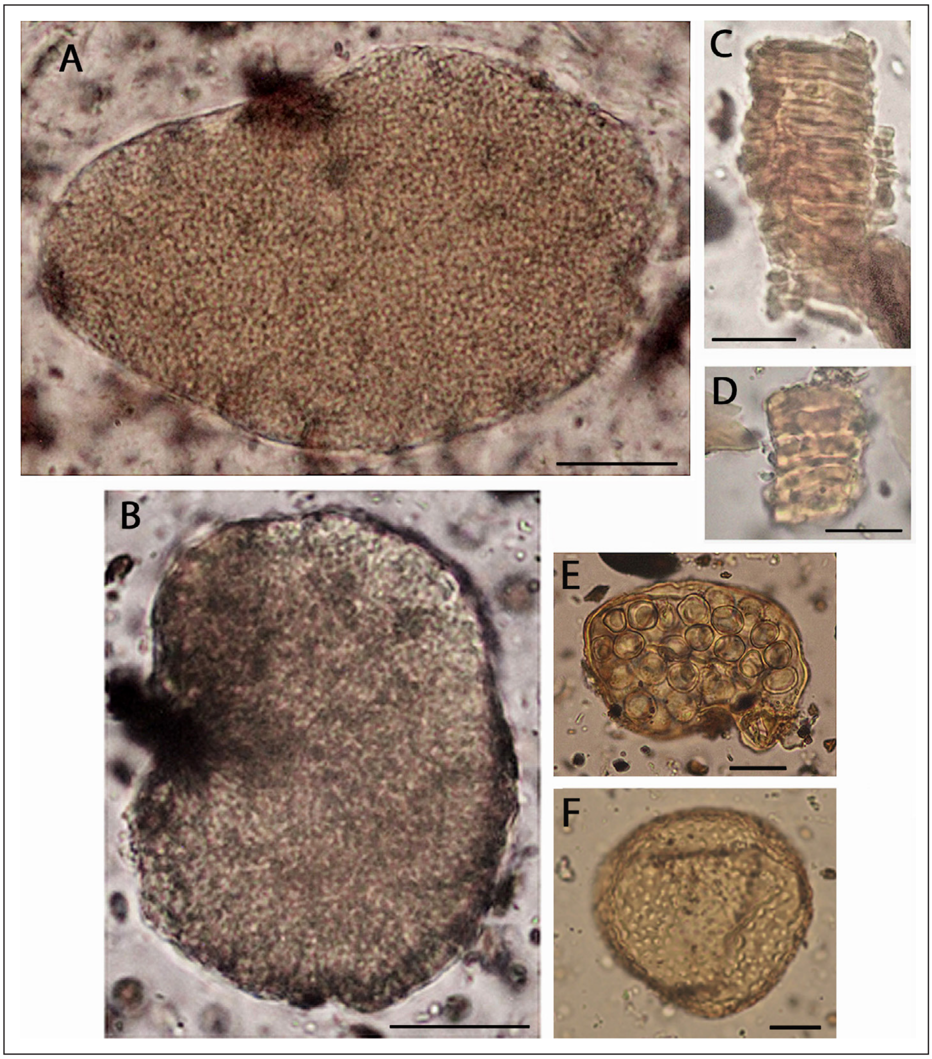

Figure 12. Microfossils of *cf*. *Colocasia esculenta* corm (A-D) and helminth eggs (E, F) from Palliser Bay. Sample sites in brackets; mounted in glycerol jelly; 600x; black background: cross-polarised light; scale bars: 20 µm. A, B (286810) well preserved, typically ovoid amyloplasts showing characteristic densely packed, sharply angular, tiny (≤ 4 µm) starch grains (thousands), and the central vacuole seen as a dark grey/black dot giving a distinctive grainy appearance (cf. Fig. 13C, D). C, D xylem cell fragments showing characteristic helical wall thickening (*cf*. Fig. 13E). E (797296) *Dipylidium caninum* egg packet, containing un-dehydrated, characteristic more or less oval eggs. F (797301) *Toxocara canis* egg, showing characteristic thick shell and pitted surface.

Sonchus/*Taraxacum* pollen type comprises a small number of invasive herbaceous species following disturbance and pollen of the two genera can be difficult to differentiate. Shoots and leaves of *Sonchus* spp. (pūhā) were gathered as food by early Māori (Crowe 1997). The larger amounts of Cyperaceae pollen in three of the samples could reflect damp ground conditions.

The small amounts or traces of European introduced pollen observed in four of the samples reflect mixing of older material by erosion, percolation, bioturbation, or mechanical disturbance (Fig. 7). This appears to be more the case for Sample 797431, which is the only sample with *Rumex* pollen, and which differed from all other samples in showing abundant microscopic plant material and very few mineral particles. This effect is consistent with the *in situ* sampling observation of possible modern mechanical disturbance.

The phytolith results, in particular the preponderance of Poaceae leaf and fern frond phytoliths, support the pollen and spore evidence of major landscape disturbance by people (Fig. 7, 9). Given the coincident general preponderance of *Pteridium* spores, a logical conclusion is that a large portion of the fern phytoliths is from this species. Other biosilicates in the samples, namely traces of diatom tissue and sponge spicule fragments, reflect the proximity of the sites to the coast.

Botanical evidence for agriculture

The Māori introduced food cultigens identified in this study, cf. *Colocasia esculenta*, *Cordyline* cf. *fruticosa*, and cf. *Ipomoea batatas*, are part of the small group of six introduced species cultivated by Māori at the time of European contact in the late 18th century. A recent summary is given in the work of Anderson and Petchey (2020). Almost all the numerous 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 and Kirch 1991).

Descriptions and photomicrographs of modern reference pollen, starch, and xylem of *Colocasia esculenta*, *Cordyline fruticosa*, and *Ipomoea batatas* are given in the works of Reichert (1913), Seidemann (1966), Loy *et al.* (1992), Horrocks *et al.* (2022, 2012a, 2012b), Horrocks *et al.* (2023a, b; 2004; 2007), Horrocks and Weisler (2006), Barber and Higham (2021), and the Australasian Pollen and Spore Atlas (apsa.anu.edu.au/). Details of the macro- as well as micro-remain finds of these species elsewhere in New Zealand and Polynesia are given in the works of Horrocks *et al.* (2023a, b). As ancient starch analysis is a relatively recent microfossil technique (cf. pollen and phytoliths) with new methods still developing (*e.g.*, Horrocks *et al.* 2023b), we take a cautious approach with identification. See also the works of Anderson and Petchey (2020) and Prebble *et al.* (2020) for critical perspectives on starch 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 specialised starch storage organs (Moore and Edgar 1976). Although New Zealand has several endemic species of the family to which *Cordyline fruticosa* belongs (Asparagaceae), the works of Cranwell (1953), Cranwell (1962), and Horrocks *et al.* (2022) show that *C. fruitcosa* pollen can be differentiated from those species' pollen. The most widespread and common of these species is *Cordyline australis* (cabbage tree), which we include with the photomicrography of *C. fruticosa* (Fig. 5C).

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 Palliser Bay. 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 and Higham 2021: S3 Table; Horrocks *et al.* 2004).

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. 13A). Some grains may reach 40 μm. The vacuole can sometimes be fissured. Nearly all grains have one domed surface and up to six flattened pressure facets. 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. 13B).

Colocasia esculenta corm amyloplasts, containing up to thousands of densely packed starch grains, are ovate, up to approximately 185 μm in diameter, with very thin enclosing double membranes (Fig. 13C, D). Starch grains are spherical, appearing sharply angular, and mostly <4 μm in diameter. The central vacuole often appears as a dark grey/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., masses and amyloplasts or fragments thereof. In archaeological soils and sediments, *C. esculenta* amyloplasts are commonly fragmented and without visible membrane tissue, although one of our examples appears to show a membrane outline (Fig. 12A).

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, 2024a; Horrocks and Thomas 2022; Horrocks and Weisler 2006) (Fig. 10A–R). 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). A similar result was obtained with SEM imaging of degraded *Colocasia esculenta* starch in a Marquesas Islands study (Horrocks *et al.* 2023b). Xylem cell decay involves discolouration, expansion, distortion, loss of pits, and disintegration (Fig. 11A–D).

To our knowledge, the starch results in this study provide to date the southernmost, direct evidence for premodern cultivation of cf. *Colocasia esculenta* anywhere (Barber 2004). The previous southern (terrestrial) limit was cf. *C. esculenta* starch in northwest Golden Bay (Horrocks 2004) (Fig. 1). Leach (1979b: 242) suggested that there was not suf-

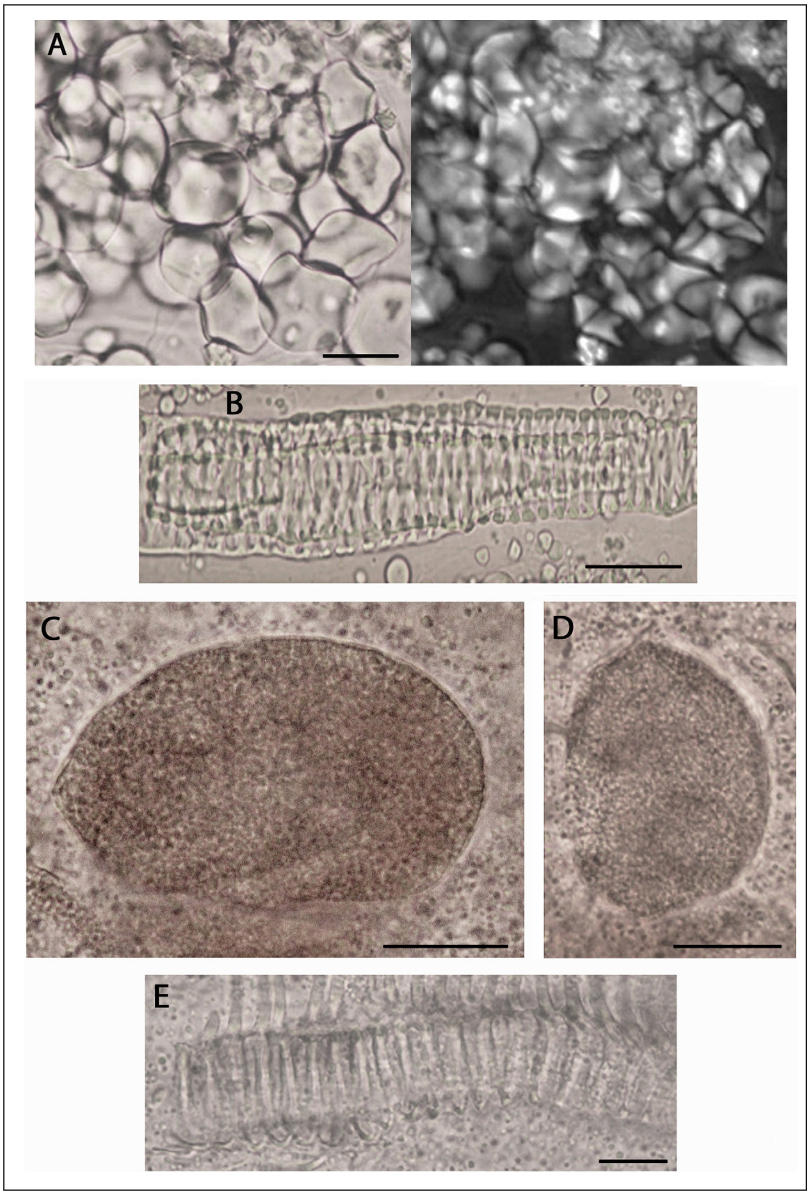

Figure 13. Modern reference *Ipomoea batatas* root starch grains and xylem (A, B), and *Colocasia esculenta* corm amyloplasts and xylem (C–E). Mounted in glycerol jelly; 600x; black background: cross-polarised light; scale bars: 20 µm. A grains of *I. batatas* showing characteristic facets and more or less central vacuole (hilum or core) seen as a white or dark grey/black dot. Grains show highly visible Maltese cross (crossing at hilum) in cross-polarised light. B xylem vessel element of *I. batatas* showing characteristic thick walls with slit like pits. C, D typically ovoid *C. esculenta* amyloplasts, with characteristic densely packed, tiny (≤ 4 µm), sharply angular starch grains (thousands), and the central vacuole seen as a dark grey/black dot giving a distinctive grainy appearance; E part of a *C. esculenta* xylem cell showing characteristic helical wall thickening.

ficient rainfall for this species at Palliser Bay, but the new research indicates that it was able to be cultivated there. Given the free-draining nature of the Palliser Bay stone gardens, Māori cultivation of this crop was presumably dryland, as opposed to wetland style. Other discussion of the southern extent of this species' cultivation is given in the works of Barber (2020) and Prebble *et al.* (2019, 2020). As this species is a shy pollinator in New Zealand, and with pollen that is less resistant to acetolysis than many other members of Araceae (Nusaifa Beevi 2009), its pollen has to date been identified at only three New Zealand sites, the others being on Greater Mercury Island (Prebble *et al.* 2019), Auckland Isthmus (Horrocks *et al.* 2023a), and a Nelson Bays off-shore sediment core (Handley *et al.* 2020) (Fig. 1).

In order to gain a fuller understanding of crop production in Palliser Bay, experimental *Ipomoea batatas* cultivation at Whatarangi was started in 2000 (Burtenshaw *et al.*

2003). This project observed the performance of traditional varieties planted using traditional methods in a location close to examples of known archaeological garden systems. Experimental *Colocasia esculenta* growing was initially included but abandoned shortly after due to poor yield (F. Leach pers. comm. 2023).

The presence of cf. *Ipomoea batatas* and cf. *Colocasia esculenta* starch remains in relatively large amounts in 18 of the 20 samples and very small amounts in 11 samples, respectively, suggests that *C. esculenta* was perhaps more of a minor crop in Palliser Bay. If this is the case, these results support the view that the southern extent of Māori cultivation of introduced warmer climate crops in temperate New Zealand was progressively, variably limited by length of growing season requirements.

The presence of cf. *Ipomoea batatas* starch material in almost all samples and the general similarity of these (barring one due to modern disturbance) in terms of content of plant material and fine microscopic mineral particles across such a wide geographic range in Palliser Bay suggests a lengthy period of extensive, intensive cultivation of this species. Given the free-draining, fine particle substrates, and windiness of the study area, coupled with widespread, intensive mechanical disturbance by Māori gardeners, frequent wind (dust) erosion of cultivated soils could be expected to have occurred, resulting in redeposition of plant microfossils during the horticultural period. The bay's proximity to Cook Strait results in a high frequency of strong winds, which are very gusty because the lower-level flow is strongly forced by the rugged topography (Chappell 2014). Baring Head, on the eastern promontory of the bay, has a very high mean number of days per year of gusts >63 km per/hr (255) and >96 km/hr (72). If wind erosion is a factor in our case, association of microfossil types with specific sampled landscape features may not necessarily be direct.

Early European explorers' accounts also reported Māori gardeners using grass as mulch (Leach 1979b). The large amounts of grass pollen in some of the samples supports this observation (Fig. 7).

To date, the southernmost direct evidence of *Ipomoea batatas* cultivation in New Zealand, and possibly anywhere, is starch grains from a pit at Pūrākaunui on the Otago coast (Barber and Higham 2021). This site is over 200 km south of the current southernmost limit of record for premodern *I. batatas* production, which is based solely on the presence of pits at the Banks Peninsula latitude deemed to be for tuberous root storage.

Helminth eggs

Descriptions and photomicrographs of modern reference eggs of *Toxocara canis* and *Dipylidium caninum* can be found in the works of Brunanska (1997), Prociv (1990), and Saari *et al.* (2018). *Dipylidium caninum* is principally a cestode of dogs, other canids, and cats, but the species has zoonotic potential if infected fleas are ingested by humans, and modern cases are nearly always reported in young children (Sapp and Bradbury 2020). *Dipylidium caninum* adults live in the small intestine of the definitive host and release gravid segments into the environment via the host faeces. The segments are full of egg packets, up to c. 100 µm or more in size, which may contain up to 30+ eggs (Fig. 12E). These are ingested by flea larvae and develop within a cyst in the adult flea. When an infected flea is eaten by a dog, the infective stage is released into the intestine of the host and becomes an adult.

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.

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 *et al.* 2023a), and an early Māori settlement north of Dunedin (*T. canis*) (Horrocks *et al.* 2024b). Eggs of *T. canis* are not common in archaeological studies worldwide but have been found at an early Lapita site in Bismarck Archipelago (Horrocks *et al.* 2024c), 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) (Richarson *et al.* 2012).

CONCLUSIONS

In this study, the plant microfossil evidence of large-scale landscape disturbance by people is consistent with palynological sediment core records from throughout New Zealand, which have documented widespread deforestation of lowland New Zealand by early Māori commencing after settlement in the early 14th century. The use of the archaeological samples obtained from infrastructure and private developments to enrich the known spatial and temporal context of these crops and track ancient parasites demonstrates the importance of the heritage management framework in New Zealand (Bickler 2018).

The identification of three specific Māori-introduced crops, namely *Colocasia esculenta, Cordyline fruticosa*, and *Ipomoea batatas*, improves upon the paucity of direct evidence of Māori agricultural activity in the Palliser Bay stone gardens, and generally in wider New Zealand linked directly to radiocarbon chronologies (Anderson and Petchey 2020).

The addition of parasitological analysis, in this case identifying *Dipylidium caninum* and *Toxocara canis*, parasites that could have adversely affected people and kurī over a wide area of Palliser Bay, extends the combined plant microfossil approach to the realm of helminthiasis. This offers an additional or alternative method to the bone and DNA analyses for tracking the Pacific-wide spread of kurī and other commensals.

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References

Anderson, A., & Petchey, 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): 351–81.

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. 169–2.

Barber, I.G. 2020. Further wet-taro evidence from Polynesia's southernmost Neolithic production margins. *PNAS*, 117(3): 1257–8.

Barber I.G., & Higham T.F.G. 2021. Archaeological science meets Māori knowledge to model pre-Columbian sweet potato (*Ipomoea batatas*) dispersal to Polynesia's southernmost habitable margins. *PLoS ONE*, 16(4):e0247643. http://dx.doi.org/10.1371/journal.pone.0247643

Best, E. 1976. *Maori Agriculture*, *Reprint*. Wellington: A.R. Shearer, Government Printer.

Bickler, S.H. 2018. *Cultural Resource Management Archaeology in New Zealand: A Guide for Students and Practitioners.* Auckland: Bickler Consultants Ltd.

Bouchet, F. 1995. Recovery of helminth eggs from archeological excavations of the Grand Louvre (Paris, France). *Journal of Parasitology*, 81(5): 785–7.

Bouchet, F., Araújo, A., Harter, S., Chaves, S M., Duarte, A.N., Monnier, J.L., & Ferreira, L.F. 2003. *Toxocara canis* (Werner, 1782) eggs in the Pleistocene site of Menez-Dregan, France (300,000–500,000 years before present). *Memórias do Instituto Oswaldo Cruz*, 98(Suppl. 1): 137–9.

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

Brunanska, M. 1997. *Toxocara canis* (Nematoda: Ascaridae): The fine structure of the oviduct, oviduct-uterine junction and uterus. *Folia Parasitologica* 44(1): 55–61.

Chappell, P.R. 2014. *The Climate and Weather of Wellington*, *2nd edn*. NIWA Science and Technology Series No. 65.

Collins, G.H. 1981. A survey of gastro-intestinal helminths of dogs in New Zealand. *New Zealand Veterinary Journal,* 29(9): 163–4.

Cooper, R.C. 1967. *Ipomoea pes-caprae* (Convolvulaceae) on Ninety Mile Beach, New Zealand. *Records of the Auckland Institute and Museum*, 6: 171–4.

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

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.

Crowther, A., Haslam, M., Oakden, N., Walde, D., & Mercader, J. 2014. Documenting contamination in ancient starch laboratories. *Journal of Archaeological Science*, 49: 90–104.

David E.D., & Lindquist W.D. (1982). Determination of the specific gravity of certain helminth eggs using sucrose density gradient centrifugation. *Journal of Parasitology*, 68(5): 916–9.

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).

Dodd, A., 2021. *Archaeological Report: Lot 2 DP443915, 2919 Cape Palliser Road South Wairarapa*. Unpublished client report.

Dodd, A., in prep. a. *Archaeological Report: Whangaimoana Cell Tower Installation, Palliser Bay*. Unpublished Report to Rural Connectivity Group and Heritage New Zealand Pouhere Taonga.

Dodd, A., in prep. b. *Archaeological Report: Fenceline Construction, 2909 Cape Palliser Road, South Wairarapa*. Unpublished client report.

Dodd, A. in prep. c. *Archaeological Report: Powerco Pole Replacement, IR14258, Cape Palliser*. Unpublished report for Powerco Ltd. and Heritage New Zealand.

Greig, K., & Rawlence, N. 2021. The contribution of kurī

(Polynesian dog) to the ecological impacts of the human settlement of Aotearoa New Zealand. *Frontiers in Ecology and Evolution*, http://dx.doi.org/10.3389/fevo.2021.757988

Greig, K., & Walter, R. 2021. A Re-Assessment of the role of dogs (*Canis familiaris*) in early Aotearoa New Zealand. *Human Ecology*, http://dx.doi.org/10.1007/s10745-021-00285-2

Handley, S.J., Swales, A., Horrocks, M., Gibbs, M., 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

Harris-Linton, M. 2001. *'Toxocara canis' (On-line), Animal Diversity Web*. https://animaldiversity.org/accounts/Toxocara_canis/ (accessed June 18 2023).

Hather, J., & Kirch, P.V. 1991. Prehistoric sweet potato (*Ipomoea batatas*) from Mangaia Island, central Polynesia. *Antiquity*, 65(249): 887–893.

Hogg, A., Heaton, T.J., Hua, Q., Palmer, J., Turney, C., Southon, J., Bayliss, A., Blackwell, P.G., Boswijk, G., Bronk Ramsey, C., Petchey, F., Reimer, P., Reimer R., & Wacker, L. 2020. SHCAL20 Southern Hemisphere calibration, 0–55,000 years cal BP. *Radiocarbon* 62(4): 759–78. http://dx.doi.org/10.1017/RDC.2020.59

Horrocks, M. 2004. Polynesian plant subsistence in prehistoric New Zealand: a summary of the microfossil evidence. *New Zealand Journal of Botany*, 42(2): 321–34.

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., Allen M.S., & Fox, A. 2023b. New microfossil approaches and multi-proxy analysis reveal pre-contact Polynesian plant translocations, Marquesas Islands. *Environmental Archaeology*, http://dx.doi.org/10.1080/14614103.2023.2226477

Horrocks, M., Bader H-D., Simmons, A. & Adamson, J. 2022. Pollen and phytoliths in archaeological features from North Island, New Zealand, reveal 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., 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., Baisden, W.T., Flenley, J., Feek, D., Haoa-Cardinali, S., González Nualart, L. & Edmunds Gorman, T. 2017. Pollen, phytolith and starch analyses of dryland soils from Easter Island show widespread vegetation clearance and Polynesian-introduced crops. *Palynology*, 41(3): 339–50.

Horrocks, M., Baisden, W.T., Nieuwoudt, M.K., Flenley, J., Feek, D., González Nualart, L., Haoa-Cardinali, S. & Edmunds Gorman, T. 2012b. Microfossils of Polynesian cultigens in lake sediment cores from Rano Kau, Easter Island. *Journal of Paleolimnology*, 47(2): 105–284.

Horrocks, M., Bickler, S., Gumbley, W. & Jones, B. 2024a. Plant microfossil and ^{14}C analysis of archaeological features at Coromandel Peninsula, New Zealand: Evidence for regional Māori use of introduced and indigenous plants. *Journal of Pacific Archaeology*, 13(2): 33–51.

Horrocks, M., Brown, A., Brown J., & Presswell, B. 2023a. 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*, 62(1): 97–119.

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., 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., Irwin, G.J., McGlone, M.S., Nichol, S.L., & Williams, L. 2003. Pollen, phytoliths and diatoms in prehistoric coprolites from Kohika, Bay of Plenty, New Zealand. *Journal of Archaeological Science*, 30(1): 13–20.

Horrocks, M., & Lawlor, I. 2006. Microfossil analysis of soil from Polynesian stone fields in South Auckland, New Zealand. *Journal of Archaeological Science*, 33(2): 200–17.

Horrocks, M., Nieuwoudt, M.K., Kinaston, R., Buckley, H., & Bedford, S. 2014. Microfossil and Fourier Transform InfraRed analyses of Lapita and post-Lapita human dental calculus from Vanuatu, Southwest Pacific. *Journal of the Royal Society of New Zealand*, 44(1): 17–33.

Horrocks, M., Presswell, B., & Smith, I.W.G. 2024b. New discoveries from the early Māori village at Shag River Mouth, New Zealand, reveal intestinal parasites. *Archaeology in Oceania*, http://dx.doi.org/10.1002/arco.5315

Horrocks, M., Shane, P.A., Barber, I.G., D'Costa, D.M., & Nichol, S.L. 2004. Microbotanical remains reveal Polynesian agriculture and mixed cropping in early New Zealand. *Review of Palaeobotany and Palynology*, 131(3–4): 147–57.

Horrocks, M., Summerhayes, G., & Presswell, B. 2024c. Palaeoparasitology confirms Early Lapita evidence of pig and dog at Kamgot, Bismarck Archipelago. *Journal of Helminthology*, 98(e8): 1–5, http://dx.doi.org/10.1017/S0022149X23000998

Horrocks, M., & Thomas, F. 2022. Botanical remains of the last 1800 years from Tarawa, Republic of Kiribati, reveal ancient aroid (*Cyrtosperma merkusii* and *Colocasia esculenta*) pit cultivation and other cultigens. *Journal of Island and Coastal Archaeology*, http://dx.doi.org/10.1080/15564894.2022.2069178

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.

Irwin, G.J., Horrocks, M., Williams, L.J., Hall, H.J., McGlone, M.S., & Nichol, S.L. 2004. Evidence for diet, parasites, pollen, phytoliths, diatoms and starch grains in prehistoric coprolites from Kohika, In G.J. Irwin (ed.) *Kohika. The Archaeology of a Late Maori Lake Village in the Ngati Awa Rohe, Bay of Plenty, New Zealand*. Auckland: Auckland University Press, pp. 217–38.

Kahn, J.G., Horrocks, M., & Nieuwoudt, M.K. 2014. Agriculture, domestic production, and site function: Micro-fossil analyses and late prehistoric landscapes of the Society Islands. *Economic Botany*, 68(3): 246–263.

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

Leach, B.F. 1981. The prehistory of the Southern Wairarapa. *Journal of the Royal Society of New Zealand*, 11(1): 11–33.

Leach, B.F. & Leach, H.M. (eds.) 1979. *Prehistoric Man in Palliser Bay*. Bulletin of the National Museum of New Zealand Number 21. Wellington: National Museum of New Zealand.

Leach, B.F., Leach, H.M., & R.G. Law, 2022. *The Chronology of Pre-European Settlement in Palliser Bay: A Re-Evaluation of Radiocarbon Dating Fifty Years On*. ResearchGate Manuscript.

Leach, H. 1979a. Evidence of prehistoric gardens in eastern Palliser Bay, In Leach, F.M & H.M. Leach (eds.) *Prehistoric Man in Palliser Bay*, Bulletin of the National Museum of New Zealand Number 21. Wellington: National Museum of New Zealand, pp. 137–61.

Leach, H. 1979b. The significance of early horticulture in Palliser Bay for New Zealand prehistory, In F.M. Leach & H.M. Leach (eds.) *Prehistoric Man in Palliser Bay*, Bulletin of the National Museum of New Zealand Number 21. Wellington: National Museum of New Zealand, pp. 241–9.

Leach, H. 1984. *A Thousand Years of Gardening in New Zealand*. Wellington: A.H. & A.W. Reed Ltd.

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: 898–912.

Ma, Z., Zhang, C., Li, Q., Perry, L., & Yang, X. 2017. Understanding the possible contamination of ancient starch residues by adjacent sediments and modern plants in Northern China. *Sustainability*, 9(5): 752.

McFadgen, B., 2003, *Archaeology of the Wellington Conservancy: Wairarapa: A Study in Tectonic Archaeology*. Wellington: Department of Conservation.

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, N.T. 1993. Paleovegetation studies of New Zealand's climate since the Last Glacial Maximum, In H.E. Wright, J.E. Kutzbach, T. Webb III, W.F. Ruddiman, F.A. Street-Perrott, & 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. *PNAS,* 107(50): 21343–8.

Moore L.B., & Edgar E. 1976. Indigenous Tracheophyta. Monocotyledones except Gramineae. Wellington: Government Printer.

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.). Unpublished PhD thesis. Thiruvananthapuram: University of Kerala.

Pearsall, D.M. 2015. *Paleoethnobotany: A handbook of Procedures, 3rd Edn.* 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. *PNAS*, 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. *PNAS*, 117: 1259–60.

Prickett, N. 1979. Prehistoric occupation in the Moikau Valley, Palliser Bay, In F.M. Leach & H.M. Leach (eds.) *Prehistoric Man in Palliser Bay*. Bulletin of the National Museum of New Zealand Number 21. Wellington: National Museum of New Zealand, pp. 163–184.

Prociv, P. 1990. Observations on the morphology of *Toxocara pteropodis* eggs. *Journal of Helminthology*, 64(4) 271–7.

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

Richardson, D.J., Guillén, S., Beckett, R., Kyle, W., Conlogue, G., & Harper-Beckett, K. 2012. Archaeohelminthology of the Chiribaya Shepherd, *Canis familiaris* (700–1476 AD) from southern Peru. *Comparative Parasitology*, 79(1): 133–7.

Saari, S., Näreaho, A., & Nikander, S. 2018. Canine parasites and parasitic diseases. Academic Press, http://dx.doi.org/10.1016/C2016-0-05286-5

Sapp, S.G.H., & Bradbury, R.S. 2020. The forgotten exotic tapeworms: a review of uncommon zoonotic Cyclophyllidea. *Parasitology*, 147(5): 533–58.

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

Walter, R., Buckley, H., Jacomb, C., & Matisoo-Smith, E. 2017. Mass migration and the Polynesian settlement of New Zealand. *Journal of World Prehistory*, http://dx.doi.org/10.1007/s10963-017-9110-y

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

Whistler, W.A. 2009. *Plants of the Canoe People: An ethnobotanical voyage through Polynesia*. Lawani: National Tropical

Botanical Garden.

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(3): 523–40.