DOI: 10.20417/nzjecol.42.21

Two new Holocene vegetation records from the margins of the Canterbury Plains, South Island, New Zealand

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Published online: 23 May 2018

Abstract: Canterbury's gravelly outwash plains offer few of the natural deposits in which floral remains are typically preserved and hence represent a significant geographical gap in our knowledge about New Zealand's pre-settlement terrestrial ecosystems and their response to anthropogenic activities. We contribute new insights into the poorly known Holocene vegetation history of this region by reporting two new mid-late Holocene pollen records from the western (Hallsbush) and eastern (Travis Swamp) margins of the Canterbury Plains. Both records show local forest dominance prior to Polynesian settlement. Forest was cleared rapidly after human settlement at the eastern site, but despite local fires that burnt the wetland the forest was retained at the western site until after European settlement. Together with the few pollen records previously published from the margins of the Canterbury Plains, a clear pattern of beech forest dominance in the west and podocarp/hardwood forest dominance on the plains to the east at the time of human settlement emerges. However, additional sites on the Canterbury Plains are essential for a better understanding of the pre-settlement composition and heterogeneity of vegetation communities within this region.

Keywords: beech; deforestation; fire; forest composition; palaeoecology; palynology; podocarp

Introduction

The Canterbury Plains, which extend from the flood plain of the Rangitata River in the south to that of the Waimakariri River in the north (Fig. 1), represent a significant geographical gap in our knowledge about New Zealand's pre-settlement terrestrial ecosystems and their response to the onset of anthropogenic actitives. These gravelly outwash plains offer little in the way of lake or wetland deposits where floral remains are typically preserved. The limited deposits that do exist therefore provide an important window into the past ecology of the Canterbury Plains, improving our understanding of the natural ecosystems of the region and of the impact of past human activities on the vegetation. Analyses of such deposits can also provide important baseline data for guiding ecological restoration projects on the Canterbury Plains.

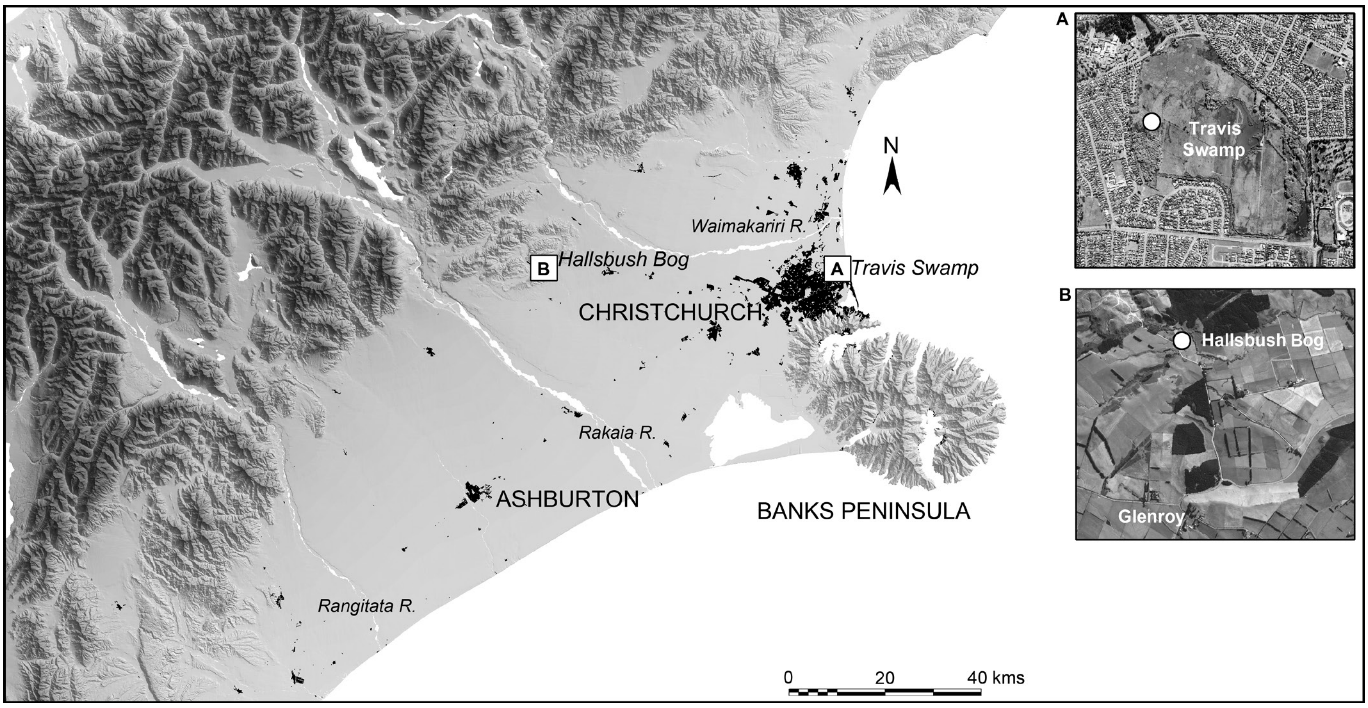

Figure 1. Canterbury plains, showing location of new pollen records presented in this paper.

Early investigations of the past vegetation on the Canterbury plains and adjacent uplands relied on charcoal and wood preserved in gravel and silt deposits (Speight 1911; Raeside 1948; Cox & Mead 1963; Molloy et al. 1963; Molloy & Cox 1972; Molloy & Ives 1972). The Holocene vegetation of the plains was summarised on the basis of soil, charcoal and wood evidence by Molloy (1968), who postulated that podocarp forest, including mataī (*Prumnopitys taxifolia*), miro (*P. ferrruginea*), tōtara (*Podocarpus totara*) and thin-barked tōtara (*P. laetus*; after Molloy 2015), formerly grew on the silt-dominant soils within the flood plains of the major rivers. On the stonier, older and more drought-prone interfluves, he suggested that stunted *P. laetus* coexisted with low kānuka (*Kunzea*) forest. Rare remnants of the latter vegetation type still exist on the Canterbury plains, such as at Eyrewell Scientific Reserve north of the Waimakariri River (Molloy and Ives 1972).

Palynological records provide a broader and more representative range of information about past vegetation communities than do charcoal and macrofossils. Although late Quaternary palynological records exist for the wider mid-Canterbury region, they tend to be concentrated either at high-altitude sites or inland montane basins (e.g. Moar 1971; 1973; Lintott and Burrows 1973; Burrows & Russel 1990; Burrows et al. 1993; Burrows 1995; Burrows & Moar 1996; McGlone et al. 2004) and/or be early-Holocene or older in age (e.g. Moar & Gage 1973; Burrows & Moar 1996; Shulmeister et al. 1999). Just eight late Holocene pollen records exist from low altitude sites on, or adjacent to, the Canterbury Plains. These are concentrated along the south-west margin of Banks Peninsula (Moar & Mildenhall 1988; Woodward & Shulmeister 2005; van Dijk 2011) and along the east Coast from Christchurch to Mt Cass (Moar 1971; 2008) (Fig. 1). All of these records demonstrate significant loss of woody vegetation communities associated with human arrival, from initial Polynesian settlement (13th Century AD) through to the time of European landscape modification (mid-19th Century to present).

Here, we summarise existing pollen records from the Canterbuy Plains and contribute new insights into the Holocene vegetation history of this region by reporting two new mid-late Holocene pollen records from the western and eastern margins of the Canterbury Plains.

Methods

Study sites

Hallsbush Bog

A 150 cm long core was collected using a D-section corer from a small spring-fed bog adjacent to the QEII covenanted forest remnant at Hallsbush in the Wairiri Valley (Landcare Research site code X01/12; approximately 43°30′07.5″ S, 171°50′ E). The bog is situated at 300 m above sea level on the margin of the Canterbury foothills and the western edge of the Canterbury Plains (Fig. 1) and contained homogenous well-humified reddish-brown sedge peats to at least 200 cm depth.

Travis Swamp

A 200 cm long core was taken in the western sector of Travis Swamp, approximately 250 m from the terrace that marks the edge of the swamp and 80 m north of the area of extensive grey willow (*Salix cinerea*) (Landcare Research site code X95/7; approximately 43°29′08.9″ S, 172°41′13.6″ E) (Fig. 1). The swamp is < 20 m above sea level. The ground surface was dry at the time of sampling and the vegetation at the core site was almost entirely glaucous sedge (*Carex flacca*). The stratigraphy of the core was as follows: 0–12 cm, dark-brown peat with numerous live sedge roots; 12–35 cm, dark-brown humified sedge peat; 35–45 cm, grading into the unit below; 45–80 cm, red-brown sedge peat; 80–109 cm, fine structured dark-brown peat (wood fragment noted at 93 cm); 109–112 cm, peat with sedge bases; 112–144 cm, light-grey, banded organic-rich clay with occasional silt and sand; 144–175 cm, blue-grey silty sand with flecks of dark-brown organics; 175–200 cm, grades down to coarse sand.

Palynology

Both cores were sub-sampled along their length for pollen analysis. The outer contaminated surfaces of the cores were removed by scraping horizontally and 0.6 cm^3 subsamples were taken at regular intervals from the cleaned faces. These were processed for pollen analysis using the standard protocol: disaggregation of the sample and boiling in 10% KOH; sieving with a 100 µm mesh; digesting in 40% HF acid; acetolysis; staining and mounting on a microscope slide in glycerine jelly (Moore et al. 1991). A total of 250 pollen grains were counted from each sample to calculate pollen percentages (sum excludes pollen from wetland taxa and fern spores other than *Pteridium*, as their typically high abundances tend to dominate and obscure the sum). Microscopic charcoal abundance was determined through point counting (using an 11 point grid per field of view) and the result expressed as a percentage of the terrestrial pollen sum (Clark 1982). Boundaries between different pollen zones were determined based on marked changes in the dominant pollen types and charcoal abundance. For the Travis Swamp core, detailed quantification of pollen and charcoal was performed in the upper 50 cm. Microscope slides were made from the lower part of this core, but only scanned for the dominant pollen types. Therefore, only the pollen data from the upper 50 cm is presented in the pollen diagram (Fig. 3).

Radiocarbon dating

Bulk peat samples were taken from the Hallsbush core at depths of 52 cm and 150 cm and were submitted to the Waikato Radiocarbon Dating laboratory, Waikato University, for Accelerator Mass Spectrometry (AMS) radiocarbon dating. Peat samples from the Travis Swamp core were taken at 138, 113 and 37 cm depths and were submitted to the New Zealand Radiocarbon Dating Laboratory (Lower Hutt) for AMS radiocarbon dating. Radiocarbon dates were calibrated using the ShCal13 calibration (Hogg et al. 2013) in OxCal v.4.2 (Bronk Ramsey 1995).

Results

Hallsbush Bog

The pollen record from Hallsbush Bog (Fig. 2) comprises five distinct zones, reflecting differences in the dominant pollen types deposited at the site through time. These zones are described below in chronological order.

<u>Zone 5 (150–70 cm)</u>. The pollen assemblage of zone 5 is dominated by mataī (*Prumnopitys taxifolia*), with lesser amounts of miro (*Prumnopitys ferruginea*), rimu (*Dacrydium*

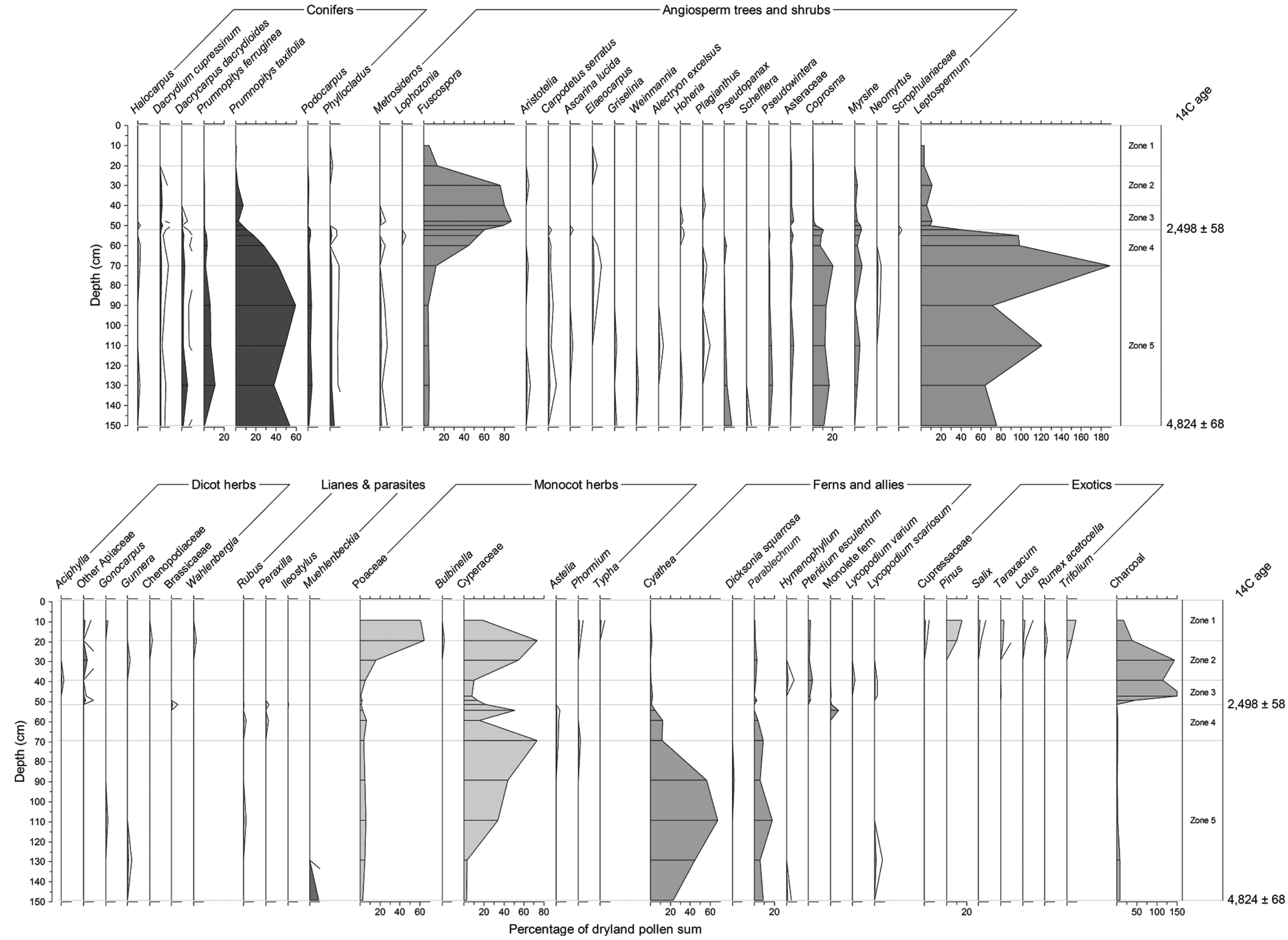

Figure 2. Pollen diagram from Hallsbush Bog, Wairiri Valley, South Island, New Zealand.

cupressinum), tōtara (*Podocaprus totara*), tree ferns (*Cyathea smithii* and *Dicksonia squarrosa*) and many hardwood tree taxa. Pollen from plants likely to have been growing directly on the bog is dominated by mānuka (*Leptospermum*-type) and sedges (Cyperaceae).

Zone 4 (70–52 cm). Zone 4 is a transitional zone, where mataī, ground ferns (*Blechnum* spp.) and tree ferns (notably *Cyathea* spp.) gradually decline and *Fuscopora* beeches increased.

Zone 3 (52–40 cm). Zone 3 reflects a period of relative stability in the local vegetation community. At this time *Fuscospora* beeches dominated the pollen assemblage.

Zone 2 (40–20 cm). In zone 2 charcoal increased sharply and bracken (*Pteridium esculentum*) was recorded consistently for the first time. Grasses became increasingly abundant towards the surface, whereas mānuka (*Leptospermum*-type) and *Coprosma* pollen declined sharply.

Zone 1 (0–20 cm). The uppermost zone of the core is marked by the sudden appearance of pollen from exotic species, in particular pine (*Pinus*), macrocarpa (Cupressaceae), willow (*Salix*), clover (*Trifolium*), sorrel (*Rumex*) and dandelion (*Taraxacum*), which collectively indicate European farming activities in the area. Charcoal and beech pollen declined and podocarp pollen was completely absent. Grass and sedge pollen became dominant. Beech was the only tall forest tree represented in the pollen spectra of this zone and was present in only minor amounts (c. < 10%).

Radiocarbon dating shows that the core extends back to the mid-Holocene, with the base (150 cm) having a calibrated age of 5644–5322 cal BP (95.4% confidence) (Table 1). The boundary of zones 3 and 4 (52 cm), by which point beeches had replaced podocarps as the dominant pollen type, had an age of 2715–2359 cal BP (95.4% confidence) (Table 1).

Travis Swamp

Four distinct zones, characterised by different vegetation communities, were identified in the pollen analysis of the Travis Swamp core (Fig. 3). These zones are described below in chronological order.

Zone 4 (200–38 cm). The coarse sand at the base of the core (175−200 cm) did not contain preserved pollen. The organic-rich clay lying above the sand had high levels of *Apodasmia* pollen and abundant pollen of mataī, miro, rimu and beeches. From 140 cm upwards there was an increase in represenation of tōtara, *Coprosma*, *Myrsine*, ribbonwood (*Plagianthus regius*), lacebark (*Hoheria*), bracken and other scrub species. From 110 cm upwards there was an increase in sedge and mānuka pollen, as well as freshwater aquatic elements such as *Pediastrum*

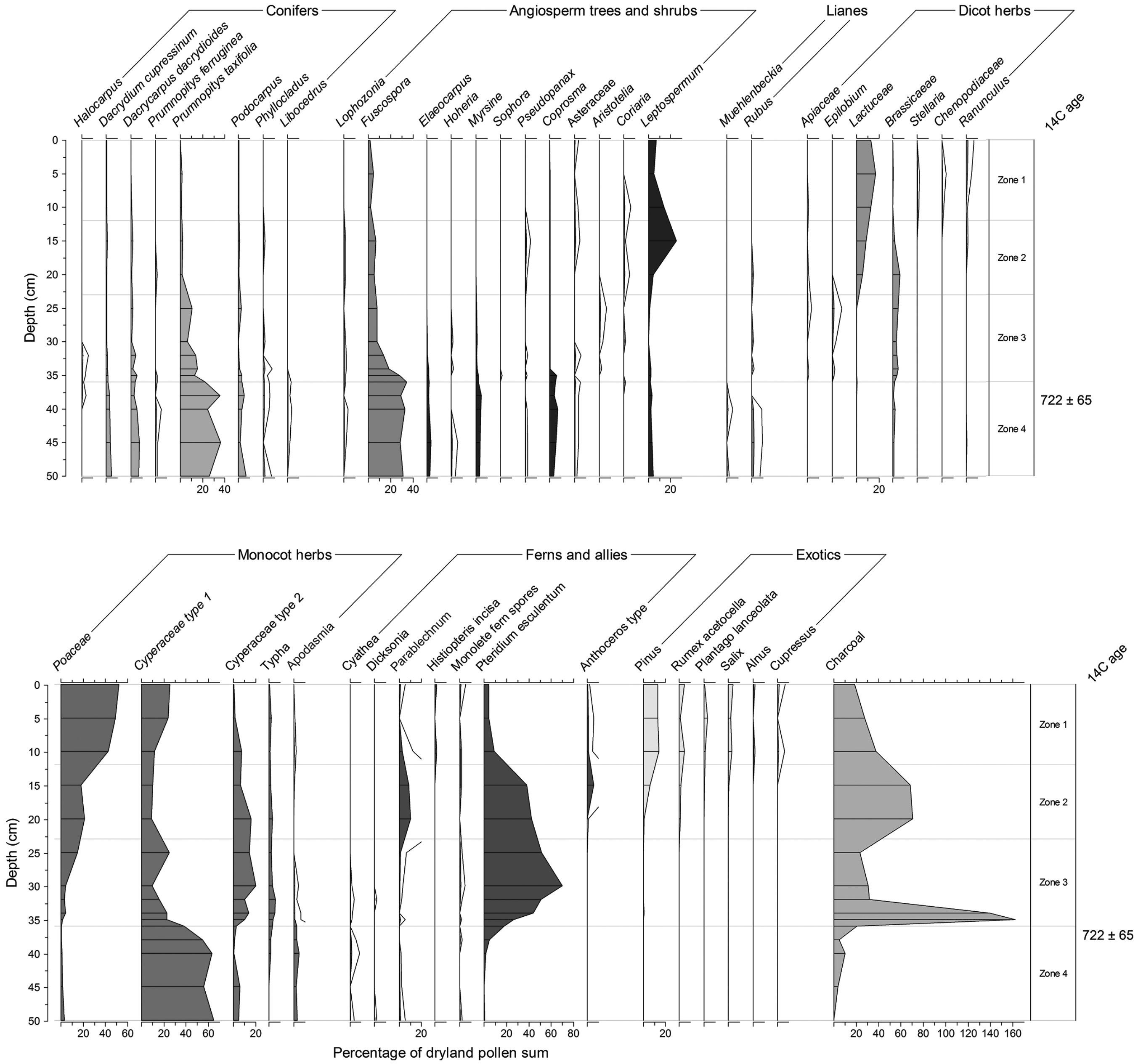

Figure 3. Pollen diagram from Travis Swamp, Christchurch, South Island, New Zealand.

Table 1. AMS radiocarbon dates from the Hallsbush Bog and Travis Swamp peat cores.

Site	Lab code	Depth (cm)	^{14}C age and error (years Before Present (i.e. AD 1950)	Calibrated age ranges and confidence (calibrated years Before Present)
Hallsbush Bog	WK-10900	52	2498 ± 58	2715–2359 cal BP (95.4%)
	WK-10899	150	4824 ± 68	5644–5440 cal BP (73.8%)
				5419–5322 cal BP (21.6%)
Travis Swamp	NZA-6649	37	722 ± 65	724–550 cal BP (95.4%)
	NZA-6355	113	1341 ± 70	1320–1058 cal BP (95.3%)
				1342–1339 cal BP (0.1%)
	NZA-6653	138	6290 ± 120	7424–6880 cal BP (94.9%)
				6871–6860 cal BP (0.5%)

(a colonial freshwater alga) and *Potamogeton*. By 80 cm, *Apodasmia* was recorded only at low levels and mānuka was abundant. The composition of the pollen assemblage did not change markedly from 80–38 cm (the top of zone 4).

Zone 3 (38–23 cm). There was a steep rise in the abundance of bracken spores and a concomitant steep decline in forest trees and dryland scrub pollen types at 38 cm. The charcoal abundance index remained low for the first few cm of this zone, before rising steeply and including the larger size classes of charcoal only after bracken had become the dominant pollen/spore type. *Apodasmia* and *Leptospermum* declined and *Baumea*-type, raupō (*Typha*) pollen and *Sphagnum* spores increased. Grass pollen increased towards the top of zone 3.

Zone 2 (23–12 cm). In zone 2 there was a renewed upsurge in charcoal abundance and the appearance of exotic pollen types such as sorrel and docks (*Rumex*). There was also a marked increase in dandelion-type pollen (Asteraceae: Lactuceae) abundance and spores of the swamp kiokio fern (*Parablechnum minus*). At the top of this zone, mānuka and grass pollen increased and bracken spores declined.

Zone 1 (12–0 cm). In zone 1, pollen from pine, grasses, willow and pasture weeds increased and charcoal abundance decreased, with only smaller size fragments (< 10 μm) remaining at relatively high abundance. *Baumea*-type pollen (attributable to *Machaerina*) was eliminated and mānuka and swamp kiokio declined.

Radiocarbon dating shows that the core likely extended back to the early Holocene, with a date of 6290 ± 120 years BP at 138 cm depth (Table 1). The beginning of zone 3 corresponds to a radiocarbon date of 722 ± 65 years BP (Table 1), approximately the time of initial human settlement.

Discussion

Hallsbush

The spring bog at Hallsbush began forming peat deposits prior to 5500 years ago. From this time, until about 2600 years ago, the local wetland vegetation was dominated by a shrubby cover of *Coprosma*, mānuka and *Myrsine* with sedges. Mataī, miro, rimu, tōtara and kahikatea with the occasional beech (most likely black, red and mountain beech, but not silver) and other hardwood trees dominated the surrounding drier ground. Ground ferns such as swamp kiokio and tree ferns including *Cyathea smithii* were abundant. The pollen record from Hallsbush captures the mid-late Holocene transition from podocarp to beech forest dominance, which has been noted in other pollen records from across the South Island (e.g. Wilmshurst et al. 2002; McGlone et al. 2004; Turney et al. 2017).

The decline in wetland shrubs and sedges and concomitant increase in bracken fern, grasses and charcoal in zone 2 reflects early Māori burning in the area. This signal of this Initial Burning Period (McWethy et al. 2010) is also present in other pollen diagrams in the area, e.g., at Porter's Pass (Moar 2008) and more widely in the South Island (McWethy et al. 2010). The long period of time that elapses between only 52 cm (calibrated age of 2715–2359 cal BP) and 50 cm (where the anthropogenic charcoal increase begins) suggests peat accumulated very slowly during a dry period and this signature is seen in several cores from the South Island (e.g., McGlone & Wilmshurst 1999). Although it is possible that this may represent an unconformity where peat was burnt, this is unlikely. Water saturated peats will not burn, and any loss of peat during a fire would thus be confined to the temporarily dried out surface; representing perhaps no more than a few decades. Moreover, observations after fires have shown that recovery of the peat forming plant cover occurs relatively rapidly (Timmins 1992; Johnson 2001). Interestingly, the early Māori fire disturbance seems to have only affected the wetland vegetation at this site; the surrounding beech forest was not cleared until much later in the European period. This may reflect the fact that the mix of shrubs on the wetland is likely to have been more flammable than the surrounding tall wet forest (Perry et al. 2014; Battersby et al. 2017). There is an indication that grasses were beginning to increase in dominance before zone 1 (i.e. the European farming period) and this may reflect grass pollen grains blown in from post-fire episodes elsewhere on the plains.

Travis Swamp

The coarse sand at the base of the Travis Swamp core (zone 4) likely reflects a period when the local landscape was dominated by sand dunes, with little permanent plant cover, perhaps surrounding a wetland with some tidal influence. In support of this, is the abundance of *Apodasmia* (*Apodasmia*) pollen, and the fact that the the age of the base of this core corresponds to the time when present mean sea level was first attained and may have been exceeded, in the Canterbury region (Clement et al. 2016). Encroachment of taller vegetation (forest and shrub cover), is represented by an increase in these pollen types and decrease in *Apodasmia* pollen from 140 cm upwards, reflecting reduced marine influence and stabilisation of the surrounding dunes. The steep rise in the abundance of bracken spores and equally steep decline in forest trees and dryland scrub pollen types, at about 38 cm reflects the initial period of widespread Māori forest clearance in the Christchurch area. The radiocarbon date of 722 ± 65 (724–550 cal BP) at 37 cm (Table 1) confirms this as the Initial Burning Period. The pollen evidence suggests that there was little forest, but substantial areas of grass and bracken surrounding the core site during the late Māori period (top of zone 3). The top of the core (zones 2 and 1) corresponds to the European era, with an increase in charcoal abundance reflecting further vegetation clearance, likely to be land clearing for agriculture. The increase in agricultural land is also reflected by an increase in pollen from grasses and agricultural weeds including *Rumex* and *Plantago* (Fig. 3).

Pre-settlement vegetation of the Canterbury Plains

The palaeovegetation records from Hallsbush Bog and Travis Swamp (summarised in Fig. 4) contribute to our wider understanding of the dominant forest types that existed on the Canterbury Plains prior to human settlement. The composition of thirteen pollen assemblages from east of the Southern Alps and at the same latitude as the Canterbury Plains, immediately prior to the timing of human settlement, shows a clear pattern in the dominant canopy species (Fig. 5). Beeches dominated pollen assemblages from the western foothills, with the exception of Mt Horrible which had approximately equal amounts of beech and podocarp pollen. Pollen assemblages from the eastern margin of the plains exhibited equal or greater amounts of podocarp pollen compared with beech pollen, and tended to be more diverse, with higher proportions of other tree and shrub taxa lianes/parasites, dicot herbs and grasses

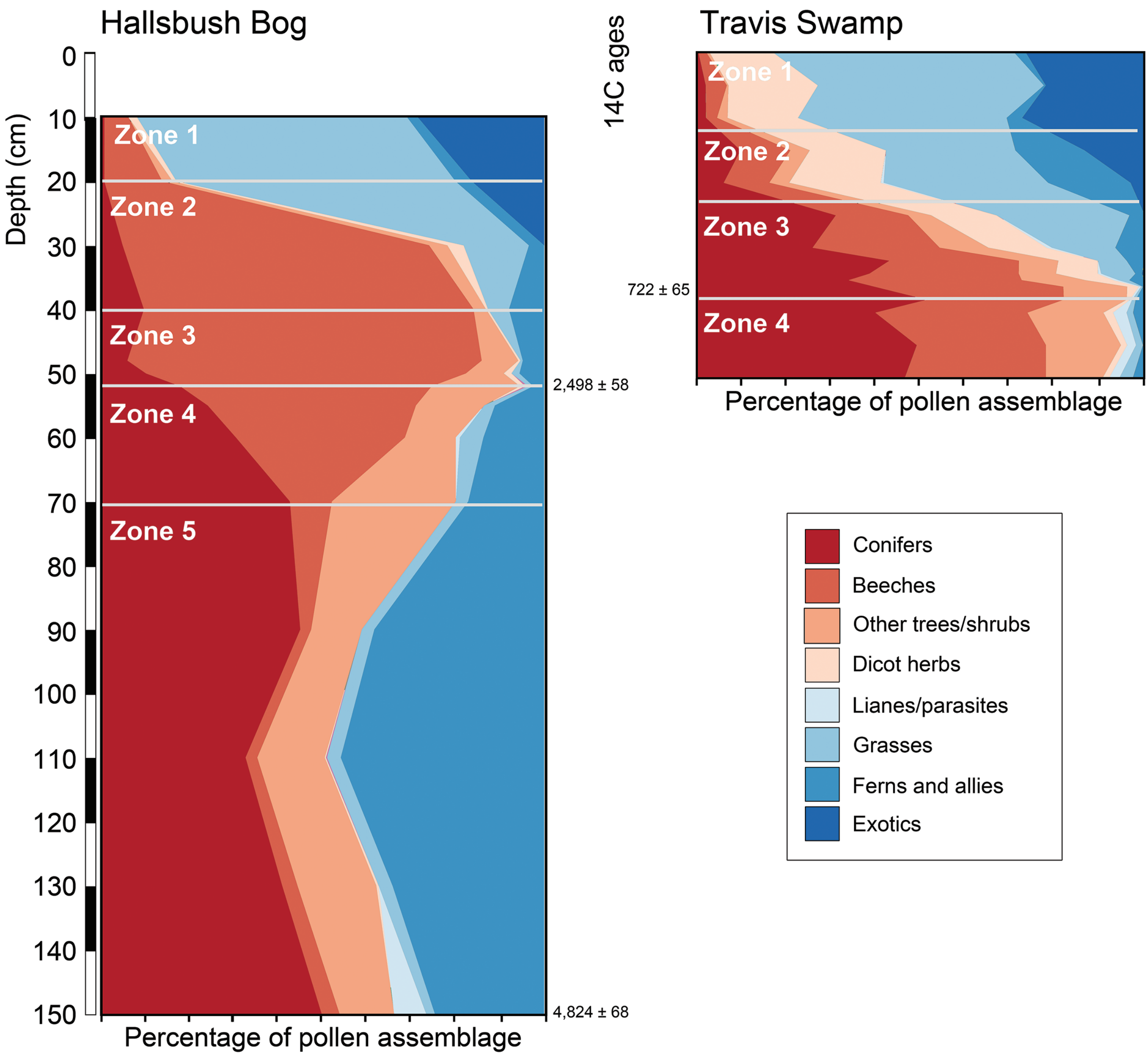

Figure 4. Summary of key groups in the pollen records from Hallsbush Bog and Travis Swamp.

(Fig. 5). Interestingly, the frequent occurrence of kānuka in soil charcoal records (e.g., Cox & Mead 1963; Molloy 1970; Molloy & Ives 1972) is not mirrored by an equally frequent occurrence in the pollen records, but this is likely to be due to the fact that kānuka prefers dry sites (the pollen records are from wet sites) and its pollen does not disperse far from source. Both podocarp and beech pollen (particularly *Fuscospora* type) can disperse long distances (McKellar 1973; Myers 1973; Moar et al. 2011) and so the proportion of beech pollen in the eastern cores that originates from distant vs. local sources is uncertain. However, given the predominant westerly windflow across the Canterbury foothill region, the pattern observed in the pollen assemblages (Fig. 5) is consistent with beech forests having been present on the foothills along the western margins of the Canterbury plains (where beech represented 49.5–98% of pollen assemblages at the time of human settlement) (Fig. 5). Although the plains themselves were dominated by podocarp or mixed podocarp/hardwood forest types, it is likely that beeches were also locally common towards the east, perhaps in suitable micro-environments. The beech pollen in the eastern and more coastal sites is likely to be of local origin rather than wind blown from western sources of beech forest, as the wind flow becomes increasingly dominated by north easterly flows towards the coast. For example, higher proportions of beech pollen at Travis Swamp, Kaiapo Pa and Mt. Cass Road (30.9–34.1%) compared with other eastern sites (11.4–20%) may indicate that more beech was growing locally at these sites.

Conclusions

The pollen records from Hallsbush and Travis Swamp provide additional evidence for the pre-settlement composition of vegetation communities along the margins of the Canterbury Plains. Assessed along with other palaeovegetation records from similar locations, a consistent pattern is now emerging

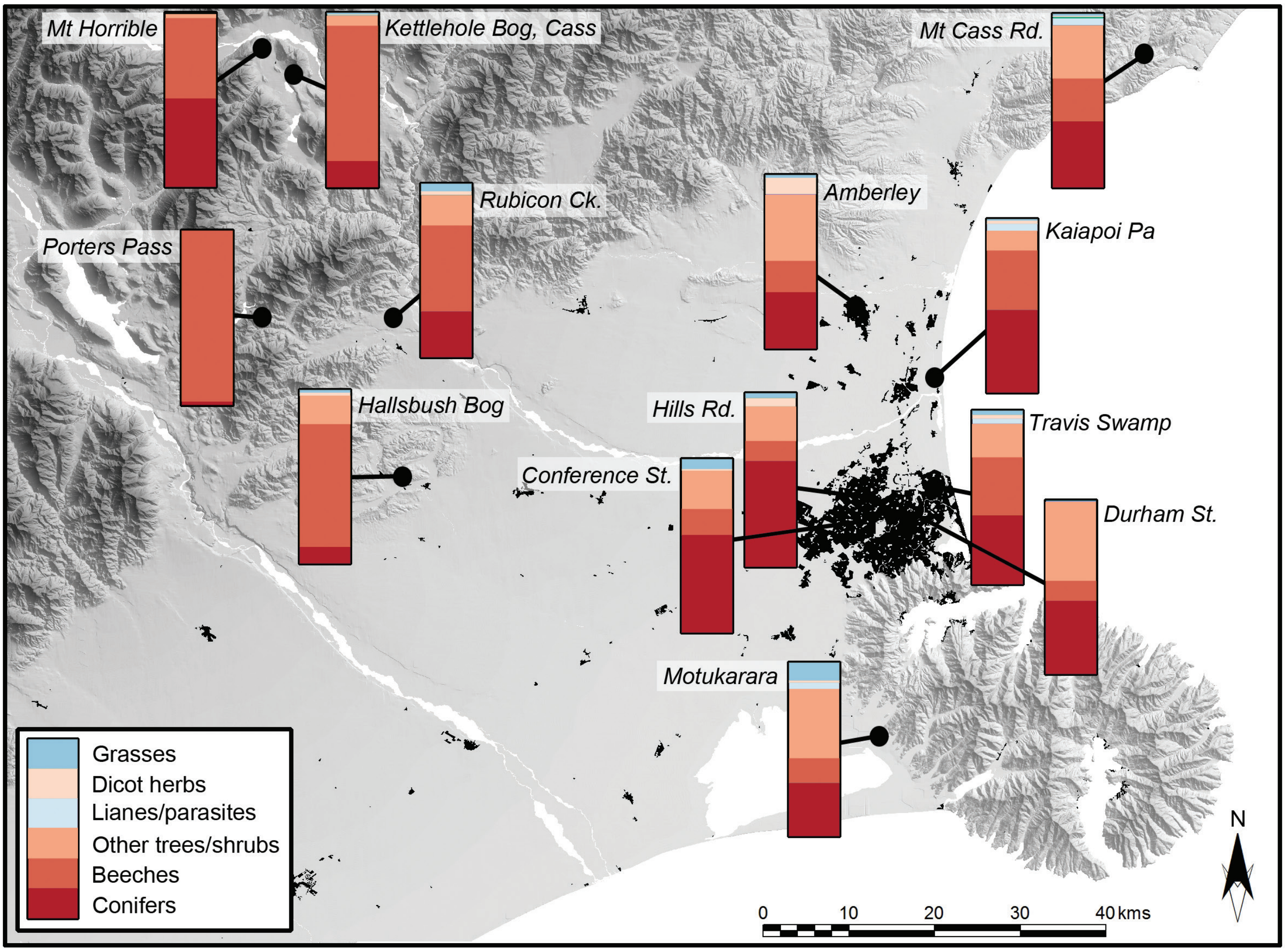

Figure 5. Summary pollen assemblages from the mid-Canterbury region immediately prior to human arrival in New Zealand. Data from Moar 1971 (Amberley, Hills Road, Conference Street), Moar 2008 (Mt. Horrible, Porters Pass, Rubicon Creek, Durham Street), van Dijk 2011 (Motukarara), McGlone et al. 2004 (Kettlehole Bog, Cass) and this study (Hallsbush Bog and Travis Swamp). Ferns are excluded from the pollen sums.

that indicates at the time of human settlement beech forest dominated the western foothills while podocarp/hardwood forest dominated the plains to the east. However, the Canterbury Plains still represent a large geographic void in regards to pollen records (Fig. 5) and the discovery of new pollen-bearing deposits in this area will be critical for better understanding the vegetation history of this part of New Zealand and for guiding restoration schemes on the Canterbury Plains.

Acknowledgements

We thank Neville Moar and Alison Watkins for assistance with the peat coring, Alison Watkins for preparing the pollen slides, Miles Giller (QEII National Trust) for helpful discussions about the Hallsbush wetland, Nadia Zviagina for help with the Hallsbush pollen analysis and Roger and Shirley Dennis for their hospitality and access to their land. Dr Trevor Partridge assisted with interpretation of the historic record of Travis Swamp. The Travis Swamp record was commissioned by Travis Country Estates Ltd and the Christchurch City Council. Funding for two radiocarbon dates was provided by the QEII National Trust.

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Received 18 December 2017; accepted 3 April 2018
Editorial board member: Hannah Buckley