MĀORI FIRE USE AND LANDSCAPE CHANGES IN SOUTHERN NEW ZEALAND

ERIN WILLIAMS
University of Otago

In a short period after Māori arrival massive fires, thought to be anthropogenic in origin, are witnessed in almost every pollen diagram in New Zealand. It is thought that human firing caused the reduction of the original forest cover of New Zealand from around 80 percent to somewhere nearer 15 percent (Ogden, Basher and McGlone 1998). The rapid nature of vegetation changes attributed to firing "might suggest either that Māori were indifferent to the substantial loss of forest, or perhaps... they had no control over the impact of an increased incidence of ignition" (Anderson 2002a: 30). A growing corpus of evidence suggests that shortly after Māori arrival in New Zealand, the vegetation of southern New Zealand underwent a significant transformation from a mosaic of shrub-, grass-, fern-lands and forest to a largely grassed expanse as a result of human firing.

This article explores Anderson's two suggestions by considering published literature in the light of these issues. By focusing on how Māori used fire during New Zealand's prehistory and how fire use affected vegetation changes, this paper will argue against Māori indifference to substantial forest loss. Although vegetation changes occurred as a result of fire throughout New Zealand, the attention will focus on southern New Zealand, defined here as the region south of Banks Peninsula.

EVIDENCE OF BURNING

Before Māori arrived in New Zealand around 850 BP (Anderson 1991), there is evidence for limited and sporadic vegetation disturbance in both islands, which is thought to be a result of climatic changes and infrequent natural fire events. The nature and extent of pre-human vegetation has been established from extant remains of forest, charcoal in soils and alluvial deposits, pollen from lakes and bogs, macrofossil remains and subfossil logs. Although New Zealand was largely forested, there can be no doubt that the first Māori to enter inland areas of the southeastern South Island encountered landscapes with a significant component of light vegetation as a result of a long history of natural fires in the dry interior. Central and eastern areas of southern New Zealand are naturally arid regions, prone to desiccating westerly winds and low rainfall. The dry conditions on the leeward side of New Zealand are further exaggerated by a water deficit which generally occurs from October

to April, supplementing the fire risk in this area (McGlone, Mark and Bell 1995: 4). In contrast, southern and western parts of southern New Zealand carry a water surplus for much of the year.

Palynological records show a rapid development of this mosaic landscape in southern New Zealand, with overall increases in grass and bracken (*Pteridium esculentum*) pollen and spores. It was suggested early on that fire was likely to have played a part in destroying the original vegetation (Buchanan 1868), although it was not until the publication of radiocarbon dates from subfossil logs found in the tussock grasslands of Central Otago (Molloy *et al*. 1963) that it was accepted that these fires were contemporaneous with Māori in the landscape (McGlone 2001). Evidence for anthropogenic fires is indicated by a variety of analytical tools. The palynological record shows a dramatic and sustained decrease in woody taxa, and an equally abrupt and sustained increase in charcoal, *Pteridium esculentum* spores and non-woody taxa. Palaeoenvironmental evidence shows that within the first c. 100 years of Māori settlement in New Zealand dramatic landscape and vegetation changes occurred.

Hawksburn, an early moa-hunting site located in a semi-arid tussock grassland environment of steep hills in the upper Hawks Burn Valley in Central Otago, demonstrates some of the significant vegetation changes of southern New Zealand. Despite obvious archaeological evidence of an occupation site and prior forest and wetland areas, present environs are almost totally devoid of food resources and materials for making shelters; the only woody plant present is *matagouri* shrub (*Discaria tomatou*), which provides hot firewood but poor building material. A recent identification of firewood charcoal from Hawksburn suggests that at the time of occupation *Coprosma arborea*, *Myrsine divaricata* and *Olearia* sp. were present in the local environment (Deng, Smith and Walter n.d.).

Before human settlement an open, discontinuous podocarp-angiosperm forest bordered the dry interior of Otago. Hall's *totara* (*Podocarpus hallii*), *toatoa* (*Phyllocladus alpinus*), bog pine (*Halocarpus bidwillii*), and small leaved and Asteraceae shrubs formed low forest and scrub associations in the semi-arid interior, with silver beech (*Nothofagus menziesii*) prominent in the upper montane-subalpine zones (McGlone 2001: 1). Palynological evidence from Earnscleugh Cave, less than 20km southeast of Hawksburn on the Old Man Range, indicates the vegetation before 1550 BP consisted of a mosaic of podocarp stands, open woodlands of *kowhai* (*Sophora* sp.), ribbonwood (*Plagianthus regius*) and *kanuka* (*Kunzea ericoides*), and small-leaved scrub on the lower flanks of the range (Clark *et al*. 1996: 375-76). At altitudes above 700 m the mosaic would have been progressively replaced by Hall's *totara* (*P. hallii*), *toatoa* (*P. alpinus*) and silver beech (*N. menziesii*).

The arrival of Māori in the landscape is marked by an opening of the dense scrub vegetation, a restriction of podocarp forest and the expansion of trees favouring open habitats such as *kowhai* and ribbonwood (Clark *et al*. 1996: 371). Around 750 BP anthropogenic fires are indicated in the palynological record throughout central and eastern regions of southern New Zealand (McGlone, Moar and Meurk 1997). Vegetation transformations appeared slightly later on wetter parts of the Old Man Range, as well as in the Catlins (650 BP) and in western Fiordland (400 BP) (McGlone *et al*. 1997, Vandergoes, Fitzsimons and Newnham 1997, Wilmshurst, McGlone and Charman 2002). During this post-settlement phase, the palaeo-environmental record demonstrates an increased occurrence of fire in humid areas such as the Catlins and Fiordland as anthropogenic fire extended to environments usually outside the natural fire envelope.

MĀORI AND EAST POLYNESIAN FIRE USE

The ecological impacts Māori had on the New Zealand environment were very similar to those witnessed elsewhere in Polynesia. Throughout the 4000 years or so since the arrival of humans in Oceania (Anderson 2002b) fire has influenced Polynesian cultures and environments. As Polynesian colonisers travelled through the Pacific they brought with them a horticulture based economy in which shifting cultivation involving the use of fire as a forest clearance tool was a major component (Kirch 1991: 120). Patches of forest were cleared and planted with crops, harvested, and then allowed to fallow (Leach 1999). Through use of fire the colonisers initiated considerable environmental changes on each of the islands they settled, mainly as a result of the introduction of fire into a finely balanced pre-human ecosystem (Fosberg 1963: 5). Human-environment interaction studies have recorded such effects as the loss of endemic species, an increase in erosion and a loss of forest (Anderson 1989; Ellison 1994; Kirch 1996; Kirch and Ellison 1994; Kirch *et al.* 1992; McGlone 1983, 1989, 2001; Steadman 1995; Wilmshurst 1997; Wilmshurst *et al*. 2004). Underlying those changes was the use of fire—inexplicably neglected as a subject of study in itself as a most significant tool for prehistoric Polynesians.

Fire was intimately involved and extensively employed throughout pre-European Polynesia for everything from land clearance to domestic and religious uses. In many places in the Pacific the forest was rapidly cleared soon after settlement. Where cleared land was gardened and fired repeatedly, secondary growth such as fern, grass and scrub came to replace the original vegetation. Areas where the distinctive vegetation pattern left by constant firing was present were generally avoided by cultivators as they were known to have unproductive soils that were prone to further erosion (Clarke 1994: 16,

Mark 1976). The original soils from these areas often eroded into productive, cultivated valleys. In some areas it has been suggested that hill slopes were intentionally degraded to encourage the movement of soils to the valleys (Kirch 2000: 255). While there are records of intentional burning of such wastelands (Clarke 1994: 25, Gill 1876: 317) and it is known that Pacific peoples would burn some parts of the landscape for no economic purpose (Janet Davidson pers. comm., Masterton 2008; Kasey Robb pers. comm., Dunedin 2008), it is highly unlikely that Polynesians, who have a heavy dependency on tree crops, would be indifferent to the loss of their orchards. While not dismissing that there is every likelihood fire did burn out of control (probably on a regular basis), it is likely from a survival perspective that fire and fire risk was intensively and extensively managed by Polynesians.

When Polynesian settlers arrived in New Zealand they brought with them a pre-established fire culture with associated belief systems and rules surrounding the sacredness of fire and its uses. Fire was an integral part of life for Māori, who were reliant on it for almost every aspect of their daily lives. It was of primary importance in the domestic sphere where it was used for both cooking and heating. Food preparation and cooking practices were well documented by European visitors to New Zealand. The earth ovens (*umu*) that they saw in use in New Zealand were very similar to those seen by Cook's crew in Tahiti that were described as "holes in the ground fill'd with Provision & hot stones, & covered over with leaves & Earth" (Banks in Morrell 1958: 73). Along with steaming in an *umu*, food could be prepared in embers, on embers, on a cooking stage, in a cooking bowl, in ashes; food could be wrapped in leaves and steamed beside a fire, covered in clay and baked, or skewered on a stick and cooked over a fire (Beattie 1994: 291-93). Fire was also used to preserve food by smoking. Yate 1835: 109-10) recorded eels being strung on racks and placed over a smoky fire for several days to dry them, and fish dried in a similar manner. They were gutted, washed in sea water, drained, par-cooked in an oven and then placed on a wattled stage under which burnt a strong fire. The fish were only smoked overnight and then sun dried.

Houses were recorded as having fireplaces but no chimneys that produced an incredibly hot and smoky interior abhorred by the Europeans (Marsden in Elder 1932: 159, 191). In 1769 Parkinson noted that the venting of smoke from Māori houses did not seem to be a priority at the time "or they would have found out some means to have removed it; for necessity is the mother of invention" (Parkinson 1984: 86). Several people slept within each house, and the elders slept in beds called *rara* (the same name refers to a cooking stage) around a central hearth, with a firestick placed to the side of each bed. Internal hearths were commonly recorded as being stone edged or stone lined,

which effectively confined the fire, and it has been suggested that hot embers or hot rocks were preferred over a risky roaring fire as a method of heating (Beattie 1994: 471, Bellwood 1971: 86-87, Leach 1972: 62).

External fires were recorded by a number of Europeans as being used to deter insects, a practice quickly adopted by the visitors, particularly in the sandfly-infested regions of Fiordland and the West Coast. In 1773, during Cook's second voyage, Menzies recorded the large fire they lit and maintained all night at Goose Cove, Fiordland, in an attempt to keep the sandflies at bay (Menzies in Salmond 1997: 193). Brunner also used this method, stating that

> fire is the best protection [from sandflies and mosquitoes]; and you see all the houses with a fire inside and outside, placed so that the smoke protects the entrance, or doorway. You partake of your meals under the shelter or the smoke of a circle of fires.... (Brunner in Host 2006: 151)

Fire was used to prepare ochre and gums for paint and perfumes. Ochre was highly valued in Māori society, particularly when in its red form, haematite (McGovern-Wilson *et al.* 1996: 178). Red ochre was often associated with *tapu* objects (Holdaway 1984: 125), and red articles were the things most valued by Māori (Shawcross 1967: 74). It is possible to transform limonite (yellow) and goethite (orange) into red ochre (haematite) by cooking. This process was described by Walsh, as he understood it to occur in Northland, where raw material was "first roasted in a very hot *haangi*, or native oven, and afterwards ground to a fine powder" (Walsh 1903: 5) before being used as a ceremonial pigment or body paint in religious ceremonies (Beaglehole 1968: 584, Holdaway 1984: 118, Polack 1838: 79). Ovens used for the preparation of ochre have been excavated at various localities in the Otago region (see McGovern-Wilson *et al*. 1996, Skinner 1960, Teviotdale 1948), including a circular hollow filled with layers of wood ash sandwiching a central layer of red ochre excavated at Tarewai Point and interpreted as "an oven with kokowai in preparation" (Teviotdale 1948: 114).

M.M. Monneron, who travelled to New Zealand with de Surville, and J.M. Crozet both noted the practice of burning *kauri* (*Agathis australis*) gum, with Monneron commenting "on the sea-shore is found a transparent gum brought there by the sea: it shows while burning a bright flame, and emits a rather sweet odour" (Monneron in McNab 1914: 287), which Crozet described as "like incense" (Crozet in Roth 1891: 73). A perfumed gum could also be extracted from Spaniard (*Taramea*, *Aciphylla* spp.) leaves by setting a fire next to the plant and scorching the leaves (Beattie 1994: 248, Brunner in Host 2006: 122, Colenso 1891: 458-59).

Fire was a simple and very effective form of retaliation. Numerous European visitors recorded burned villages which they interpreted as evidence that the inhabitants had been driven out (Roux in Ollivier 1985: 131, Crozet in Roth 1891: 55). The French adopted this tactic after the murder of Marion du Fresne and 24 crew members in the Bay of Islands; they ordered the razing of 30 houses, along with nets and canoes, in several villages (Labe in Dunmore 1981: 263). In response, local Māori promptly retaliated by setting fire to the French huts (Crozet in Roth 1891: 36, 54). A classic account of retaliation by fire is that of the siege at Ngāi Tahu's Kaiapoi Pā. Te Rauparaha and his war party held the *pā* captive for three months before fire broke the siege. Te Rauparaha had stockpiled quantities of dry *manuka* around the periphery of the *pā* in preparation for a siege-breaking fire. Pureko, one of the besieged chiefs, decided to use the northwest wind and set fire to the *manuka* in the hope it would burn away from the *pā*. In a stroke of appallingly bad luck, the wind swung around to the southwest, enveloping the *pā* in flames (Stack 1893: 71-74).

FIRE RISK

Pre-European New Zealand was a world in which the risk of an out-of-control fire was constant and widespread. Fire risk varied across New Zealand and was influenced by a variety of factors including precipitation, evapotranspiration, wind aspect and speed, climate history, daily weather conditions, elevation and human influences. Fire risks were apparent in almost every aspect of Māori life; this was a world of wooden *whare* 'dwellings', fern bedding, open fires for cooking and the preservation of food, of swidden horticulture, seasonal burn-offs, signal fires, and of retaliation by arson.

Overall, New Zealand probably maintained a low frequency of natural fires before human settlement (McGlone 2001, Ogden *et al.* 1998, Rogers *et al*. 2007). As a result, most tree and scrub species are killed outright by fire. Natural fire is more influenced by vegetation flammability than climate (Rogers *et al*. 2007). Flammability is driven by two factors: ignitibility and combustibility, whereby ignitibility influences the likelihood of a fire starting, and combustibility is the capacity of vegetation to sustain fire (Bradstock, King and Carey 2004). The majority of New Zealand's natural fires would have been a result of volcanic activity, which was confined to the central and northern areas of the North Island. Most natural fires in the South Island would have been a result of lightning strikes, or coal and lignite combustion.

New Zealand has a low lightning frequency by world standards. Most lightning activity in the South Island is associated with low pressure troughs and occurs around the mountainous terrain of the West Coast; therefore, any lightning strikes would be unlikely to ignite, let alone have a significant impact, on the vegetation patterns of southern New Zealand. The spontaneous

combustion of coal and lignite seams probably posed a more significant natural fire risk in southern New Zealand. Many of the coal or lignite deposits in Otago and Southland have undergone *in situ* combustion, resulting in the creation of paralavas or baked sediments such as porcellanite. Given the widespread nature of these deposits (including Wedderburn, Galloway, Roxburgh, Kaitangata, Croydon, Dolamore Park, Waimumu, New Vale, Waituna and Eden Leith Farm), it is fair to say that the combustion of coal and lignite posed a significant natural fire risk in southern New Zealand (Rait 1993, Rogers 1917).

Conditions are far more favourable to catastrophic natural fire on the east coast of the South Island, where there is a much larger water deficit caused by a combination of periodic drought, strong foehn winds[1] and lower precipitation as a result of a rain shadow effect. Central and eastern parts of southern New Zealand have sustained more frequent natural fires than southern and western areas. This was largely owing to drier conditions, and therefore an increased incidence of ignition. This is indicated by the distribution of fire adapted traits in *manuka* (*Leptospermum scoparium*), charcoal in soil samples and the occurrence of porcellanite (Bond, Dickinson and Mark 2004, McGlone 2001, Rait 1993). Conversely, southern and western areas remain largely unaffected by natural and anthropogenic fires, owing to the low fire risk posed by vegetation and climatic conditions.

POPULATION DENSITY

Throughout New Zealand's occupation, southern New Zealand has sustained a relatively lower population than northern areas. The distribution of known archaeological sites indicates that coastal sites were more attractive to Māori than inland sites. During New Zealand's prehistory the interior of southern New Zealand was subject only to transient human occupation (McGlone 2001), yet it exemplifies one of the most extensive human-induced fire histories in the country.

The frequency and magnitude of pre-European fires appears to be completely unrelated to population size; indeed, only in dense moist forests that require labour-intensive clearing and drying time before a burn should one expect to see a relationship between human density and burning intensity. During times of water deficit, which were common in central and eastern areas of southern New Zealand, it is conceivable that a single person could be responsible for destroying hundreds of square kilometres of dryland forests. Therefore, in dry areas, small groups travelling over large parts of the country would "leave as obvious a signature as large groups, provided their return time was sufficiently frequent to prevent forest regeneration" (McGlone and Wilmshurst 1999).

MĀORI FIRE USE AND THE SOUTHERN LANDSCAPE

Although they relied heavily on coastal resources, prehistoric southern Māori had a dramatically different subsistence focus to Māori living elsewhere in New Zealand. While in the warmer northern regions gardening was common, the impossibilities of growing traditional Polynesian cultigens in southern New Zealand meant Māori led a fairly transient lifestyle; they commonly travelled hundreds of kilometres across the South Island in pursuit of economic objectives, mostly involving the procurement of food on a seasonal basis (Leach 1969). Initially, southern Māori based themselves in "transient villages" close to rich resources, notably of *moa* and seal (Anderson and Smith 1996). Although these villages were fairly permanent, early Māori would have travelled across the landscape to target other non-local resources such as stone for tools, and bracken (*Pteridium esculentum*) and cabbage tree (*Cordyline australis*) for carbohydrates. As stocks of easily exploited megafauna ran low, the southern Māori subsistence strategy shifted to the pursuit of widely distributed small game, necessitating the adoption of a more transient lifestyle to target resources from a much larger catchment.

The impossibility of growing *kumara* (*Ipomoea batatas*) in southern New Zealand put increased importance on bracken as a major carbohydrate source. Bracken stands establish in successional and open environments and require regular fire to maintain their dominance. Māori fired bracken stands in winter, which eliminated competitive species, rejuvenated the rhizome network and cleared a choking mass of fronds and spores. The rhizomes were harvested in spring while the re-growth was still minimal (McGlone, Wilmshurst and Leach 2005: 177).

Before Māori settled New Zealand bracken formed a transient phase of the natural succession of vegetation; after their arrival bracken became a persistent and dominant species. Anthropogenic fires were more widespread and regular than natural fires, and Māori maintained bracken's dominance by repeated firing (McGlone *et al*. 2005). The risk of fire, particularly in the dry central and eastern parts of southern New Zealand would have increased as Māori moved through those areas. At every stop fires would be lit for the minimum requirements of cooking and warmth, further increasing the risk of damaging and out-of-control fires in the landscape.

Burning encouraged the replacement of taller woody vegetation with lower-growing cover or bare ground, and thus may have decreased the water holding capacity of the landscape. Additionally, the removal of a forest canopy, and therefore the forest microclimate, increased the rate of evapotranspiration further accelerating moisture loss. As subsurface moisture is drawn out of the soils, mineral salts are elevated to the surface leaving concretions and further

increasing the aridity. This sequence of events can occur within months of deforestation, meaning that the eventual re-establishment of forest after a devastating fire is lengthy (Katharine Dickinson pers. comm., Dunedin 2007, McGlone *et al.* 1995). Regular firing of the vegetation in central and eastern areas of southern New Zealand caused the lower forest margins to contract, resulting in the development of more extensive tussock grasslands. By the time the first European settlers arrived in the Maniototo there was no timber to be had for anything but firewood. With the exception of *matagouri* (*Discaria tomatou*), the closest bush was over 100 miles away (Cowan 1948: 3)

INTENTIONALITY AND INDIFFERENCE

It has been suggested that Māori were indifferent to the considerable loss of forest that coincided with their arrival in the New Zealand landscape. There is no evidence to suggest that the landscape was fired as a result of indifference to the loss of forest. Intentional burning would have taken place on a regular basis in southern New Zealand to manage carbohydrate sources such as bracken and cabbage trees. The introduction of a fire-based culture to the southern New Zealand landscape posed a significant threat and in all likelihood accidental out-of-control fires were a common occurrence in prehistory. There is no dispute that the introduction of human fire into the New Zealand landscape had a significant effect on the pre-human vegetation; what has not been proven is that the loss of original forest was the result of indifference. The most significant firing took place within a hundred years or so of Māori arrival. It is very unlikely that these people, with a historical dependency on tree crops, would be blasé about forest loss.

Rather, I suggest that Māori had an important relationship with the forest. Pre-contact Māori had a widespread knowledge of New Zealand's vegetation. The early European visitors to New Zealand made detailed records and observations which show that Māori assigned names to plant species, most of which remain in common use to this day (Beaglehole 1968, Beever 1991, Best 1925, 1942, Colenso 1880, Parkinson 1984). Māori also made extensive use of the medicinal properties of plants; again, this has been comprehensively recorded (Riley 1994).

When Polynesians arrived in New Zealand they readily adopted food plants with similar growing or processing methods to those they left behind, and their Māori names reflect this (Leach 1983, 1986, 2003). Plants which looked similar to those in their homeland were often given either the same or a similar name (Biggs 1991). Māori made extensive use of plant species for sustenance and their medicinal properties.

* * *

The current understanding of anthropogenic impacts on the New Zealand environment is largely focused on the loss of endemic species. It has been suggested that pre-European Māori operated as optimal foragers, based on the assumption that Māori maximised their overall intake of a resource during a bout of foraging without necessarily considering the impact they may have had on the sustainability of the resource (Anderson 1997, Begon, Harper and Townsend 1996: 359). I do not dispute the application of the optimal foraging theory to the pre-European New Zealand environment. Although its application neatly justifies the loss of bird species, it does not fully explain the vegetation changes witnessed in New Zealand.

The need to maintain control and management over fire was a constant concern for Māori. In 1827 Augustus Earle observed local Māori pouring water over the thatched roofs of houses being threatened by fire in the Bay of Islands thereby lessening the probability that they would ignite (Earle 1909: 84). Māori were intensely aware of the risks that fire posed on their lifestyle. These people used fire in almost every aspect of their daily lives. With the exception of land clearance, the application of fire to the landscape would have achieved very little.

Māori were not indifferent to substantial forest loss. Forest loss would have occurred for one of two reasons: intentional land clearance, or as a result of out-of-control fire. The arrival of humans in southern New Zealand coincided with an increase in the frequency of fire, particularly in the dry central and eastern regions. As the fire-reliant culture moved through the dry landscape the risk of fire escaping control increased dramatically. This is demonstrated by the amplification of fire on the landscape shortly after human arrival. I argue that vegetation changes occurred not as a result of indifference, but as a direct result of the introduction of a culture for which fire was a dominant tool in a flammable environment.

ACKNOWLEDGEMENTS

Special thanks to Helen Leach and Ian Smith, for recommending I take on this project as a Master's thesis, and for the constant support, advice, criticisms, obscure references and editing pens. Particular thanks to Janet Wilmshurst and Matt McGlone for offering me a part in their Marsden project. I am very grateful for the useful comments and feedback from Janet Stephenson. I would like to acknowledge the financial support of the Department of Anthropology, Gender and Sociology at the University of Otago, Landcare Research Manaaki Whenua, the Marsden Fund, and the University of Otago Research Committee for granting me a University of Otago Postgraduate Publishing Bursary (Master's).

NOTE

1. Hot, dry, strong winds which descend on the lee side of a mountain barrier, as is the case with New Zealand's Southern Alps.

REFERENCES

Anderson, A.J., 1989. *Prodigious Birds: Moas and Moa-Hunting in Prehistoric New Zealand*. Cambridge: Cambridge University Press.

——1991. The chronology of colonization in New Zealand. *Antiquity*, 65: 767-95.

——1997. Prehistoric Polynesian impact on the New Zealand environment: Te whenua hou. In P.V. Kirch and T.L. Hunt (eds), *Historical Ecology in the Pacific Islands*. New Haven: Yale University Press, pp. 271-83.

——2002a. A fragile plenty: Pre-European Maori and the New Zealand environment. In E. Pawson and T. Brooking (eds), *Environmental Histories of New Zealand*. Oxford: Oxford University Press, pp. 19-34.

——2002b. Faunal collapse, landscape change and settlement history in Remote Oceania. *World Archaeology*, 33(3): 375-90.

Anderson, A.J. and I.W.G. Smith, 1996. The transient village in southern New Zealand. *World Archaeology*, 27(3): 359-71.

Beaglehole, J.C. (ed.), 1968. *The Voyage of the Endeavour 1768-1771. The Journals of Captain James Cook on his Voyages of Discovery*. Cambridge: Cambridge University Press for the Hakluyt Society.

Beattie, J.H., 1994. *Traditional Lifeways of the Southern Maori*. Edited by A.J. Anderson. Dunedin: Otago University Press.

Beever, J., 1991. *A Dictionary of Maori Plant Names*. Auckland: Heinemann Educational Books.

Begon, M., J.L. Harper and C.R. Townsend, 1996. *Ecology: Individuals, Populations, and Communities*. Malden: Blackwell Publishing.

Bellwood, P., 1971. Fortifications and economy in prehistoric New Zealand. *Proceedings of the Prehistoric Society*, 37: 56-95.

Best, E., 1925. *Maori Agriculture*. Wellington: Board of Maori Ethnological Research for the Dominion Museum.

——1942. *Forest Lore of the Maori*. Wellington: The Polynesian Society.

Biggs, B., 1991. A linguist revisits the New Zealand bush. In A. Pawley (ed.), *Man and a Half: Essays in Pacific Anthropology and Ethnobiology in Honour of Ralph Bulmer*. Auckland: The Polynesian Society, pp. 67-72.

Bond, W.J., K.J.M. Dickinson and A. Mark, 2004. What limits the spread of fire-dependent vegetation? Evidence from geographic variation of serotiny in a New Zealand shrub. *Global Ecology and Biogeography*, 13: 115-27.

Bradstock, R., K. King and G. Cary, 2004. Flammable connections—a landscape template for understanding the role of fire in shaping Australian vegetation. In *Southern Connections: Programme and Abstracts of IV Southern Connections Conference*, 19-23 January 2004, University of Cape Town, South Africa, p. 65.

Buchanan, J., 1868. Sketch of the botany of Otago. *Transactions of the New Zealand Institute*, 1: 181-212.

Clark, G.R., P. Petchey, M.S. McGlone and P. Bristow, 1996. Faunal and floral remains from Earnscleugh Cave, Central Otago, New Zealand. *Journal of the Royal Society of New Zealand*, 26(3): 363-80.

Clarke, W.C., 1994. Traditional land use and agriculture in the Pacific Islands. In R.J. Morrison, P.A. Geraghty and L. Crowl (eds), *The Science of Pacific Island Peoples*. Suva: University of the South Pacific, pp. 11-38.

Colenso, W., 1880. On the vegetable food of the ancient New Zealanders before Cook's visit. *Transactions and Proceedings of the New Zealand Institute*, 13: 3-39.

——1891. Vestiges: Reminiscences: Memorabilia of works, deeds and sayings of the ancient Maoris. *Transactions and Proceedings of the New Zealand Institute*, 24: 445-67.

Cowan, J.C., 1948. *Down the Years in the Maniototo*. Dunedin: Otago Centennial Historical Publications and Whitcombe and Tombs.

Deng, Y., I.W.G. Smith and R. Walter, n.d. Refining the Chronology of Early Maori Impacts on the Vegetation of South Island, New Zealand: Data from Archaeological Charcoal Analysis. Unpublished report. [Copy held by author.]

Dunmore, J. (ed.), 1981. *The Expedition of the St Jean-Baptiste to the Pacific 1769-1770. From the Journals of Jean de Surville and Guillaume Labe*. London: The Hakluyt Society.

Earle, A., 1909. *A Narrative of a Nine Months' Residence in New Zealand in 1827*. Dunedin: Whitcombe & Tombs Ltd.

Elder, J.R. (ed.), 1932. *The Letters and Journals of Samuel Marsden 1765-1838*. Dunedin: Coulls Somerville Wilkie and A.H. Reed for the Otago University Council.

Ellison, J., 1994. Paleo-lake and swamp stratigraphic records of Holocene vegetation and sea-level changes, Mangaia, Cook Islands. *Pacific Science*, 48: 1-15.

Fosberg, F.R., 1963. The island ecosystem. In F.R. Fosberg (ed.), *Man's Place in the Island Ecosystem: A Symposium*. Honolulu: Bishop Museum Press, pp. 1-7.

Gill, W.W., 1876. *Life in the Southern Isles: Or, Scenes and Incidents in the South Pacific and New Guinea*. London: Religious Tract Society.

Holdaway, S., 1984. Colour as a Symbol in New Zealand Prehistory. Unpublished MA thesis, University of Otago.

Host, E., 2006. *Thomas Brunner: His Life and Great Journeys*. Nelson: Nikau Press.

Kirch, P.V., 1991. Polynesian agricultural systems. In P.A. Cox and S.A. Banack (eds), *Islands, Plants, and Polynesians: An Introduction of Polynesian Ethnobotany*. Portland: Dioscorides Press, pp. 113-33.

——1996. Late Holocene human-induced modifications to a central Polynesian island ecosystem. *Proceedings of the National Academy of Sciences*, 93: 5296-300.

——2000. *On the Road of the Winds: An Archaeological History of the Pacific Islands Before European Contact*. Berkley: University of California Press.

Kirch, P.V. and J. Ellison, 1994. Palaeoenvironmental evidence for human colonization of remote Oceanic islands. *Antiquity*, 68: 310-21.

Kirch, P.V., J.R. Flenley, D.W. Steadman, F. Lamont and S. Dawson, 1992. Ancient environmental degradation: Prehistoric human impacts on an island ecosystem: Mangaia, Central Polynesia. *National Geographic Research and Exploration*, 8(2): 166-79.

Leach, H.M., 1969. Subsistence Patterns in Prehistoric New Zealand: A Consideration of the Implications of Seasonal and Regional Variability of Food Resources for the Study of Prehistoric Economies. Unpublished PhD thesis, University of Otago.

——1972. The hearth as an archaeological feature in New Zealand. *New Zealand Archaeological Association Newsletter*, 15: 59-75.

——1983. Model gardens and the acceptability of new crops to Polynesian horticulturalists. *New Zealand Journal of Archaeology*, 5: 139-49.

——1986. A review of culinary and nutritional adaptations involving wild plant foods following Polynesian settlement of New Zealand. In G.K. Ward (ed.), *Archaeology at ANZAAS Canberra*. Canberra: Canberra Archaeological Society, pp. 132-42.

——1999. Intensification in the Pacific: A critique of the archaeological criteria and their application. *Current Anthropology*, 40(3): 311-39.

——2003. Fern consumption in Aotearoa and its Oceanic precedents. *Journal of the Polynesian Society*, 112: 141-55.

Mark, M.V., 1976. The Relationship between Ecology and Myth in Mangaia. Unpublished MA thesis, University of Otago.

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

——1989. The Polynesian settlement of New Zealand in relation to environmental and biotic changes. *New Zealand Journal of Ecology*, 12: 115-29.

——2001. The origin of the indigenous grasslands of southeastern South Island in relation to pre-human woody ecosystems. *New Zealand Journal of Ecology*, 25: 1-15.

McGlone, M.S., A.F. Mark and D. Bell, 1995. Late Pleistocene and Holocene vegetation history, Central Otago, South Island, New Zealand. *Journal of the Royal Society of New Zealand*, 25: 1-22.

McGlone, M.S., N.T. Moar and C.D. Meurk, 1997. Growth and vegetation history of alpine mires on the Old Man Range, Central Otago, New Zealand. *Arctic and Alpine Research*, 29(1): 32-44.

McGlone, M.S. and J.M. Wilmshurst, 1999. Dating initial Maori environmental impact in New Zealand. *Quaternary International*, 59: 5-16.

McGlone, M.S., J.M. Wilmshurst and H.M. Leach, 2005. An ecological and historic review of bracken (*Pteridium esculentum*) in New Zealand, and its cultural significance. *New Zealand Journal of Ecology*, 29(2): 165-84.

McGovern-Wilson, R.J., B. Allingham, P. Bristow and I.W.G. Smith, 1996. Other artefacts. In A.J. Anderson, B. Allingham and I.W.G. Smith (eds), *Shag River Mouth: The Archaeology of an Early Southern Maori Village*. Research Papers in Archaeology and Natural History, Canberra: ANH Publications, pp. 223-36.

McNab, R., 1914. *From Tasman to Marsden. A History of Northern New Zealand from 1642 to 1818*. Dunedin: J. Wilkie & Co., Ltd.

Molloy, B.P.J., C.J. Burrows, J.E. Cox, J.A. Johnston and P. Wardle, 1963. Distribution of sub-fossil forest remains, eastern South Island, New Zealand. *New Zealand Journal of Botany*, 1: 68-77.

Morrell, W.P., 1958. *Sir Joseph Banks in New Zealand*. Wellington: A.H. & A.W. Reed.

Odgen, J.L., L. Basher and M.S. McGlone, 1998. Fire, forest regeneration and links with early human habitation: Evidence from New Zealand. *Annals of Botany*, 81: 687-96.

Ollivier, I., 1985. *Extracts from Journals Relating to the Visit to New Zealand in May-July 1772 of the French Ships* Mascarin *and* Marquis de Castries *under the Command of M.–J. Marion du Fresne.* Early Eyewitness Accounts of Maori Life, 2. Wellington: Alexander Turnbull Library.

Parkinson, S., 1984. *Journal of a Voyage to the South Seas*. London: Caliban Books.

Polack, J.S., 1838. *New Zealand*. London: Richard Bentley.

Rait, R.J., 1993. Mineralogy and Geochemistry of Paralavas in Otago and Southland, New Zealand. Unpublished BSc (Hons) dissertation, University of Otago.

Riley, M., 1994. *Maori Healing and Herbal—New Zealand Ethnobotanical Sourcebook*. Paraparaumu: Viking Sevenseas.

Rogers, G.M., S. Walker, L.M. Basher and W.G. Lee, 2007. Frequency and impact of Holocene fire in eastern South Island, New Zealand. *New Zealand Journal of Ecology*, 31(2): 129-42.

Rogers, G.S., 1917. *Baked Shale and Slag Formed by the Burning of Coal Beds*. United States Geological Survey Professional Paper, 108-A. Denver: United States Geological Survey.

Roth, H.L. (ed.), 1891. *Crozet's Voyage to Tasmania, New Zealand, the Ladrone Islands, and the Philippines in the Years 1771-1772*. London: Truslove and Shirley.

Salmond, A., 1997. *Between Worlds: Early Exchanges Between Maori and Europeans 1773-1815*. Auckland: Viking.

Shawcross, K., 1967. Maoris of the Bay of Islands 1769-1840: A Study of Changing Maori Responses to European Contact. Unpublished MA thesis, University of Auckland.

Skinner, H.D., 1960. Excavation at Little Papanui, Otago Peninsula. *Journal of the Polynesian Society*, 69: 187-98.

Stack, J.W., 1893. *Kaiapohia: The Story of a Siege*. Christchurch: Whitcombe & Tombs.

Steadman, D.W., 1995. Prehistoric extinctions of Pacific Island birds: Biodiversity meets zooarchaeology. *Science*, 267 (5201): 1123-31.

Teviotdale, D., 1948. Excavation of Maori implements at Tarewai Point, Otago Heads. *Journal of the Polynesian Society*, 48: 108-15.

Vandergoes, M.J., S.J.Fitzsimons and R.M. Newnham, 1997. Late glacial to Holocene vegetation and climate change in the eastern Takitimu Mountains, western Southland, New Zealand. *Journal of the Royal Society of New Zealand*, 27(1): 53-66.

Walsh, A., 1903. On the Maori method of preparing and using kokowai. *Transactions and Proceedings of the Royal Society of New Zealand*, 36: 4-10.

Wilmshurst, J.M., 1997. The impact of human settlement on vegetation and soil stability in Hawke's Bay, New Zealand. *New Zealand Journal of Botany*, 35: 97-111.

Wilmshurst, J.M., T.F.G. Higham, H. Allen, D. Johns and C. Phillips, 2004. Early Maori settlement impacts in northern coastal Taranaki. *New Zealand Journal of Ecology*, 28(2): 167-79.

Wilmshurst, J.M., M.S. McGlone and D.J. Charman, 2002. Holocene vegetation and climate change in southern New Zealand: Linkages between forest composition and quantitative surface moisture reconstructions from an ombrogenous bog. *Journal of Quaternary Science*, 17(7): 653-66.

Yate, W., 1835. *An Account of New Zealand*. Shannon: R.B. Seeley.