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Late Holocene development of two wetlands in the Te Paki region, far northern New Zealand

N. J. Enright*, R. F. McLean and J. R. Dodson†**

The history of two wetlands in far northern New Zealand is examined from stratigraphic and palynological evidence. Although both the Te Werahi and Ponaki wetlands appear superficially similar (both are dominated by raupo, *Typha orientalis*, and both are barriered by unvegetated coastal sands), radiocarbon dates show that they are of very different ages. The Te Werahi wetland shows organic sedimentation covering at least the last 3,700 years. This suggests it originated at the time that sea-level reached its present position around 6,500 years B.P. A sharp rise in the abundance of charcoal particles in sediments from the Te Werahi wetland indicates an increase in fire frequency between 2,620 and 2,150 years B.P. A phase of forest reduction, and destabilization of coastal sands, may date to this period. The Ponaki wetland has developed within the last 200-300 years. We argue that fire removed the vegetation and led to erosion of catchment soils and destabilization of coastal sands. Blocking of the stream outlet by a sand barrier probably accounts for subsequent wetland development or expansion. Pollen and sediment data support these conclusions.

Keywords: pollen analysis, wetlands, fire history, Te Werahi, Ponaki, forest clearance, erosion.

INTRODUCTION

Little is known about the pre-European vegetation and environmental history of the far north compared with the rest of New Zealand (McGlone, 1983). While pollen analysis of wetland sites has provided a wealth of information on post-glacial and Holocene vegetation change in the South Island, and in the southern and central North Island (*e.g.* McGlone and Topping, 1973, 1977, 1983; Moar, 1971, 1980; McGlone, 1978; McGlone *et al.*, 1978), data for the area north of Auckland are extremely limited. The only published pollen diagram is for a site near Marsden Point (Kershaw and Strickland, 1988). Limited pollen data are also available in several unpublished theses (Wright, 1951; MacDonald, 1984; Chester, 1986).

The Northland region of New Zealand contains many wetlands. However, sediment disturbance caused by Maori agriculture, exploitation for fossil gum of kauri (*Agathis australis*), and conversion to dryland for farming, reduces their potential value for historical vegetation reconstruction. These factors, combined with the absence of palynologists based in the north, may explain the lack of information for this area. Neverhteless, the region is of considerable interest, since (1) it is potentially an area of refuge for forest species during periods of colder climate (*i.e.* glacials); (2) the post-glacial history of species such as kauri, which is restricted to areas north of a line running from Kawhia in the west to Tauranga in the east, is almost completely unknown (Kershaw and Strickland, 1988); and (3) the origin of the locally extensive mobile dune systems requires explanation.

Although the northern-most part of New Zealand is also likely to have been the most densely populated during the pre-European Maori period (Sutton, 1987), the impact of Maori occupation on the environment is less well documented there than further south

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because there is so little palynological, stratigraphic and archaeological evidence available. McGlone (1983) reviews the likely role of Maori burning in modifying vegetation patterns. He notes the historical increases in the frequency of fire during the last 600-800 years, and the coincident changes from forest to shrub and grassland pollen taxa, and concludes that there was considerable deforestation in the east of the South Island and over much of the North Island. Coastal dune systems may also have been destabilised by the destruction of vegetation on previously stable dunes (McGlone, 1983; J. Coster, unpublished). Chester (1986) has used short wetland cores to describe the timing of deforestation in the Bay of Islands, Northland.

This paper describes the recent environmental histories of two wetland catchments in the far north from stratigraphic and palynological evidence. Both are coastal wetlands apparently created by the development of sand barriers which slow the access of drainage waters to the ocean. These systems may have arisen after sea-level reached its present position about 6,500 years B.P., as is common in lagoonal and backswamp habitats elsewhere in New Zealand (Gibb, 1979; Kershaw and Strickland, 1988) and Australia (Thom and Chappell, 1975). Both wetlands are bordered by shifting dunal sands on at least one side. It is not clear whether these shifting sands have helped to develop the wetlands, nor whether the wetland/heathland/shifting sand mosaics at these sites are natural or are a result of human activities (*e.g.* fire and catchment destabilization). While Maori burning is generally accepted as one of the factors that convert forest to heathland and grassland, we are unaware of any suggestion that it may also have led to the formation of wetlands.

SETTING

The two field sites are located within the Cape Reinga—North Cape geological block, a Cretaceous to Tertiary basalt and sandstone outlier which is separated from similar parent materials to the south by extensive Quaternary sand deposits (Suggate *et al.*, 1978). The area was isolated from mainland New Zealand by marine straits at various times during the Pliocene and early Pleistocene, but was joined to the rest of Northland by sand deposition during the late Pleistocene (Stevens, 1980; Hicks, 1975). Soils on Tertiary volcanics are described as moderate to well drained red brown clays, and those on sandstone as poorly drained and podzolized loams and silt loams (Sutherland *et al.*, 1979). Soil development in Quaternary sands, especially the degree of podzolization, depends upon age of deposition and drainage characteristics. The climate of the area is mild, with a mean annual temperature in the vicinity of 15.5°C. Rainfall is low to moderate, averaging from 992 mm Y^{-1} at Cape Reinga to 1440 mm y^{-1} at Te Paki Station only a few kilometres to the south (NZMS, 1984).

Present vegetation cover is mostly heathland, with small forest remnants restricted to moist gullies on volcanic and conglomerate parent materials. Forest remnants contain species such as kauri, nikau palm (*Rhopalostylis sapida*), taraire (*Beilschmiedia taraire*), miro (*Prumnopitys ferruginea*), totara (*Podocarpus totara*), rata (*Metrosideros* spp.), kohekohe (*Dysoxylum spectabile*), rewarewa (*Knightia excelsa*), rimu (*Dacrydium cupressinum*), puriri (*Vitex lucens*), kahikatea (*Dacrycarpus dacrydioides*), towai (*Weinmannia silvicola*) and karaka (*Corynocarpus laevigatus*) (Mitchell and Park, 1983). Heathlands are generally species-poor and are strongly dominated by manuka (*Leptospermum scoparium*) on sandstone sites and kanuka (*Kunzea ericoides*) on volcanics. Other species present in heathlands and regenerating forest include flax (*Phormium tenax*), cabbage tree (*Cordyline* sp.), bracken fern (*Pteridium aquilinum*), *Coprosma* spp., and several genera within the Epacridaceae and Cyperaceae. Pine (*Pinus radiata*) plantations and pasture are also present along with several invasive exotics including *Hakea gibbosa, H. sericea* and *Ulex europaeus* (gorse).

The Te Werahi wetland is on the western coast, and the Ponaki wetland is on the eastern coast of the Northland peninsula in the region of Te Paki (Fig. 1). Te Werahi wetland is a large and complex system covering 422 ha within a large catchment (3365 ha) dominated by pasture and livestock farming, and is bordered on the west by advancing sand, exposed rock and deep gullies. The upper, middle and lower parts of the system are separated by narrow, sandy braided stream channels which are maintained by the

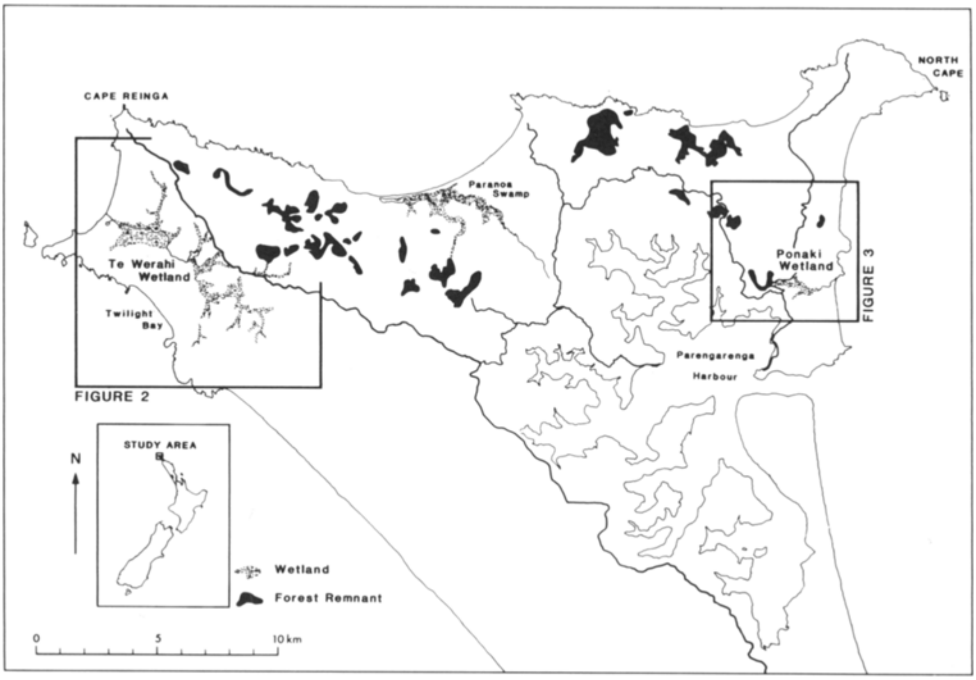

Fig. 1 — Location of major wetlands and forest remnants in the Te Paki region, far northern New Zealand.

flow of the Te Werahi Stream in spite of constant incursions of sand. The eastern side of the catchment lies on Tertiary volcanics, while the western side is dominated by shifting Quaternary sands (including reworked Pleistocene soils). Swamp vegetation consists of extensive floating mats dominated by raupo (*Typha orientalis*), *Elaeocharis sphacelata* and *Baumea articulata*. Large areas of open water are also present. There are no forest remnants within the catchment, but regenerating forest is found on the eastern margins, and the closest remnant forest patch is within about 2 kilometres. Sample cores were obtained from sites in the upper, middle and lower parts of the wetland (Fig. 2).

Ponaki wetland is a small system (46 ha) within a catchment of 775 ha. The wetland occupies a long (1.5 km), narrow and steep-sided valley covered with heathland dominated by manukà and bracken fern. Catchment geology comprises a combination of mudstones, sandstones and conglomerates. There are several small forest remnants near the headwaters of Ponaki Stream, which feeds this system (Fig. 3). Drainage to the ocean is restricted by a mobile sand barrier, which includes reworked material from eroding Quaternary podzolized sands. Swamp vegetation is similar to that at Te Werahi, except that there is less free water below the floating mat, and open water areas are somewhat smaller. Nevertheless the two wetlands appear to have the same type of vegetation and gross geomorphological characteristics. Sample cores were obtained from two sites in the middle and lower parts of the swamp (Fig. 3).

METHODS

Sediment cores were collected from a number of sites within each wetland, spaced so as to sample the variability in stratigraphy from swamp margin to swamp centre, and from upper to lower parts of the systems. From these, a subsample of cores was selected for stratigraphic and palynological investigation. For Te Werahi, three cores are detailed. Stratigraphy is described and interpreted for each, while pollen analysis was restricted to one site (Woolshed). This site contained the longest sequence of organic deposition. Cores were collected using a D-section corer (Jowsey, 1966) with extension rods allowing

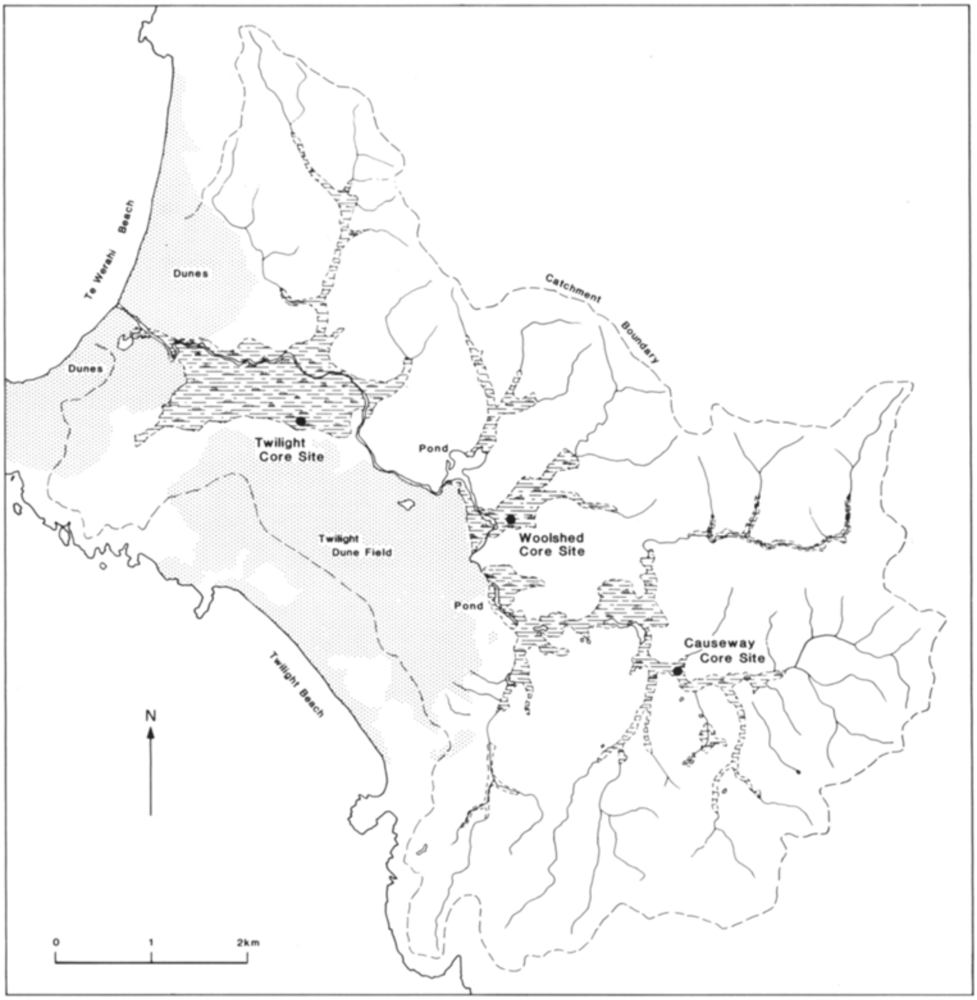

Fig. 2—The Te Werahi wetland and catchment area, showing locations of sample cores and areas of unvegetated sands.

coring to 5.5 m in easily worked organics. At Ponaki, two cores were analysed, with pollen analysis also restricted to one core.

Stratigraphy was described in the field, with particular attention to the texture of inorganics and the presence of organic fines, roots, coarse organic fractions and charcoal inclusions. Samples characteristic of stratigraphic zones were subject to sediment analysis (sieving and pipette analysis) to determine percentages of sand, silt and clay fractions (Carver, 1971). Percentage organics was determined using H_2O_2 digestion (Jackson, 1958). Soil samples characteristic of the surrounding catchment areas were analysed in the same way for comparison with wetland sediments.

Four samples from the Te Werahi Woolshed core, and one sample from Ponaki site A core, were submitted for radiocarbon dating to the Institute of Nuclear Sciences, Wellington. Dates reported are based on the Libby half-life (5,568 years) (Table 1). The calibration procedure described by Stuiver and Becker (1986) was used for radiocarbon ages <250 years B.P.

Pollen and charcoal were prepared using standard alkali and acetolysis procedures. In addition, the samples were spiked with aliquats of *Alnus rugosa* marker grains in order to

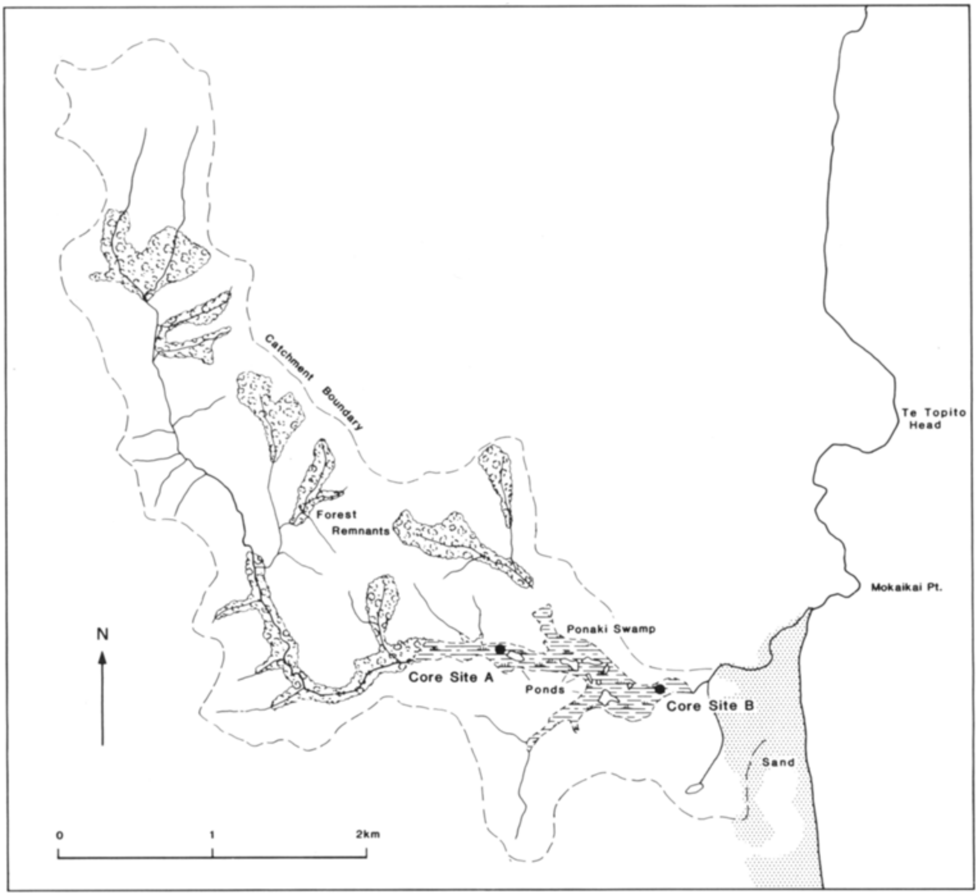

Fig. 3 — The Ponaki wetland and catchment area, showing locations of sample cores, forest remnants and unvegetated sands.

estimate concentrations of pollen and charcoal, then dehydrated in an alcohol series and mounted in silicone oil (Moore and Webb, 1978). Pollen was counted until at least 200 grains of terrestrial taxa had been identified, and charcoal was counted by the point sampling method of Clark (1982). Wetland cores are housed in the Department of Geography, University of Auckland, and prepared pollen slides in the Department of Geography, University of New South Wales.

RESULTS

Te Werahi wetland

The Te Werahi wetland is a large and diverse system. Core samples collected from its upper, middle and lower reaches show different histories of sedimentation. Swamp stratigraphy at the Causeway Site (upper reaches) is described from a sediment core to 3.20 m (Fig. 4). The site is occupied by a raupo floating mat community overlying uncompacted organics in water to 1.40 m, compacted swamp organics and layered muds to 2.0 m, inorganic muds to 2.60 m, and then sands to the base of the core. The site has not been affected by sand inputs in the recent past, and the nearest mobile sands are at present at least 1 kilometre away to the south and west. Coring could not penetrate the sand layer at the base of this sequence. Present swamp accumulation derives from organic production within the wetland, and input of inorganic fines from the surrounding catchment area.

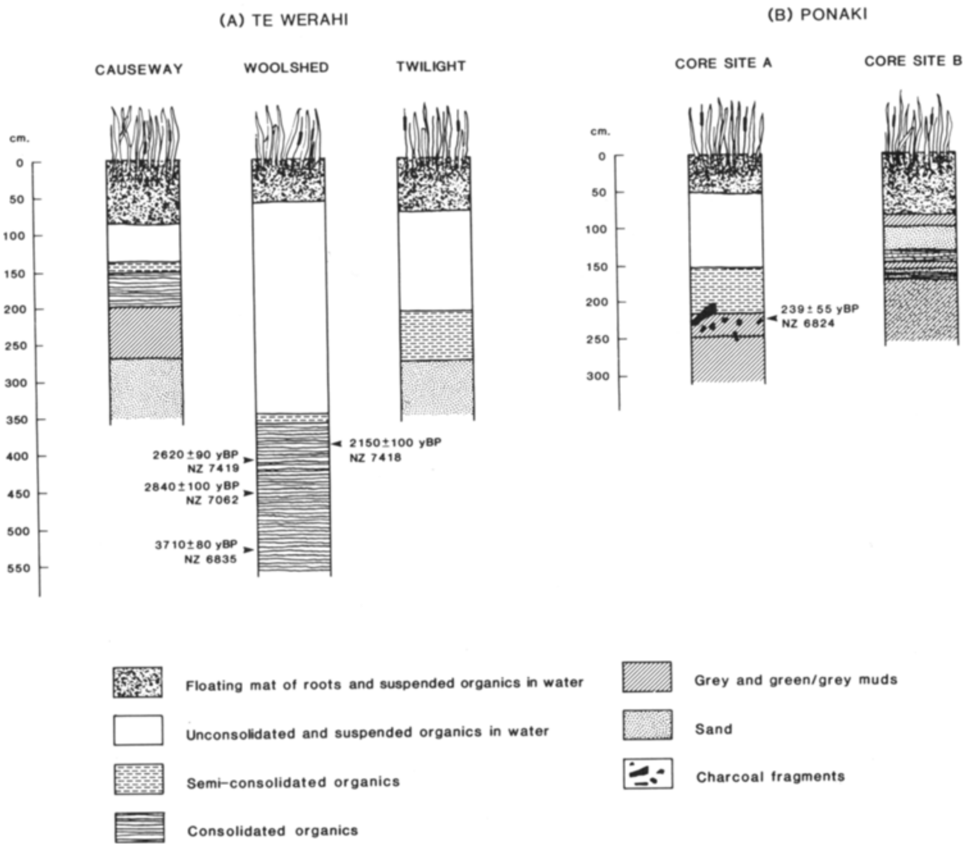

Fig. 4—Stratigraphies of sediment cores from the Te Werahi and Ponaki wetlands.

The Woolshed Site, in the middle reaches of the system, is located within a larger arm of the wetland with open water areas and floating mats of raupo and *Elaeocharis sphacelata* (Fig. 4). Here, the floating mat extends to about 0.60 m and is underlain by water and suspended organics to 3.50 m. Consolidated organics extend to the base of the core at 5.45 m. The extent of organic deposition is not known. Four radiocarbon dates were obtained from this site (Table 1). The base of the core (5.35-5.45 m) has a radiocarbon age of 3710 ± 80 years B.P. (NZ6835), while the age at 4.50-4.58 m is 2840 ± 100 years B.P. (NZ6835). Two further dates were obtained to bracket a sharp rise in charcoal particle count found during pollen analysis. These dates were 2620 ± 90 years B.P. (NZ7419) at 4.00-4.06 m, and 2150 ± 100 years B.P. (NZ7418) at 3.94-4.00 m. Thus, the rate of organic accumulation appears faster in the lower part of the sequence than in the upper part. Although a large, mobile sand sheet is located less than 500 m to the west of the core site and impinges directly upon the edge of the wetland, there is no evidence of sand input at this site.

The Twilight Site typifies the lower part of the Te Werahi system. Here, there is limited organic and fine inorganic deposition over sands (Fig. 4). The vegetation is a floating mat of raupo to 0.70 m overlying unconsolidated organics in water to 2.20 m, semi-consolidated organics to 2.75 m and sands to the base of the core at 3.25 m. Grain size analysis of sands from the base of this core, the Causeway core, and the mobile sands of Twilight Bay nearby, suggest a similar source (Table 2). Sands were all grouped within the fine sand class with mean grain size in the range 2.28-2.30 phi.

Pollen analysis was carried out on the Woolshed core for the consolidated organics between 3.50 and 5.45 m. Pollens of *Pinus* and *Plantago lanceolata* were present at 3.50 m,

Table 1 — Radiocarbon dates for samples from the Te Werahi Woolshed and Ponaki site A sediment cores. $T^{1/2} = {}^{14}C$ half-life. NZ = Radiocarbon laboratory, Institute of Nuclear Science, D.S.I.R. Wellington.

Site	Fossil Record No.	Sample No.	Depth (m)	Libby age $T^{1/2}$ old 5568y)
Te Werahi Woolshed	M02/f43	NZ7418	3.94-4.00	2150 ± 100
	M02/f44	NZ7419	4.00-4.06	2620 ± 90
	M02/f35	NZ7062	4.50-4.58	2840 ± 100
	M02/f34	NZ6835	5.35-5.45	3710 ± 80
Ponaki Site A	NO2/f125	NZ6824	2.17-2.30	239 ± 55

indicating deposition within the European period (probably < 100 years B.P.) Fig. 5 shows the pollen diagram with pollen and spore percentages calculated on a sum of total terrestrial pollen excluding *Leptospermum/Kunzea*. Charcoal values are concentrations of particles per cm^3 of sediment. Forest taxa were dominated by rimu throughout. Totara and miro pollens were common between 3,700 and 2,800 years B.P. but then declined. Kauri also declined after a peak at about 3,000 years B.P. *Nothofagus* values were low throughout, indicating a minor or long-distance role for beech.

The major shrub taxon was *Leptospermum/Kunzea* which increased after the decline of the podocarps. This in turn was followed by a rise in *Coprosma* and flax. A sudden increase in the input of charcoal suggests an increase in the incidence and intensity of fire between 2,620 and 2,150 years B.P. The change from forest to heathland is suggested by the presence of *Pomaderris* and *Dracophyllum* pollens and bracken spores.

The swamp surface clearly experienced a dramatic change in vegetation cover. For much of the time it appears to have been a *Gleichenia*/Cyperaceae community with raupo a minor component. However, *Gleichenia* disappeared as raupo especially, but also *Blechnum* and other ferns that produced monolete spores, increased dramatically on the surface layers.

Ponaki wetland

Two cores from the middle and lower parts of the wetland are described (Fig. 4). Ponaki Site A was characterised by a floating mat of raupo overlying unconsolidated organics in water to 1.50 m, semi-consolidated organics to 2.17 m, a distinct charcoal band at 2.17 m and charcoal fragments in grey muds to 2.40 m. Consolidated grey-green muds extended to the base of the core at 2.90 m. The radiocarbon age of charcoal fragments and other organics extracted from 2.17 m was 239 ± 55 years B.P. (NZ6824). However, because of fluctuations in radiocarbon concentrations in the atmosphere over the last 300 years no single age range can be assigned within the probability margin of one standard deviation for such a sample (Stuiver and Becker, 1986). For this reason it is more appropriate to refer to the possible calibrated ages which are; 423-390 cal B.P., 319-273 cal B.P., 212-147 cal B.P. and 11-0 cal B.P. The depth of accumulated organics above the charcoal layer suggests that the true age was probably close to the calculated radiocarbon age and dates to the pre-European period.

Ponaki Site B is in the lower part of the system and close to mobile Quaternary sands which form a partial barrier to water flow from the wetland (Figs. 3 and 4). This site is dominated by raupo overlying a thin layer of organics and muds to 1.07 m, and then consolidated sediments made up of varying quantities of organics, muds and sands to 1.72 m. Muds continue to the base of the core at 2.60 m. It is clear that sand has drifted across from the unstable coastal dunes from time to time, although this has not happened at Ponaki Site A which is located further from the coast. A charcoal band in grey-green muds is located at 1.55 m and is assumed to correlate with a similar band found at 2.17 m in Ponaki Site A. The marked change in rate of input for sands versus silts and clays near the charcoal band is clearly illustrated in Fig. 6. While sands are derived from the eroding coastal dunes (and soils), silts and clays can come only from erosion of silt/loam

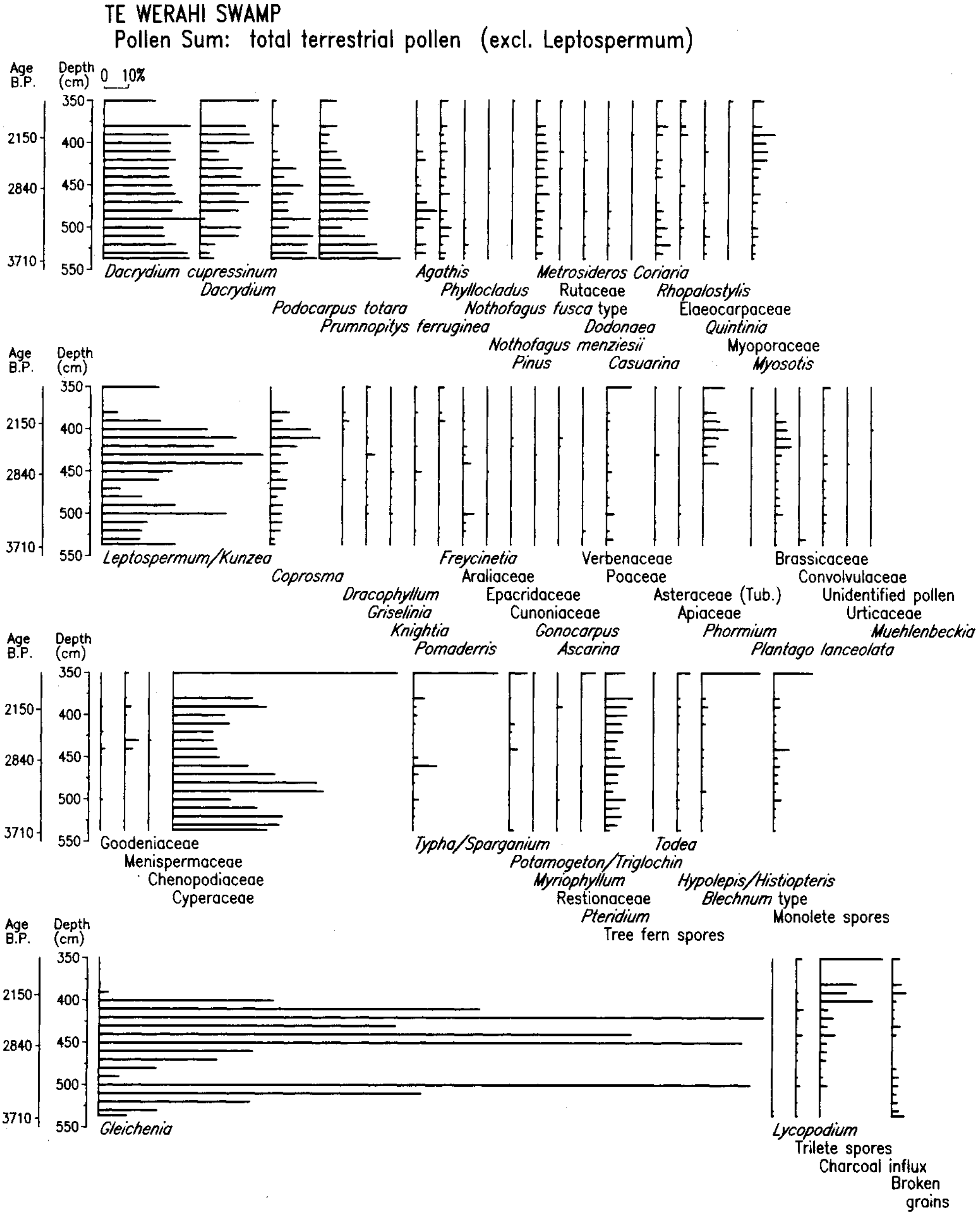

Fig. 5—Pollen diagram for the Te Werahi Woolshed core site in the middle part of the wetland system.

soils within the catchment. The similarity between the grain size distribution in the wetland muds and in the podzolized silt loam soils of the catchment supports this contention (Table 2).

The pollen diagram for Ponaki Site A clearly reflects the massive changes in the vegetation of this area over the last few centuries (Fig. 7). Shrub and swamp taxa dominate the diagram. Forest taxa were relatively low except for rimu, which showed a small rise in the surface sample, possibly reflecting a small recovery in forest cover. The major taxa

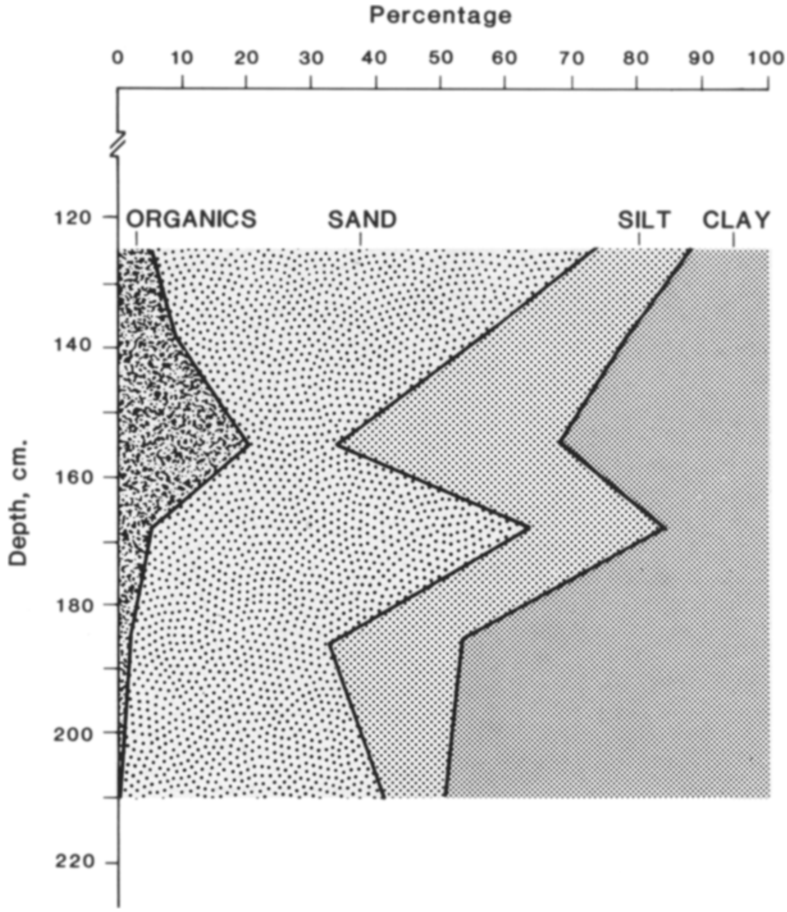

Fig. 6—Percentage of organics, sand, silt and clay fractions by depth for Ponaki core site B. Note: the charcoal band at this site is at 1.55 m.

Table 2—Comparison of grain size distributions for soils, dunes and wetland muds and sands in the Ponaki and Te Werahi catchment areas.

Terrestrial	Percentage Sand	Silt	Clay	Wetland	Percentage Sand	Silt	Clay
Ponaki							
podzolized silt-loams	35	51	13	Ponaki B (155 cm)*	32	35	32
	30	44	26	Ponaki B (185 cm)	32	21	47
	26	55	19				
Te Kopuru sands	93	6	1	Ponaki B (125 cm)	73	15	12
Dune sands	100	0	0	Ponaki B (138 cm)	56	23	21
				Ponaki B (168 cm)	64	20	16
Te Werahi							
red-brown clay-loams	23	28	43				
	25	19	52				
Dune sands	100	0	0	Causeway (300 cm)	98	2	0
				Twilight (300 cm)	98	2	0

* Value in brackets is the core depth from which the sample was taken.

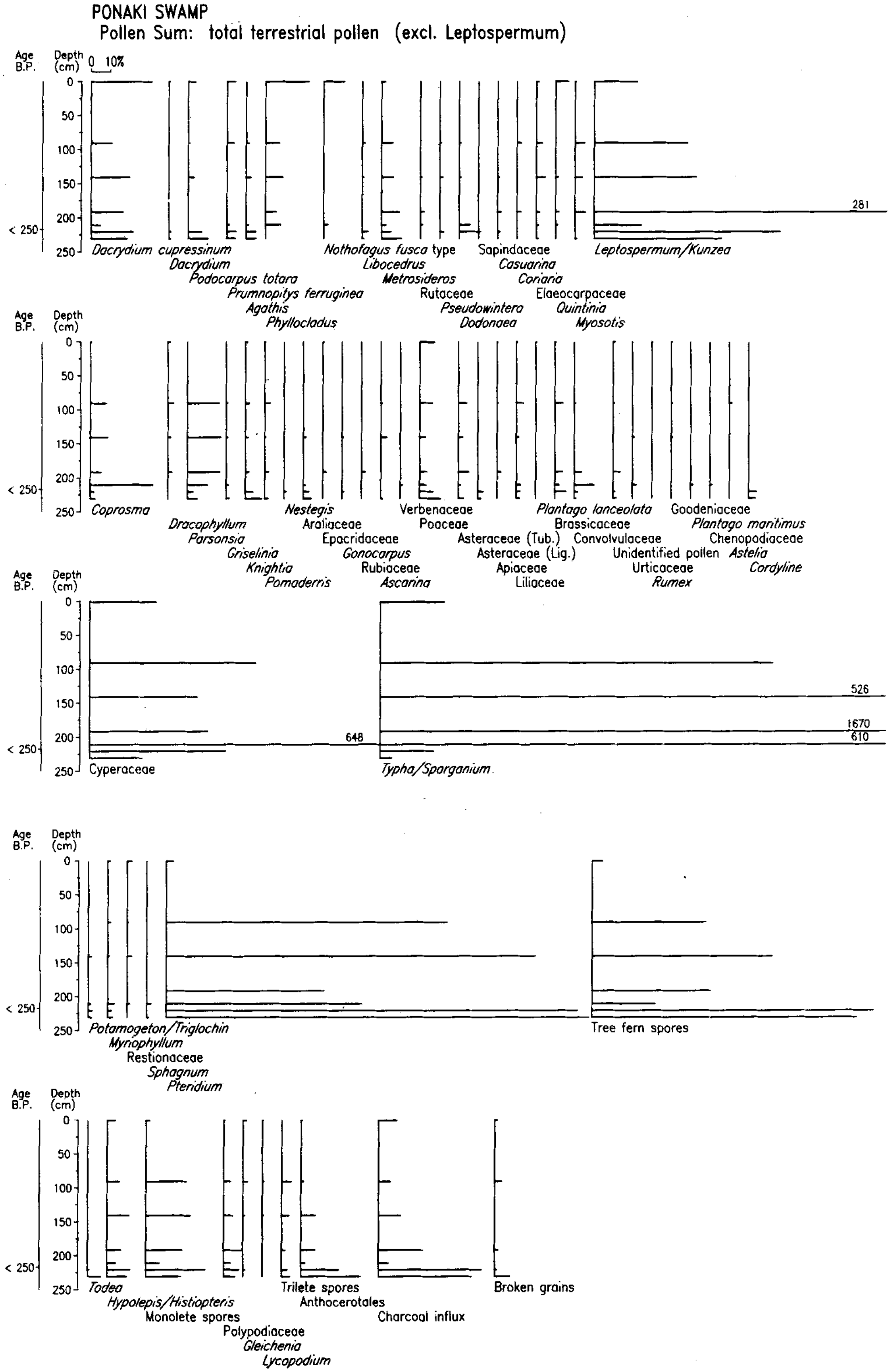

Fig. 7 — Pollen diagram for Ponaki core site A.

were *Leptospermum/Kunzea, Coprosma, Phyllocladus*, bracken and tree ferns. These indicate a history of predominantly heathland vegetation, but with pockets of forest, perhaps as remnants, much as today.

The earliest records of swamp taxa were in low values, suggesting ephemeral fresh water conditions. The site was then colonized by raupo and Cyperaceae and some ferns. There appears to have been a recent slight decrease in their abundance. The high values for Cyperaceae and bracken are clearly associated with higher charcoal abundance, while the peaks in raupo and *Leptospermum/Kunzea* pollen lie immediately above the charcoal layer.

The presence of small quantities of exotic pollens at both sites, for example *Casuarina*, suggests some long distance dispersal from Australia. Given (1981) comments that many Australian plants with small seeds or spores, especially ferns and orchids, have also been wind-dispersed to the more northern parts of New Zealand.

DISCUSSION

Stratigraphic evidence from the Te Werahi wetland suggests that the lower swamp has become filled in, mainly by the movement of wind-blown sand from the western and southern sand sheets. This also occurred early in the development of the upper swamp. Catchment-derived clays and silts have also been injected into the system, notably in the upper swamp and around the eastern edges of the other areas. The sequence of the mineral and organic layers at Causeway are consistent with intermittent inputs of catchment sediment into a vegetated swamp environment.

The Woolshed Site shows no sand invasion. However, sand is entering the western margins of the middle swamp not far from this site. This part of the wetland is characterised by areas of open water more than 3.5 m deep. Floating mats of raupo and *Elaeocharis sphacelata* appear to be slowly encroaching upon these areas. Sediment accumulation below the mats is wholly organic and derives almost completely from the decay of mat vegetation. Radiocarbon dates of compacted organics indicate that this part of the system has been a wetland for at least the last 3,700 years. The total depth of organic accumulation is not known, but in parts is more than 5.5 m deep. It seems likely that the origin of this wetland dates back to the time in the Holocene when sea-level reached its present position, i.e. at least 6,000 years B.P. Coastal dunes may have started to interrupt the flow of water from the area at that time.

The Twilight core shows a phase of sand deposition preceding swamp development, or perhaps burying an earlier swamp. Wright (1951) encountered sand to a depth of 3.0 m during attempts to locate peat deposits at Te Werahi. A site photograph suggests that her site was also in the lower system near Twilight Beach. Sand input is from eroding dunes on the western margins of the wetland, and from stream deposition of sand from the middle reaches of the system. In places this has led to conversion of wetland to dryland.

The pollen diagram (Fig. 5) shows that podocarp-hardwood forest, including kauri, dominated the terrestrial vegetation until about 3,000 years B.P. After that it declined, while *Metrosideros* and *Leptospermum/Kunzea* increased in abundance. Rimu remains stable throughout. A marked increase in charcoal particle density suggests the increased incidence of fire near the top of the core. This increase is dated to between 2,620 and 2,150 years B.P. and coincides with minimum pollen percentages for totara, miro and kauri, while values for *Coprosma*, flax and tree ferns are high. The timing of charcoal particle increase seems too early to be associated with Maori occupation of the area. Rather, it suggests a natural increase in fire frequency, possibly due to a drier, more droughty climate as has been postulated for other sites in both the North and South Island (McGlone *et al.*, 1984; McGlone and Moar, 1977).

The pollen data also indicate marked changes in wetland vegetation coinciding with the increased charcoal inputs. *Gleichenia*, previously common, declines markedly, while raupo, bracken and Cyperaceae increase in the top sample. The reduced rate of organic accumulation since about 2,100 years B.P. could be explained by an increase in the area of open water at the Woolshed core site. This is consistent with pollen evidence and suggests a rise in wetland water level which may have resulted from sand input to the lower reaches (Twilight area) of the system. It is most likely that sand mobilization happened at the same time as the increase in fire frequency, and that the two are related, as has been suggested for other sites by McGlone (1983).

The work of Fleming and Powell (1974), and Millener (1981), lends support to the suggestion of dune mobilization around 2,100 years B.P. Fleming and Powell (1974) obtained a radiocarbon age of 2,140 ± 90 years B.P. for a flax snail shell (*Placostylus ambigiosus priscus* [Powell]) from eroding sands in the vicinity of Herangi Trig near Twilight Beach. Indeed, they comment that destruction of forest by fire may have triggered the advance of coastal sands at this time. Although Cox (1977) questioned the accuracy of their date, since snails can incorporate old carbon into their shells, our dates bracketing the rise in charcoal abundance at the Woolshed site support their hypothesis. Millener (1981) provides a large number of radiocarbon dates for flax snail shells, and several for wood, from the same area. There is a clustering of dates around 2,200-1,900 years B.P. (radiocarbon samples NZ4710C, NZ4836C, NZ4706C, NZ5091C, NZ5090C, NZ5089C, NZ5034C, NZ4708C), including samples buried by dune sands at the edge of Te Werahi Stream which drains the wetland under investigation. Fossil shell and wood material has allowed dating of a number of palaeosurfaces in the Twilight beach—Cape Maria-Van Diemen area, and suggests a complex history of disturbances over the last 2,000 years (Millener, 1981).

Millener (1981) documents the decline of certain forest bird species in the far north, noting the rarity of fossil remains after about 1,000 years B.P. and their absence after about 500 years B.P. He suggests that while the total extent of forest may have begun to decline before 1,000 years B.P., there must still have been areas of coastal forest present until closer to 500 years B.P. The earliest evidence of human occupation close to Te Werahi is a midden site at Twilight Beach dated to 668 years B.P. (Taylor, 1984). The period of Maori occupation cannot be identified from the Woolshed core.

The stratigraphy and age of the Ponaki wetland sediments indicates a recent history of wetland development. At core site A, raupo swamp overlies water and loosely compacted organics which are separated from inorganic muds by a charcoal band at 2.17 to 2.40 m. There is little pollen in the basal muds, which suggests that the site did not support a permanent wetland. No reliable pollen counts could be done for these muds below 2.40 m. The age of the charcoal is probably in the range 200 to 300 years B.P., and therefore pre-dates the European period. This is supported by the fact that *Plantago lanceolata* pollen is restricted to the surface pollen sample. Further, indirect support is provided by early accounts of the vegetation of this area even though no mention is made of the wetland itself. For example, Dieffenbach (1843) and Cheeseman (1896) note the scant and uninteresting nature of the vegetation implying the existence of fire-induced heath, while Bell and Clarke (1909) indicate unvegetated sands at the mouth of Ponaki Stream.

The charcoal peak correlates with high percentages of bracken, Poaceae and tree fern spores. This is followed first by a peak in Cyperaceae, then raupo and *Leptospermum/Kunzea*. Gymnosperms show a sudden decline and then slow recovery (most marked for *Phyllocladus*). Values for raupo, Cyperaceae and bracken decline towards the surface. These trends suggest fire(s) in heathland, and forest remnants, about 200 to 300 years B.P., resulting in the influx of charcoal and catchment soil to the valley floor. The stratigraphy at core site B is consistent with a period of sand input, both immediately before and after this event. However, swamp organics accumulate only above the charcoal, indicating a major change in the drainage, and perhaps nutrient, characteristics of the valley floor. We suggest that fires at this time led to the erosion of catchment soils and the destabilization of coastal dunes, including podzolized sands. This may have interfered with the drainage of the valley and led to the development of a raupo wetland which did not previously exist.

CONCLUSIONS

Valley floor wetlands are commonly created by sand barriers forming across stream exists. However, such systems usually evolve in response to periods of coastal progradation and sediment transport associated with a stable sea-level (Thom and Chappell, 1975). The Te Werahi wetland probably originated this way, although the system may have grown in size since then because of more recent changes in drainage caused by deforestation of the coastal dune complex. The marked increase in charcoal particle inputs at 4.00 m in the Woolshed core suggests a natural increase in fire frequency between 2,620 and 2,150 years B.P. as a causal factor in deforestation.

The Ponaki wetland is also a valley floor—barrier system. However, this wetland did not exist until about 200-300 years B.P. and probably owes its origin to the destabilizing effects of fire on both catchment and coastal vegetation and soils. The input of fine sediments and organic matter from the heath and forest covered catchment area must have markedly increased nutrient supply to the valley floor. Removal of coastal vegetation caused erosion of both young dunal material and soils of the older coastal complex (*i.e.* podzolized sands). These sands were redeposited in the lower reaches of the valley, impeding discharge and so producing a wetland over the valley floor.

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