– ARTICLE –

Archaeological Charcoal Analysis in New Zealand

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ABSTRACT

Charcoal is well preserved and abundant in many New Zealand archaeological sites. When identified to species it provides a means of reconstructing past vegetation communities adjacent to occupation sites. However, the way charcoal deposits accumulated needs to be considered before species identifications are converted into vegetation reconstructions. Here a number of examples from New Zealand archaeological sites illustrate how charcoal identification when combined with a consideration of the contexts from which samples are derived allow inferences to be made about human interaction with the fire histories of past vegetation communities.

Keywords: charcoal identification, floral remains, fire history, New Zealand archaeological hearths

INTRODUCTION

Charcoal is abundant and well preserved in many New Zealand archaeological sites and has long been used to obtain samples for radiocarbon determinations. As part of this process charcoal is identified to species, a service provided by Brian Molloy from the 1960s and by RW since the early 1990s. Species identification ensures dated charcoal contains only material with insignificant inbuilt age (McFadgen 1982: 384). However, identifications of wood and charcoal samples have the potential to provide a much wider variety of information on how people in the past interacted with the vegetation in the landscapes they occupied. This paper summarises the results of a number of New Zealand charcoal identification studies and indicates the types of information charcoal can supply and the questions that may addressed with these data. Sample collection procedures are discussed with an emphasis on how field documentation affects the ability of the analyst to interpret the charcoal record.

NEW ZEALAND FLORA

New Zealand's large and diverse native woody flora includes 60 or so large and over 500 smaller native woody species, most endemic to the country having evolved in some degree of isolation for millions of years. Palynological studies provide a general understanding of the pre-human vegetation cover (McGlone 1983, 1989; McGlone & Wilmshurst 1999). Prior to human arrival most of the country below the timberline on the mountains was clothed in evergreen forests, conifer–broadleaf in the lowlands and southern beech (Nothofagus) at higher altitudes. Except in areas directly affected by volcanic eruptions (Froggatt 1997), grasslands were restricted to high altitudes and to limited areas in regions of low rainfall. In contrast to countries with a continuous history of fire (e.g. Australia) or a long history of anthropogenic burning (e.g. Mediterranean Europe), fire was uncommon in New Zealand prior to Polynesian arrival (Butler 2008).

After Polynesian arrival anthropogenic fires became extremely common with dramatic effects on the New Zealand landscape (McWethy *et al*. 2010). As McWethy *et al.* (2013) state:

> Rapid forest transitions in biomass-rich ecosystems such as New Zealand and areas of Tasmania and southern South America illustrate how landscapes experiencing few fires can shift past tipping points to become fire-prone landscapes with new alternative stable state communities.

Forest clearance was often rapid and widespread especially along the drier eastern side of the country from Southland to East Cape. Local effects were strongly influenced by topography with lowlands suffering the greatest transformation while in hilly or mountainous areas, forest clearance either occurred more slowly or not at all. Plants that colonise land after fires, such as bracken fern (*Pteridium esculentum*) which burns readily but has underground rhizomes which ensure it rapidly regrows, came to occupy extensive areas (McGlone *et al.* 2005). In drier regions, bracken established after initial fires was progressively replaced by equally fire tolerant tussock grasslands (McGlone 1989: 116) however in higher rainfall areas bracken remained dominant as long as it was regu-

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larly burnt. Another plant association that flourished was manuka (*Leptospermum scoparium)* and kanuka (*Kunzea ericoides)* dominated scrub which can form near monospecific stands on recently burnt ground (Allen *et al.* 1992; de Lange 2014; Stephens *et al.* 2005). These fire tolerant plant associations were maintained by repeated landscape fires which suppressed forest regeneration and created a complex mosaic of grassland, bracken, scrub communities, and forest remnants which varied regionally depending on rainfall and topography.

Pollen studies reflect region wide patterns rather than local plant ecosystems as they are biased towards taxa that produce abundant wind distributed pollen. In contrast, charcoal analysis allows palaeo-botanical reconstructions for the immediate vicinity of sites. These reflect human interactions with local ecosystems and illustrate behaviours such as land clearance for gardening as well as firewood and building timber collection. Reviewing charcoal studies from temperate Europe and the western Mediterranean, Asouti and Austin (2005) concluded that understanding localised human activities and wood sources provides the means to consider the similarities and differences between data obtained from archaeological charcoal samples and more regional patterns obtained from pollen, a statement that applies equally to New Zealand. The information available from charcoal analysis depends on what kind of fires were involved and how archaeological charcoal accumulated, an observation made very early on in archaeological charcoal studies (Godwin & Tansley 1941; Théry-Parisot *et al.* 2010).

NEW ZEALAND ARCHAEOLOGICAL CHARCOAL ANALYSIS

Charcoal identification involves the examination of cell structures visible in snapped or cleaved surfaces under incident light microscopy at 20 to 500 times magnification. Most New Zealand woods have a cell anatomy that is sufficiently distinctive to allow identification to specific or generic level. A few important groups, however, can be difficult to identify. An example consists of puriri (*Vitex lucens*), tarairi (*Beilschmiedia tarairi*), mangeao (*Litsea calicaris*), and kohekohe (*Dysoxylum spectabile*) which are difficult to tell apart when the charcoal from small diameter sapwood typical of firewood remains is concerned. Karaka (*Corynocarpus laevigatus*) and tutu (*Coriaria spp.*), although very different plants, can only be reliably separated when large fragments of good quality charcoal are available.

Charcoal recovered from sites may relate to a range of different firing events. Derived from the manufactured objects such as building timbers, it could be considered an artefact. As remains of firewood associated with domestic cooking features it is certainly the result of human action but not the product of intended manufacture. Similarly, landscape fires may be the result of human agency but are unlikely to be directly associated with the occupation of a particular site. Charcoal generated as a result volcanic activity will not relate to human agency yet it can occur in archaeological sites as examples illustrated here show. The source of charcoal and how it came to be incorporated into the archaeological record therefore needs to be considered when interpreting results and when attempting to reconstruct past floral communities.

Wood as fuel

Much of the charcoal found in New Zealand archaeological sites originates from wood used as domestic fuel. Wood combustion produces radiant heat with carbon dioxide and water vapour the main exhaust gases. Though denser woods contain more potential calorific value per volume, on a weight for weight basis energy output varies little between species (Théry-Parisot *et al.* 2010:144–5). As the moisture content of wood can range from 30% to 70% and the conversion of free water to steam consumes energy, the best firewood is always dry firewood (FirewoodNZ 2016). This generally means firewood selection was dictated by availability, size, and dryness rather than species composition. Firewood, therefore, usually reflects the composition of the local vegetation. This said, certain species may have been selected for certain cooking purposes (Huebert *et al.* 2010).

Both ethnographic accounts and archaeological data suggest pre-European Maori used firewood mainly for cooking rather than heating. Most Maori 'houses' (w*hare*) were small rectangular timber structures with thatched walls and roofs that were mainly used for sleeping where hearths were often absent, but if present typically contain little charcoal. They appear to have held hot coals or rocks supplied from fires located elsewhere rather than open fires (Prickett 1981). Cooking was carried out away from houses (see Petre 2015 Figure 24) where, in the absence of pottery, food was roasted on hot coals or cooked by steam in earth ovens. Typically a fire was lit in a hollow in the ground to which stones were added. When these had heated the fire was quenched and food was placed on the hot stones and covered to trap the steam. This procedure yields the abundant unburnt charcoal found in most cooking features.

Firewood sources

Firewood collection was likely a daily task for the pre-European Maori being sourced close to the point of use. While local vegetation probably supplied most of this fuel some exceptions occur. Many New Zealand sites are located on coastlines where beach driftwood was available. Figure 1 shows a beach immediately in front of the Te Hoe whaling site, Hawkes Bay where the mass of driftwood present was transported some distance from where it originally grew (Smith & Prickett 2008).

Figure 1. Driftwood on a beach at Mahia Peninsula. (Photo supplied by Professor Ian Smith, Anthropology and Archaeology Department, Otago University).

The presence driftwood in charcoal samples may be indicated by the occurrence of non-local species. For example, mangrove (*Avicennia marina*) is an intertidal species whose dead wood is always shed into water. In sites R08/197 and R08/198 at Mangawhai Heads (Figure 7, Carpenter 2015) a third of the pieces identified were mangrove despite the nearest modern mangroves being several kilometres up the harbour (Table 1). This likely indicates that much of the firewood was collected as beach driftwood. A further case study from Great Mercury Island examining this issue is provided below.

Firewood does not necessarily originate from living vegetation. Mature New Zealand forests have large trees whose logs and stumps contain durable heartwood that can persist on the land surfaces long after forest clearance. On the east coast of the South Island forests destroyed more than 500 years ago left behind sub-fossil wood (Molloy *et al.* 1963). When used for firewood these wood sources will obviously not reflect vegetation contemporary with site occupation and will yield old C14 dates (Fankhauser 1992).

The presence of sub-fossil wood may be indicated where samples containing a few large forest trees are otherwise dominated by short-lived secondary scrub and shrub species especially when the full range of trees expected in a living forest community are absent. Charcoal results from a large number of sites on Matakana Island were dominated by bracken, manuka, and other small shrubs yet had a minor component of kauri (*Agathis australis*), matai (*Prumnopitys taxifolia*), and totara (*Podocarpus totara*) (Wallace 2004) (Table 2). Such a pattern is explicable if the firewood concerned was collected from fern and scrub vegetation where old stumps and logs from former forest also occurred.

Table 1. *Charcoal species proportions from Mangawhai (sites R08/197 and R08/198)*

Fern	2%
Shrub spp.	40%
Pohutukawa	2%
Kauri	23%
Mangrove	34%
# Pieces	**172**
# Samples	**21**

Table 2. *Charcoal species proportions from 40 Sites on Matakana Island dunes*

Bracken	5%
Manuka	66%
Other shrub spp.	17%
Conifers	12%
# Pieces	**545**
# Samples	**45**

The use of sub-fossil wood for firewood is also indicated at site T10/777, Opito Bay (Bickler *et al.* 2014; Hand 2013; Wallace 2014). Over half the charcoal in fire features dating to the 16th century consisted of kauri with the remainder mainly small shrub species (Table 3). Kauri forest does not grow as pure stands with an understory of shrubs. Therefore charcoal identifications indicate that firewood was not collected from a living forest. Kauri trees do, however, yield resinous and durable branch and root wood that survives in sub-fossil form on the ground for long periods (Steward & Beveridge 2010). At T10/777 charcoal identifications indicate that this may be the source from which firewood was obtained. Cooking features from this site dated to the 18th century, in contrast, have only traces of kauri suggesting the sub-fossil wood previously available was by this time largely used up.

Table 3. *Firewood charcoal species proportions from Opito (T10/777)*

	***Ca.* 1600 AD**	**1700–1800 AD**
Shrub spp.	40%	75%
Pohutukawa	4%	24%
Other Broadleaf Trees	1%	0.3%
Kauri	55%	0.3%
Total pieces	**551**	**368**
# Samples	**20**	**16**

Charcoal from building timbers

Post-occupation landscape fires were a common occurrence on abandoned pre-European Maori settlements and charred building timbers are often found. The excavation of an early historic village on the shores of Lake Taupo (U18/21) provides an example. Here a series of semi-subterranean houses were uncovered where many of the mainly totara structural timbers were found charred *in situ* (Don Prince pers. comm.). In contrast, charcoal from hearths in the houses mainly consisted of manuka or other shrub species (Table 4). This suggests firewood collection from a local vegetation dominated by manuka and indicates the totara used for house construction was sourced some distance from the site (Wallace 2009).

Table 4. *Charcoal species proportions from Acacia Bay, Taupo (U18/21)*

Species	Timbers	Hearths
Manuka		48%
Shrubs		37%
Conifers	100%	15%
Total pieces	**146**	**49**
# Samples	**146**	**10**

Patterns of species occurrence in different site contexts may indicate the presence of charred building timbers. Excavations at the Pohokura Gas Production Station site (Q19/336) revealed both rectangular pits with postholes indicating timber superstructures and circular *Rua* (pits) that lacked such features (Gibb & Taylor 2004). Samples from the base of the rectangular pits contained abundant large tree species while samples derived from their upper fills and from the *Rua* contained mainly shrub species and bracken (Table 5). This suggests that much of the charcoal from the base of the rectangular pits derived from superstructure timbers (Wallace 2008b).

Table 5. *Charcoal proportions from Pohokura-Waipapa (Q19/336)*

Features	**Rectangular Pits**		**Circular Rua**
Plant types	**Basal Fills**	**Upper Fills**	**Fills**
Bracken	3%	37%	40.5%
Shrub/scrub	34%	53%	45%
Broadleaf Trees	63%	8%	9.5%
Conifers	0%	2.5%	5%
Total Pieces	**35**	**238**	**42**

The form of the charcoal itself may sometimes indicate its origin as structural timbers. Charcoal from postholes that contain only one species might suggest the remains of the post. Such charcoal sometimes has one surface with a charred brown zone which occurs when a piece of a large wood is partially burnt in situ, leaving the remaining unburnt wood to decay. Figure 2 shows large diameter, trunk wood, kauri charcoal recovered from a drain in the base of a kumara pit from site S14/251 in the Waikato (Wallace 2015) with this feature as does the burnt in situ tree root illustrated later in Figure 6.

Charcoal from horticultural sites

Charcoal is sometimes recovered from horticultural sites such as those in the central Waikato where pre-European garden soils are common (Furey 2006). Excavation of sites from the region has revealed a regular pattern of oval basin-shaped depressions interpreted as planting hollows (Gumbley *et al.* 2004; Gumbley & Hoffman 2013). These are often filled with charcoal rich soil capped by a layer of sand and gravel (Figure 3). Samples from such features in site S14/195 were dominated by large forest tree species, nearly half of which were tawa (*Beilschmiedia tawa*) (Table 6). Charcoal was mainly in the form of small diameter twigs and branch wood along with abundant charred seeds plus a significant component of thin, unburnt bark. This indicates that gardening involved the clearance of virgin bush where small diameter branches trimmed from trees were burnt in oxygen starved, smouldering fires with

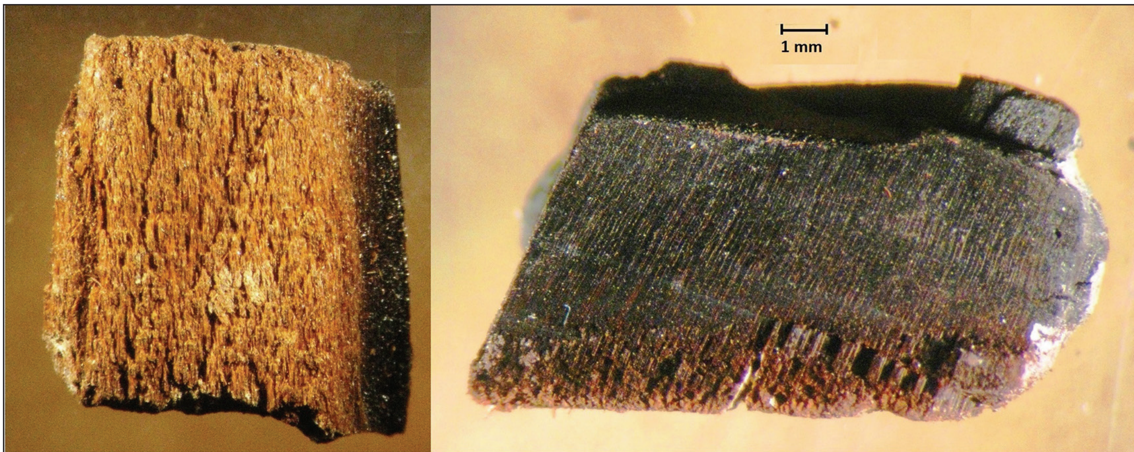

Figure 2. Charcoal from Site S14/251, Waikato partially carbonised surface layer.

Figure 3. Garden planting basin, site S14/195, Waikato. (Copied with permission from Gumbley, W. and Hoffmann, A. 2013, Figure 78, Page 91).

Table 6. *Charcoal proportions from planting hollows – Waikato (site S14/195)*

Bracken	0.1%
Ponga stem	2%
Shrubs	14%
Tawa	46%
Other Broadleaf Trees	3%
Conifers	36%
Total Pieces	**905**
# Samples	**31**

the resulting charcoal, as well as unburnt twigs and leaf litter placed in planting hollows (Wallace 2013). Evidence of former tawa dominated forests is significant as the pollen of this and related species do not survive in sediments and are therefore absent from the palynological record (Macphail 1980).

Charcoal from landscape fires

Charcoal in sites is not always deposited by direct human activities. Storage pits are common features in some New Zealand sites and their fills are often rich in charcoal. In site S14/195 mentioned above, deep rectangular pits were found with charcoal rich fills that contained mainly bracken fern aerial stems accompanied in the uppermost levels by carbonised manuka seed cases (Figure 4). Charcoal appears to have progressively accumulated in the pit from fires in post-abandonment bracken vegetation that later included some manuka (Wallace in Gumbley & Hoffman 2013).

Burnt out tree stumps that form large, irregular, charcoal rich features in the sub-soil are common on some land surfaces. In one sense these are a record of landscape fires initiated by probable human activity, however, the chronological association between them and later occupation horizons needs to be considered carefully. A case study illustrating examples of these is discussed below.

Figure 4. Storage pit from site S14/195, Waikato. (Copied with permission from: Gumbley and Hoffmann, 2013, Figure 44, Page 58).

Charcoal from volcanic events

Natural events may leave charcoal deposits in soils on which later human occupation occurred. The 1400 AD eruption of the Rangitoto volcano deposited a layer of volcanic ash that buried the old land surface on nearby Motutapu Island. This palaeosol contains abundant charcoal from eruption fires that largely destroyed the original forest of the Island. Charcoal from this eruption is found in deposits from later archaeological sites (see Davidson 2013) and is discussed in a case study below.

Numerous volcanic eruptions have occurred in New Zealand's Central Volcanic Plateau over the last few million years an example of which was the circa 200 CE Taupō eruption that buried some 20,000 km² in tephra (McKinnon 2015). These eruptions often involved incandescent pyroclastic flows that converted whole buried forests to charcoal. Sediments eroded from the plateau as a consequence typically contain abundant water rolled charcoal that can become deposited in archaeological sites, as for example at Kohika V15/80 (Irwin 2004).

Plant food remains

With the exception of charred kumara tubers from Pouerua (Yen & Head 1993), plant food remains are only rarely recovered from New Zealand sites. Seeds commonly found in charcoal samples include edible species such as tawa, hinau (*Elaeocarpus dentatus*), and karaka (Maxwell & Tromp 2016) however few occur in contexts that indicate they were definitely food remains. Charcoal from the taproot *of Ti (Cordyline australis)* is an exception. Large earth ovens identified as an *Umu Ti* sometimes contain abundant charcoal from a woody monocotyledon (Fankhauser 1992). This is almost certainly the remains of cabbage tree root cooked in the oven. Charred monocotyledon tissue found in large ovens high on Mt. Taranaki indicate that these too were *Umu Ti* (Wallace 2008a).

CHARCOAL SAMPLING

In some New Zealand sites charcoal can form a significant proportion of the sediment (see Figure 4) so collecting samples is often a simple process. This is not always the case, however, and in site T10/356 on Ahuahu, Great Mercury Island where charcoal was thinly dispersed throughout a garden soil up to 60 litres of sediment were floated to yield the results presented in Table 10. Both cases illustrate the difficulties archaeologists face when selecting charcoal samples. Understanding the context in which charcoal is found and the types of questions that charcoal analysis can help to answer are both important in determining the number and size of samples needed.

Obtaining charcoal samples by selecting only obvious chunks raises issues of representation since species with dense wood will form larger charcoal pieces while those with smaller stems and softer wood will tend to fragment more readily. In dry archaeological deposits, flotation in a bucket of water is usually the simplest and most effective way to recover most of the charcoal present. Gentle sieving with a 3–4 mm mesh to remove most of the fine sediment prior to flotation may make this process more efficient. Care is needed, however, as damp charcoal is easily crushed especially if rocks or shells are present in the sediment. In wet sediments where the charcoal is waterlogged and will not float, wet sieving followed by washing out the lighter charcoal fraction into a smaller sieve is effective. These methods need to be modified where aerial bracken stem charcoal is present as illustrated in Figure 4. This charcoal will pass through all but the finest sieve mesh sizes and is so fragile that anything more than gentle sieving will rapidly convert it to powder. Careful flotation of total samples of sediment is necessary for recovery of this species.

Charcoal is produced through diverse types of firing events so sampling procedures used during excavation are needed which take these contexts into account. Cooking features such as fire scoops and *haangi* typically relate to short term events. Wood converts to ash when burnt so most charcoal comes from the last few pieces of wood added to the fire before it was extinguished. This has an impact on the species proportions in charcoal samples as an example from site N05/302 in dunes just south of Tauroa Point near Ahipara, Northland illustrates. Here five charcoal rich lenses in a large oven thought by the excavators to represent discrete episodes of oven use over a relatively short period of time were sampled (Allen 2006:38, Figure 9). Four lenses were dominated by kanuka but one contained mainly matai, a large forest tree (Table 7). The unevenness of these results likely reflects variation in the pieces of firewood used during the separate firing events. If the goal of charcoal analysis is to reconstruct local vegetation, multiple separate fire features must be sampled in order to determine species proportions in wood sources exploited for fuel.

Table 7. *Charcoal from Tauroa Point (N05/302, Feature 74b)*

Layer	1	2	3	4	5
Shrubs	94%	83%	12%	57%	91%
Broadleaf trees	5%	18%	3%	14%	9%
Conifers	—	—	85%	14%	—
Total pieces	**56**	**45**	**34**	**28**	**46**

In order to be useful for palaeo-botanical reconstruction many independent samples from each occupation horizon may need to be collected. In New Zealand archaeological sites, from 10 to 20 samples are often needed depending on the context. Each sample needs to contain at least 250 ml of charcoal pieces in order to allow for species identification, again depending on the context. For example, when sampling is intended to provide C14 dating sub-samples of short-lived species or twig wood, larger samples may be necessary since only a tiny proportion of the sample may be suitable. Similarly, a feature such as a charcoal filled posthole may contain charcoal in addition to that derived from the post, so larger samples are necessary if the full range of species is to be identified.

DATA RECORDING

Listing results by the number of pieces of each species identified provides a representation of species abundance. One approach to obtaining such lists from different samples is to select the same number of pieces from each sample, for example, recording 20–25 identified pieces per sample. Sampling to redundancy, that is, continuing to identify pieces in a sample until no further species are found can yield acceptable results. Recording by presence and absence alone raises issues of representation since in some samples most of the material may come from only one or two pieces of charred wood broken up into many smaller chunks. Recorded as single occurrences, such counts tend not to reflect the true charcoal proportions of each species unless very large numbers of samples are involved

Some situations arise, however, where assigning numerical values is difficult. In the case of several samples obtained from the pit fills shown in Figure 4, circa 99% of the material consisted of finely divided aerial bracken stems accompanied by a few manuka seed cases. In these cases it was impossible to count the fine bracken pieces individually so alternative measures needed to be adopted. Similarly material derived from burnt structural timbers or burnt out tree stumps is not usefully recorded by fragment counts where only a single timbers or tree appears to be represented. As discussed in a case study below, relative weights of different species provide an alternative measure to fragment counts. These examples illustrate how a case by case approach may be needed for charcoal quantification.

In summary, interpretation of charcoal identifications requires the integration of information from the contexts sampled, together with the actual species identification and abundance measures. If intended for environmental reconstruction, a large number of samples from contemporary contexts are needed where the circumstances in which the fires occurred, how the charcoal accumulated, and why it has survived are well understood. In some cases, the nature of these contexts will change through time providing the potential to reconstruct the fire history at different localities.

CASE STUDIES

In the following we consider examples of charcoal analysis from New Zealand archaeological sites that illustrate the interrelationship between vegetation and cultural behaviours, paying particular attention to how these might be identified based on the contexts from which charcoal samples are derived. We use the examples from archaeological work on Motutapu Island and Ahuahu, Great Mercury Island to illustrate the ways in which charcoal deposits are created and how they are best interpreted. In both cases RW was involved in the excavation of the sites and supervised the charcoal sample collection.

Case Study I: R10/494 Motutapu Island

Motutapu is a 1,509 ha island in the Hauraki Gulf near Auckland, adjacent to the young volcanic island cone of Rangitoto (Figure 7). Site R10/494 consists of a cluster of terraces, three of which were excavated. One revealed a house structure, another a large storage pit, and the third a deposit of shell midden and oven stones (Ladefoged & Wallace 2010). Despite there being no evidence of hearths or fire scoops on the house terrace, charcoal was abundant (Table 8). Forty one percent of the sample came from large conifers such as totara, rimu (*Dacrydium cupressinum*), matai, and kauri. Detailed sample proveniences indicated almost all this conifer charcoal came from posthole fills which suggests it originated from burnt house timbers. The remainder of the house floor charcoal was dominated by bracken fern and small shrubs such as tutu, hebe (*Hebe* sp.), coprosma (*Coprosma* sp.), and manuka. Although some of the latter charcoal could reflect house

Table 8. *Charcoal results for Site R10/494, Motutapu Island.*

Plant type	Midden	House Floor	Slope wash	Palaeosol
Bracken	2%	30%	69%	
Small shrubs	74%	16%	23%	
Scrub	10%	5%	1%	
Pohutukawa/Puriri	13%	5%	2%	
Beech	0.5%	3%		100%
Conifers		41%	4%	
Total pieces	**179**	**240**	**94**	**10**
# Samples	**12**	**42**	**13**	**4**

building material these species are more typical of woody vegetation likely to have colonised the terrace soon after occupation ceased and carbonised in the post-occupation landscape fires that charred the house timbers.

Each terrace was cut into a slope through the volcanic ash layer where it exposed some of the charcoal rich palaeosol formed during the eruption of Rangitoto. Four test pits dug well away from the terraces to sample this charcoal produced samples dominated by hard beech (*Nothofagus truncata*). On the house terrace this species was found in samples from the fill of the drain that encircled the back of the house. Given the palaeosol was only exposed in the scarp immediately above this drain this charcoal likely originated from beech forest burnt during the 14th century CE Rangitoto eruption.

The soft volcanic ash overlying this part of the island erodes readily and formed layers of slope wash burying the rear of the house terrace (Figure 5) and filled the base of the large storage pit. This sediment contained multiple, thin, burnt horizons, the result of landscape fires in the post-abandonment vegetation. The charcoal in these lenses was mainly bracken and small smaller shrub species. The few fragments of conifer charcoal present probably represented mixing where these lenses merged with the house floor levels. In summary, the charcoal from the house floor reflects a mixture of charcoal from pre or post occupation landscape fires mixed with charred house building timbers. Apart from remains of these timbers, none of the charcoal present derives from vegetation dating to the time the site was occupied.

In contrast, charcoal from shell midden on the cooking terrace were dominated by the small woody shrubs tutu, hebe, and coprosma with the only common tree species being pohutukawa (*Metrosideros excelsa*) and puriri, both trees that typically survive forest clearance and, in fact, remain abundant on adjacent coastal cliffs today. Conifer charcoal was absent and the single fragment of beech charcoal probably originated from a small area of the 14th century CE palaeosol cut into when the terrace was constructed.

The charcoal results suggest that Motutapu Island originally supported beech dominated forest which was largely destroyed during the 14th century CE Rangitoto eruption. By the time R10/494 was occupied, locally available firewood was sourced from scrub and shrub vegetation accompanied by some pohutukawa and puriri trees. Bracken is not useful as firewood and doesn't appear in the

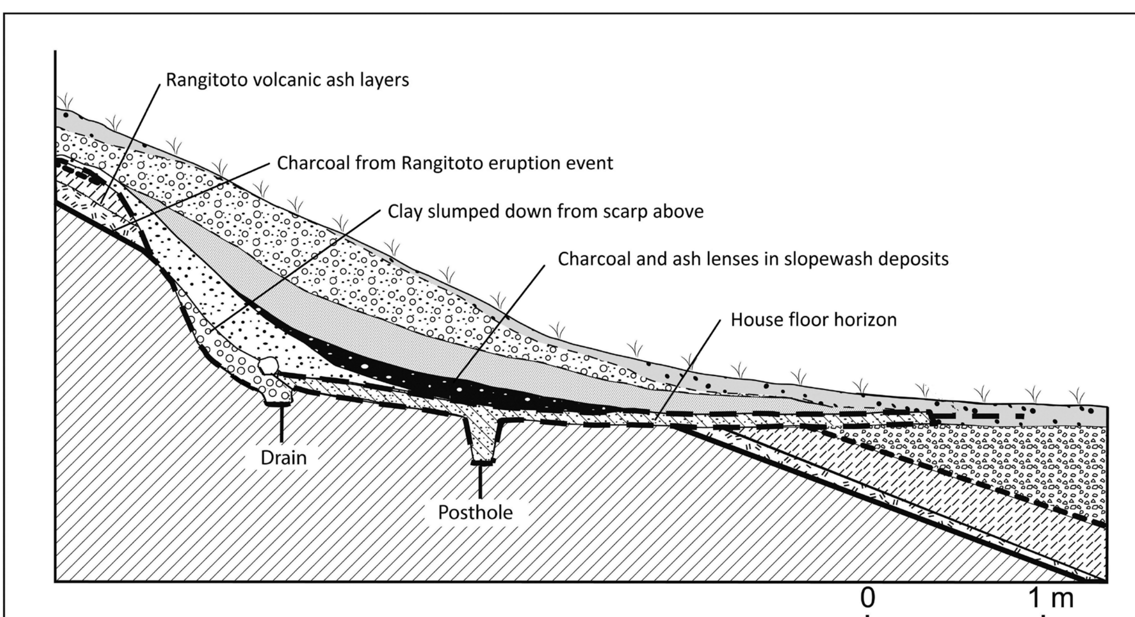

Figure 5. Profile across R10/494 Motutapu Island house terrace showing charcoal sampling locations (after Ladefoged and Wallace, 2010, Figure 4, page 174).

midden samples but its abundance in post-abandonment sediments indicates its presence in local vegetation both during and after occupation. This case study illustrates how charcoal in sites may derive from a variety of sources and attention to the nature of archaeological contexts is required to interpret charcoal identifications and abundance.

Case Study II: Ahuahu, Great Mercury Island

Ahuahu is an 1872 ha island approximately 6 km from the Kuaotunu Peninsula on the east coast of the Coromandel Peninsula (Figure 6). The northern part of the island is currently farmed and is in permanent pasture. Archaeological investigations have identified sites spanning occupation of the entire pre-European Maori period (Furey *et al.* 2013; Phillipps *et al.* 2014) with several thousand charcoal fragments now identified to taxa from a number of excavated contexts. Features sampled include cooking features, artefact rich deposits, structural features on terraces, rectangular pits, a shell midden, and stone alignments. These data and the various issues of interpretation that arise are illustrated in the examples discussed below.

Overview

Charcoal samples are dominated by shrub and scrub species with evidence for large trees in the main restricted to pohutukawa and puriri. Pohutukawa is the only large native tree currently abundant on the northern end of the island though historic accounts indicate that puriri was once common (Mizen 1998). Except in a small number of samples from fire features from the EA65 site, evidence of intact podocarp forest cover is absent. Species such as towai (*Weinmannia silvicola*) and rewarewa (*Knightia excelsa*) that are regenerating in valleys at the southern end of the island (Wright 1976) are largely absent in archaeological samples. Sub-fossil kauri gum was mined on the island in the early 20th century (Wright 1976: 25), however there is little evidence in the charcoal data that this species was common during the period of pre-European Maori occupation.

Pollen records from islands of a similar size off the east coast of northern New Zealand indicate forest cover prior to human arrival (Empson *et al.* 2002; Harris 1961; Horrocks *et al.* 2002; Wilmshurst *et al.* 2014). On islands in the Hauraki Gulf, significant areas of hardwood conifer

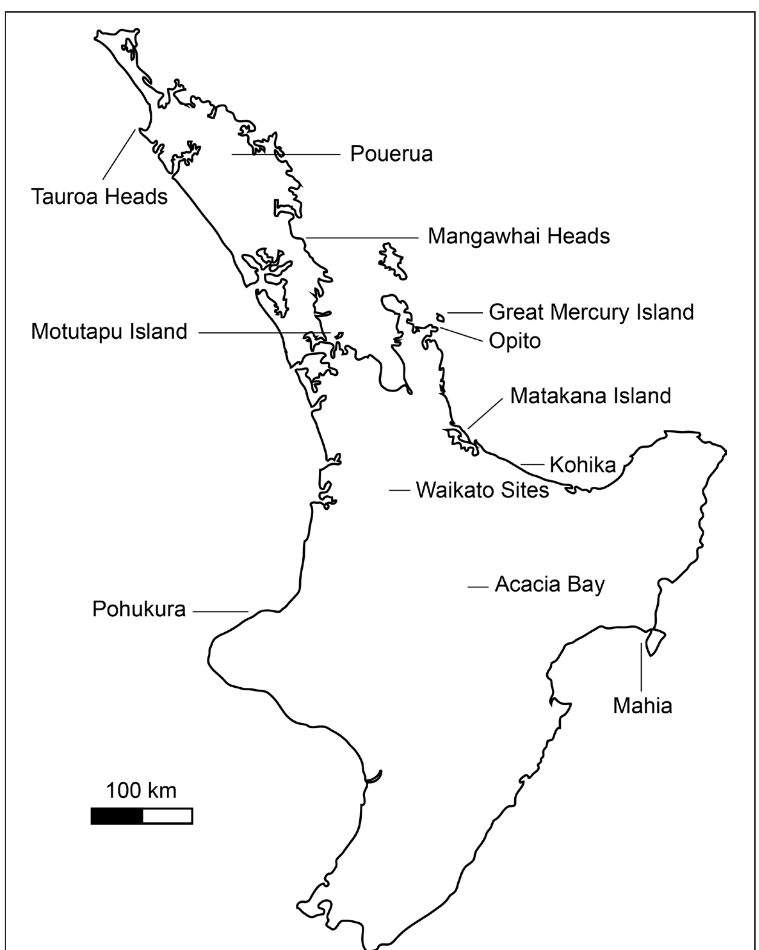

Figure 6. Outline map of New Zealand North Island site locations mentioned in the text.

forests persisted into the 19th century (Kirk 1878). However, the charcoal data from Ahuahu more closely match vegetation successions on smaller islands off the north east coast of the North Island (Atkinson 2004) where destruction of the original vegetation by the pre-European Maori was followed by the persistent pohutukawa and kanuka dominated cover (Wright 1976). This suggests the pre-European Maori had a greater impact of the vegetation of Ahuahu than on other islands of similar size with the original vegetation cover being cleared both rapidly and thoroughly shortly after human arrival. Further studies of the vegetation history of the island by coring wetland deposits to recover evidence from pollen, seeds, and insect remains are ongoing.

Driftwood

Driftwood volumes currently available on Ahuahu beaches are in general low however beaches were a possible source of driftwood suitable for firewood. Despite beech and kauri being absent or rare on the island today, logs and stumps of these species were found on island beaches during fieldwork conducted between 2012 and 2106. To help assess the influence of driftwood on archaeological charcoal samples, a collection of 104 pieces of modern driftwood was made in February, 2015. Just under half the identified pieces (excluding 12 pieces identified as exotic to New Zealand) were pohutukawa which is to be expected as this tree is dominant on coastal cliffs on the island and the adjacent mainland. Other broadleaf and conifer trees account for 25% and 21% of the sample respectively while shrub species are rare (Table 9). Apart from the pohutukawa, these results are different from the current vegetation on the island which indicates that most modern driftwood probably originated in the heavily forested upper catchments of rivers on the adjacent Coromandel Peninsula. Charcoal results from eight excavated sites on Ahuahu also differ from modern driftwood taxa (Table 9). This combined with the low availability of driftwood may indicate that this source was not significant for pre-European Maori on Ahuahu. At the same time, driftwood may account for small amounts of forest species found in some archaeological samples.

Table 9. *Modern Driftwood compared to archaeological Charcoal, Great Mercury Island*

	Modern Driftwood	Percentages from 8 sites
Shrubs/Scrub spp.	12%	54%
Pohutukawa/Puriri	44%	43%
Other large trees	23%	1%
Conifers	21%	2%
Total pieces	**91**	**2492**

Garden soil charcoal

A series of parallel stone rows at site T10/356 are interpreted as garden features (Davis & Ladefoged 2013). Charcoal was found dispersed throughout soil horizons between the stone rows. Manuka and kanuka dominate samples taken from these soils indicating vegetation fired prior to gardening was most likely a secondary scrub succession (Table 10).

Table 10. *Charcoal from T10/356 garden soil*

Bracken	3	3%
Other Shrub/Scrub spp.	32	31%
Manuka/Kanuka	62	61%
Puriri	5	5%
Totals	**102**	
# Samples	**6**	

Tamewhera (N40/63) charcoal

A number of stone fronted terraces are located on a steep hill face in the north west of Ahuahu. Charcoal samples were obtained from excavations on five of these terraces. Ninety six percent of the charcoal from the excavated samples was either from small shrubs or pohutukawa. On terrace EA103, the remains of a 4 × 2.8 m house were uncovered with 23 post slots indicating the location of postholes for dressed timber slabs. Two of these retained fragments of kauri wood. Charcoal recovered from this terrace mainly consisted of small fragments, however when larger fragments were identified, these consisted of either kauri or totara. These results suggest the kauri and totara charcoal derived from burnt building timbers. Charcoal recovered from the other four terraces revealed only two fragments of conifer charcoal (Table 11). Building timbers were likely brought to the site from elsewhere on the island or the mainland and are therefore unlikely to indicate local vegetation.

EA64 (T10/360) charcoal

Excavations on a sand covered ridge above a beach just east of the mouth of the stream which drains into Coralie Bay revealed a number of fire scoops. Charcoal samples from these features are dominated by shrubby species (64%) with trees (34%) mainly limited to pohutukawa and puriri. The firewood indicated by this charcoal was likely sourced from a local woody vegetation consisting of coastal shrubs plus pohutukawa and puriri trees (Table 12).

Stratified below these fire features, is a cultural horizon with abundant charcoal derived from two sources. Charred ends of several dressed totara and kauri timbers are indicated representing 24% of the pieces found. Underlying and mixed with this charcoal the *in situ* charred

Table 11. *Charcoal from Tamewhera (N40/63), Great Mercury Island*

	EA103 Terrace	All five terraces
Shrub/scrub spp.	67%	81%
Pohutukawa	20.5%	15%
Other Broadleaf trees	—	0.2%
Conifers	12.5%	3.5%
Total pieces	**112**	**454**
# Samples	**10**	**45**

Table 12. *Charcoal identifications – EA64 (T10/360), Great Mercury Island*

	Lower Levels	Upper Levels
Shrub/scrub spp.	9%	64%
Pohutukawa and Puriri	64%	34%
Other Broadleaf trees	2%	0.5%
Conifers	24%	0.8%
Total pieces	**883**	**1006**
# Samples	**58**	**37**

root systems of two large trees were identified, one pohutukawa and the other puriri (Figure 7). These charred roots supplied 64% of the total identified pieces but represented over 90% of the charcoal by weight. The differences between these charcoal assemblages reflects the different contexts in which the charcoal formed. Charcoal associated with the later fire scoops derives from woody species sourced as firewood. Charcoal from the lower deposits indicates firing of two trees as well as burning of timbers used for construction. In contrast, charcoal from fire features at the adjacent site of EA65 contained abundant conifer species. If these fire features can be shown to be contemporaneous with the coastal burning at EA64, it may help to indicate the timing of a change in the local woody species from conifers to shrub species associated with initial human occupation. The example illustrates the importance of comparing samples derived from similar contexts when seeking evidence for changes associated with floral succession.

Overall, charcoal samples obtained from different contexts in sites on Ahuahu indicate differences in both species composition and abundance. This reflects both the form in which wood was burnt and the nature of local vegetation at the time the burning occurred. As with the case study from Motutapu, the examples from Ahuahu emphasise how the results of charcoal analysis need to be interpreted in relation to the excavation contexts if they are to be usefully interpreted.

DISCUSSION AND CONCLUSION

The production, concentration, and preservation of charcoal in New Zealand archaeological sites relates to a variety of cultural and natural events. The nature of floral change as a result of anthropogenic burning is relatively well understood in New Zealand. This provides the opportunity to understand human environmental interaction at a local level. However, before interpretations of charcoal assemblages are made, the contexts from which the charcoal samples are derived need to be considered. People gathered dry wood for fuel from a range of contexts, from plants growing in the immediate area, from old stumps of long dead forests, and from driftwood from local beaches. These contexts will influence the species composition and abundance of charcoal in samples. Therefore, the collection of charcoal samples from archaeological sites to reconstruct palaeo-botanical communities without taking context into account is not a useful strategy. Charcoal from long-term deposits of secondary refuse has been suggested as best for vegetation reconstruction (Chabal *et al.* 1999). This may hold for some European site contexts but in the New Zealand context and probably many others it may be that identification of the specific activity which

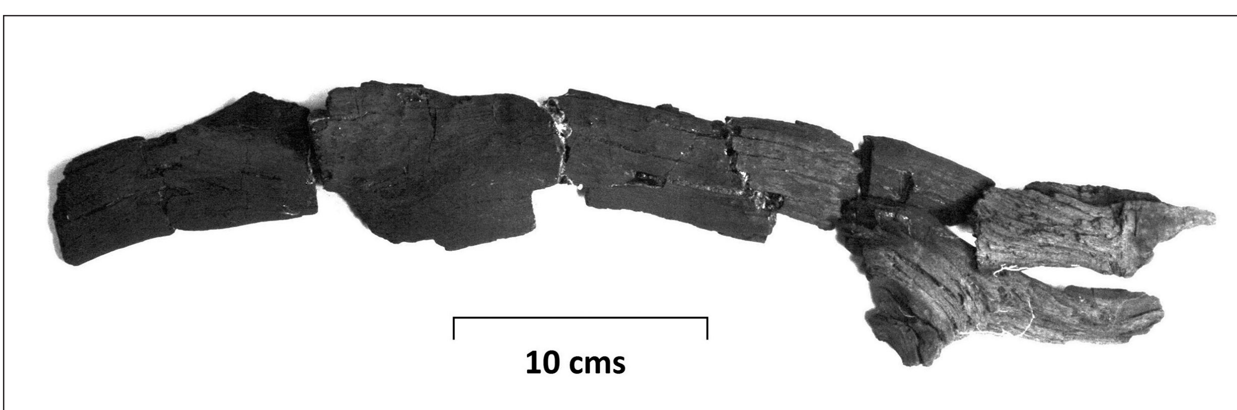

Figure 7. Charred Puriri root recovered complete in situ from the base of site T10/360, Great Mercury Island in 2016.

produced the fires from which charcoal is derived is more important. The observation by pioneering workers such as Godwin and Tansley (1941) that analysis should be based on determining what kind of fires formed the charcoal deposits in archaeological sites remains as sound today as when it was first made.

The need to consider multiple contexts should be reflected in the way charcoal samples are obtained. Both the number and size of samples needed will vary depending on availability of material in the sites. Multiple charcoal samples are needed from different locations within an area investigated with interpretation being based on the integration of archaeological inferences with the results of the botanical identifications. This may require an iterative process of sample collection, identification, and new sample collection and identification. Charcoal analysis and interpretation may provide a powerful proxy for human environmental interaction however as the examples discussed here indicate, it is unlikely that this will occur when samples derived from single contexts are considered. Much of the power in archaeological charcoal analysis comes from understanding local variations in the way people interacted with New Zealand's broad pattern of anthropogenic floral succession. Adapting archaeological sampling procedures and interpretation of charcoal analysis to reflect this will provide the most productive means to reconstruct the fire history at archaeological sites.

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