PODOCARPUS CUNNINGHAMII IN THE EASTERN SOUTH ISLAND HIGH COUNTRY

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1. Introduction

The South Island high country is a diverse and evocative landscape encompassing rugged mountains, intermontane basins, dense forest and golden tussock grassland. Much of the natural diversity found in the high country is largely driven by the domination of the climate by prevailing westerly winds rich in moisture. The Southern Alps, which form a near unbroken chain of mountains from the north to the south of the South Island, create a distinct physical barrier, causing the vast majority of the moisture carried by the prevailing wind to be deposited on the west coast, where annual rainfall values can exceed 10,000 mm (Wardle, 1991). Once east of the Main Divide there is a dramatic reduction in rainfall that follows a declining eastwards gradient; along this gradient rainfall can drop to as low as 350 mm per annum (MAF, 2001, Wardle, 1991), forming the "eastern New Zealand dryland zone", or more simply, the "drylands" (Rogers et al., 2005). Continuing eastwards to the coast, the landscape becomes increasingly affected by easterly winds carrying moisture from the Pacific and Southern Oceans. As such, the east coast receives greater annual rainfall than much of the high country east of the Main Divide.

An approximate outline of the extent of the South Island high country is provided by Swaffield and Hughey (2001) (Figure 1, page 70). It can generally be broken down into three distinct geographical areas: the Western Barrier, the Eastern Range and Basin (ERB), and the Otago Block and Basin (OBB). The eastern South Island high country, to which this research is confined, is largely delineated by the boundaries of the ERB and OBB. These Blocks differ markedly from the Western Barrier due to the dramatic rainfall gradient described earlier. The eastern boundary of the Western Barrier does not precisely follow the ranges of the Main Divide; as such, many mountains that are actually part of ranges east of the Main Divide fall within the area defined as the Western Barrier. In addition,

portions of the Seaward Kaikoura Range exist outside of the boundary of the ERB. Despite these limitations, the area bounded by the ERB and OBB largely defines the geographical scope of this research project; that is, the eastern South Island high country, which for the purposes of convenience, shall henceforth be simply referred to as 'the high country'.

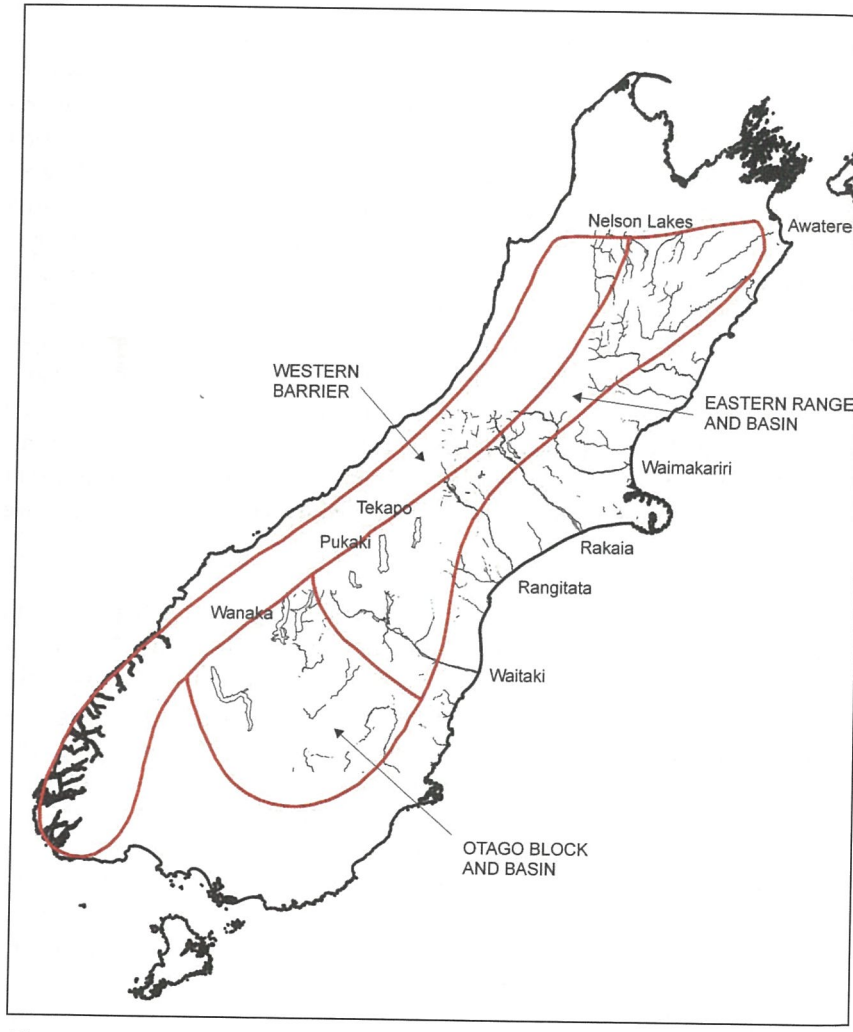

Figure 1 The high country of New Zealand's South Island. The eastern high country is largely defined by the Eastern Range and Basin and the Otago Block and Basin. The eastern mountains of the Main Divide fall within the Western Barrier. Modified from Swaffield and Hughey (2001).

Before human arrival in the South Island, the high country below tree line and above the valley bottoms was covered in two forest types: *Nothofagus* forest and podocarp-angiosperm forest (McGlone, 1989, McGlone, 2004). *Nothofagus* forest dominated the high precipitation mountain slopes along the majority of the axial ranges, from north of the Rakaia catchment up to the Kaikoura Ranges, and south from the head of Lake Pukaki all the way to Fiordland (Figure 2, page 72). The area between the Rakaia catchment and the head of Lake Pukaki is known as the "Southern Alps beech 'gap'" (Hall and McGlone, 2006). Here *Nothofagus* was largely absent, and podocarp-angiosperm forests dominated. Podocarp-angiosperm forest also dominated in the areas further to the southeast, in the dryland areas of the Mackenzie Country and Central Otago (McGlone, 1989, McGlone, 2004). Similarly, podocarp-angiosperm forest dominated much of the central portion of Kaikoura Ranges, where *Nothofagus* was absent (McGlone and Basher, 1995). *Podocarpus cunninghamii* Colenso (de Lange and Rolfe, 2010) was a major component of these podocarp-angiosperm forests, and was the dominant podocarp species (McGlone, 1989, McGlone, 2004, Molloy et al., 1963). It is these *Podocarpus cunninghamii* dominated communities, that existed in the areas where *Nothofagus* has historically been absent, that are the focus of this paper.

As a consequence of early Polynesian and later European fires, together with the introduction of grazing animals associated with European agricultural expansion, the cover of these forests has been greatly diminished, with the greatest loss occurring in the dry eastern ranges (Ewers et al., 2006). Because the greatest loss occurred in the drylands, the cover of *Podocarpus cunninghamii* forest has been massively reduced, while extensive stands of *Nothofagus* still exist, for example in Arthur's Pass National Park, Ahurriri Conservation Park and Mt Aspiring National Park. The current distribution of *Podocarpus cunninghamii* remnants is both very limited and highly fragmented (Walker et al., 2003). The current distribution is also uneven, with remnant stands being more intact or greater in extent within the wetter parts of high country, and more degraded or covering a smaller area in the drier parts. However, despite the extent of loss of this historically common vegetation type, together with its highly fragmented current distribution, information on its ecology is scanty. Furthermore, information pertaining to the current distribution of *Podocarpus cunninghamii* communities is distributed across numerous publications, many of which belong to

literature that has only limited publication and can therefore be difficult to find, such as Protected Natural Areas Programme reports. As such, information relating to the ecology and distribution of *Podocarpus cunninghamii* within the high country is limited and often difficult to find.

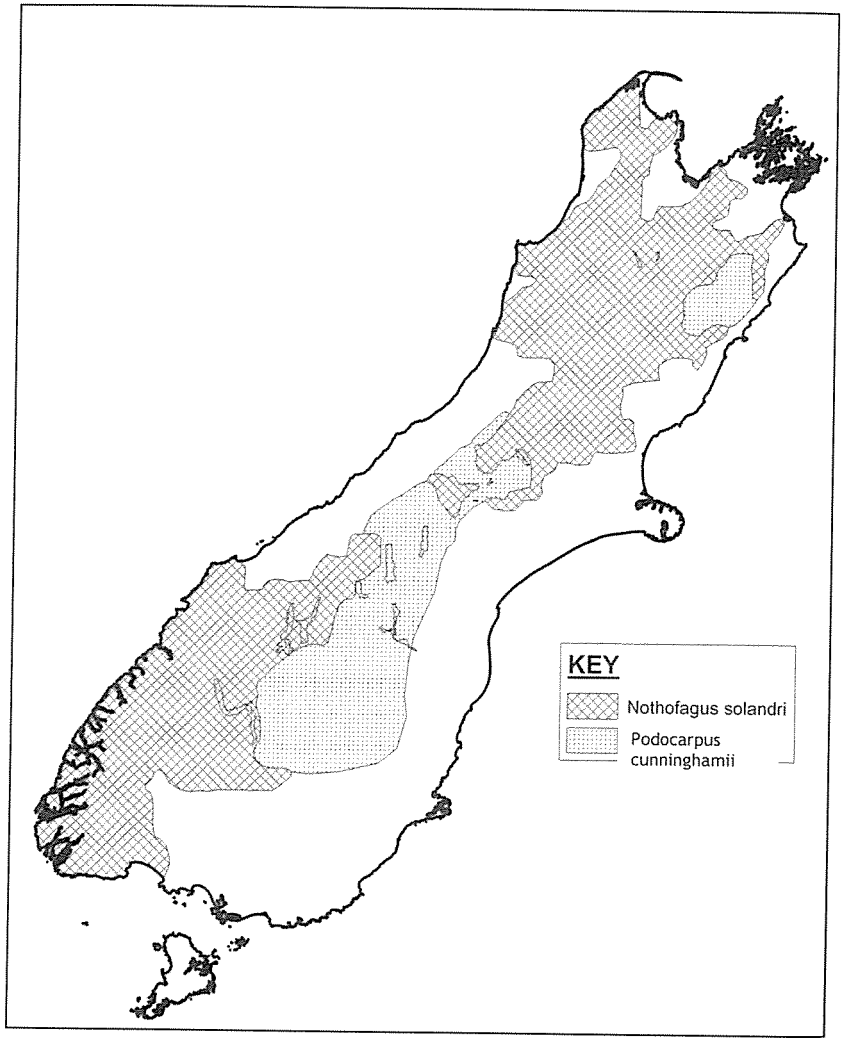

Figure 2 The current distribution of *Nothofagus solandri* (Wardle, 1984b), and the areas east of the Main Divide where, prior to human arrival, *Podocarpus cunninghamii* forest is thought to have dominated and remnants still exist.

In this article I provide an overview of the vegetation history of the eastern South Island high country, as it relates to *Podocarpus cunninghamii* dominated vegetation communities. Following this I summarise the numerous records of *Podocarpus cunninghamii* in the high country, and identify and describe the remnant patches of *Podocarpus cunninghamii* communities that remain.

2. Vegetation history of the eastern South Island high country

2.1. Pre-human cover

The contemporary landscape of much of the *Nothofagus*-free high country, especially the drier parts, notably the Inland Kaikoura Range, South Canterbury and Central Otago, are characterised by tussock grasslands. Fragments of *Podocarpus cunninghamii* dominated communities occur very sporadically and in isolation. This situation is very different to that in pre-human times, as evidenced by plentiful "totara" log remains and palynological records that indicate a formerly woody landscape. Log remains have been well documented across inland Marlborough, Canterbury and Central Otago for over 100 years (Buchanan, 1868, Cockayne, 1928, Munro, 1868, Speight, 1910, Wells, 1972). In addition to the fallen logs, less conspicuous evidence of historical forest cover has also been discovered in the form of charcoal deposits. Carbon dating of these log and charcoal remains indicates that between c. 12,000 – 10,500 years BP (McGlone, 2004) and the arrival of humans (c. 800 years BP (Higham et al., 1999, McGlone and Wilmshurst, 1999)), *Podocarpus cunninghamii* was a dominant tree throughout the high country, especially between Lakes Wanaka and Wakatipu, throughout the Mackenzie Country, and stretching northwards into the headwaters of the Rangitata and Rakaia Rivers, where plentiful remains have been found (Molloy et al., 1963). Charcoal deposits become rarer north of Porters Pass but reappear along the Awatere River, on the western faces of the Inland Kaikoura Range (McGlone and Basher, 1995, Molloy et al., 1963).

However, the heartwood of species such as *Podocarpus cunninghamii* and the associated conifer *Phyllocladus alpinus* is very strong and durable, and as such charcoal deposits and fallen log remains offer only a very selective view of the high country's historical forests; they could be taken to imply a near monoculture forest of *Podocarpus cunninghamii* and *Phyllocladus alpinus* covered the mountainsides of the high country outside the range of *Nothofagus* (Wardle, 2001b). The wood of other species that may well have

co-occurred with these conifers (e.g. *Cordyline, Hoheria* and *Sophora*) do not preserve well and are thus underrepresented in such reconstructions. Palynology, the study of spores and pollen, though also selective, offers a more complete view of historical vegetation patterns (Pocknall, 1982). In addition, the palynological records studied have allowed insight further back in time than charcoal and log remains, providing a more complete view of vegetation history since the end of the last glacial maximum.

Investigations of pollen deposits have found that immediately following the end of the last glaciation (c. 15-12,000 year BP), when temperatures were warming following the glacial maximum, the vegetation of the high country was largely gramineous, with Poaceae pollen dominant among the palynological records (Burrows and Russell, 1990, McGlone et al., 2004, Moar, 1971, Moar, 1980; Figure 3, page 75). Over the next few thousand years (13-10,000 years BP) the climate continued to warm and these grasslands were invaded and largely replaced by *Coprosma* shrublands with *Phyllocladus* (Burrows and Russell, 1990, Burrows et al., 1993, McGlone et al., 1995, McGlone et al., 2004, Moar, 1971; Figure 3, page 75). Eventually, between 10-8,000 years BP, these shrublands were themselves replaced by podocarp dominated forest below tree line from the Inland Kaikoura Range down to the Mackenzie Basin (Burrows et al., 1993, Burrows and Russell, 1990, McGlone and Moar, 1998, McGlone et al., 1993, McGlone et al., 2004, McLea, 1996, Moar, 1971; Figure 3); this vegetation transition took place later in Central Otago, circa 7,500 years BP (McGlone et al., 1997; Figure 4). At this time the tussock grasslands that now dominate much of the high country landscape were largely restricted to alpine areas; below this their populations would have been localised around pockets of particularly infertile soils and bogs, valley bottoms, and recently disturbed sites (McGlone, 1989, McGlone, 2001). Small-leaved shrub communities too, for the most part, were confined to the valley bottoms and river terraces, and at the higher reaches of the sub-alpine zone (McGlone, 1989). Instead, in the wetter regions, such as in the headwaters of the Rakaia and Rangitata Rivers, the heads of the lakes from Tekapo to Wakatipu, and the Seaward Kaikoura Range, *Podocarpus cunninghamii* formed a tall forest community with *Libocedrus bidwillii* (>2,500 mm annual rainfall), *Phyllocladus alpinus, Griselinia littoralis, Hoheria lyallii* and other angiosperm tree and shrub species (McKelvey, 1984, Veblen and Stewart, 1982). As the climate became increasingly arid, along the rainfall gradient, *Podocarpus cunninghamii*

remained present, but in a low forest form, projecting above a canopy of increasingly

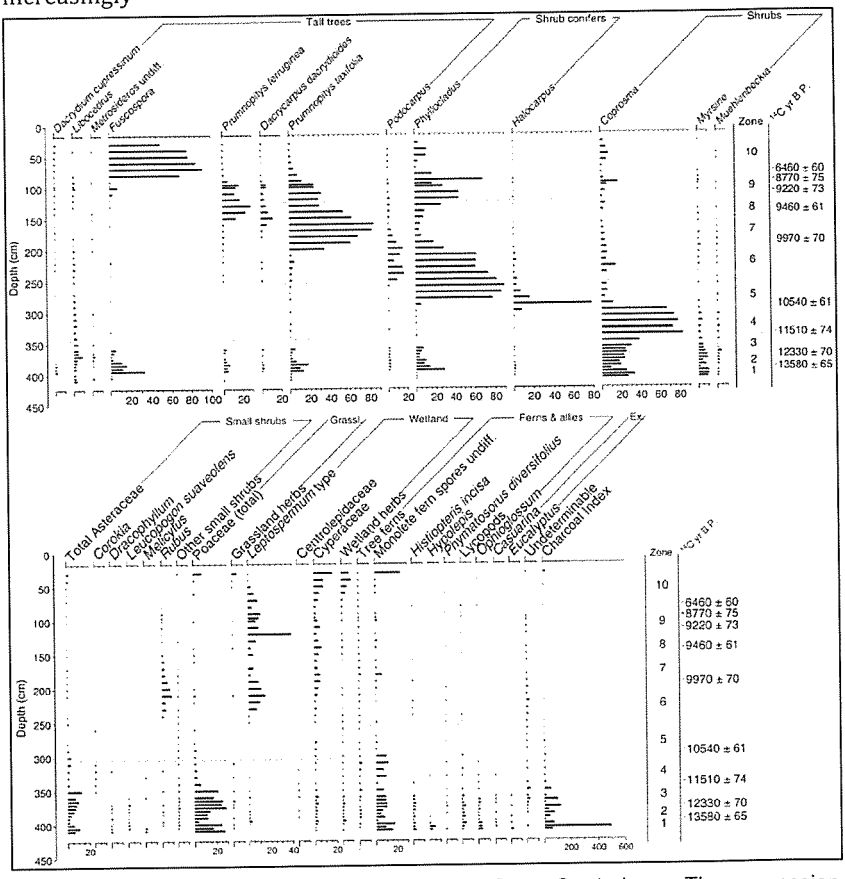

Figure 3 – Pollen diagram from Kettlehole Bog, Cass, Canterbury. The succession from Poaceae to *Nothofagus* (Fuscospora) via shrubland and podocarps is clear. Years before present are shown on the right (modified from McGlone et al., 2004)

scrub-form *Phyllocladus alpinus* and *Griselinia littoralis*. *Libocedrus bidwillii* became absent while *Sophora microphylla* and *Pittosporum tenuifolium* became more common. *Halocarpus bidwillii* would have formed a unique scrub community on the most extreme sites (McGlone, 1989, McGlone, 2004).

In the mid-Holocene, at approximately 7-6,000 years BP, the climate began to cool, with increasing incidence of more extreme weather events (droughts

and snowfalls), strong winds and evidence for an increase in fire frequency. This change favoured *Nothofagus*, which had been present throughout the period of podocarp dominance but with a very limited distribution. All along the axial ranges of the South Island, excluding the central portion of the island, *Nothofagus* came to dominate and replaced the podocarp forests (McGlone, 2004, McGlone et al., 1995, McGlone and Moar, 1998, McGlone et al., 2004; Figures 2 and 3). This expansion again took place later in Central Otago, at around 7-3,000 years BP (McGlone et al., 1997). Charcoal deposits also provide evidence of the invasion of wetter areas formerly dominated by *Podocarpus cunninghamii* by *Nothofagus* following burning events, such as the heads of Lakes Ohau and Hawea (Molloy et al., 1963). *Nothofagus* replaced podocarp forest in much of the high country; however *Podocarpus cunninghamii* communities remained the dominant vegetation type in the central portion of the South Island (e.g. the Rakaia catchment (Wardle, 1964)), along the drier mountains stretching east from the Main Divide (McGlone, 1989, McGlone, 2004; Figure 4) and in the central parts of the Inland Kaikoura Range (McGlone and Basher, 1995; Figure 2).

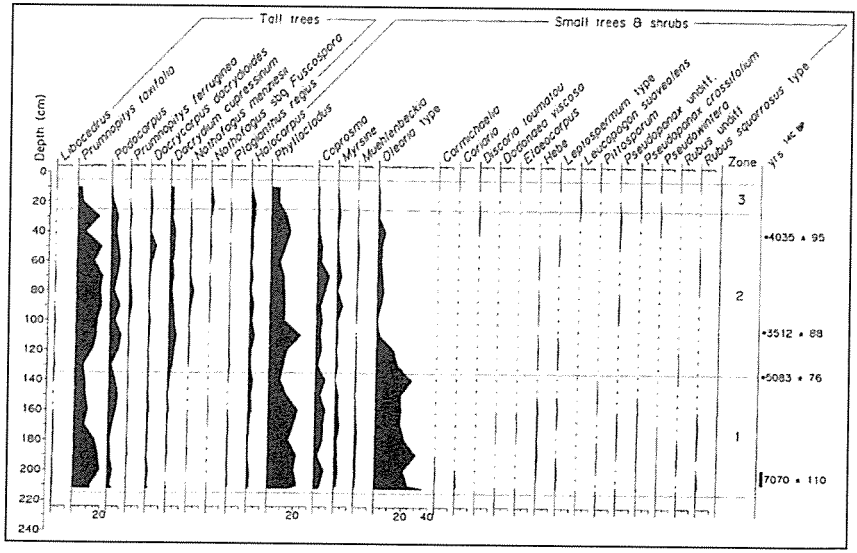

Figure 4 Pollen diagram from Central Otago. The initial shrubland expansion was eventually succeeded by podocarp forest (from McGlone and Moar, 1998).

The reason for the beech gap, where *Nothofagus* has not replaced *Podocarpus cunninghamii* forest in the central South Island, has not been

fully resolved. Initially it was thought that during the last glacial maximum, *Nothofagus* found northern and southern refugia outside of this region (Wardle, 1963), and that as the climate gradually changed in its favour, *Nothofagus* has spread but only slowly, and has yet to realise the full extent of its potential geographic range (Wardle, 1964). Models of historical forest cover based on climatic tolerances of species are in agreement with this hypothesis, predicting *Nothofagus* forest across much of the beech gap (Hall and McGlone, 2006, Leathwick, 1998). Scarcity of suitable ectomycorrhizal symbionts has also been proposed as a potential reason for the slow spread of *Nothofagus* into the predominantly arbuscular mycorrhizal podocarp forests (Baylis, 1980). However, Hall and McGlone (2006) suggest that observations of scattered *Nothofagus* stands bordering the beech gap (Wardle, 1984) indicate that *Nothofagus* was not completely excluded during the last glaciation. Hall and McGlone (2006) also state that there is "little current physiological or distributional information for forest species relevant to this area, which is the driest, most drought-prone, and most seasonal in New Zealand". As such, they may not have been able to provide their model with the necessary information to accurately predict the species composition of historical forest cover in this area.

Despite the limitations of the models by Leathwick (1998) and Hall and McGlone (2006), other modelled predictions of historical forest cover have produced results similar to that suggested by log, charcoal and palynological data. In the model produced by Leathwick (2001), *Nothofagus* forest is predicted to have covered the high precipitation axial ranges except for the central part of the South Island, where conifer forests containing *Podocarpus cunninghamii* dominated. In the driest parts of the high country, in Central Otago, Mackenzie Country and the Inland Kaikoura Range, *Podocarpus cunninghamii* forest is predicted to have been the dominant cover. Interestingly, *Podocarpus cunninghamii* and *Griselinia littoralis* were also found to have optima on sites with minimal soil water deficit and reached greatest abundance on steep to very steep, moderate to well-drained sites. This finding is somewhat at odds with their known localised abundance on very dry sites today.

The method employed by Leathwick (2001) is highly informative, especially when associated with extensive and relatively intact tracts of vegetation. In terms of canopy species composition, this approach shows close similarity to vegetation records published by McKelvey (1984) and Wardle (2001a)

within high precipitation areas at the heads of the Wilberforce and Makarora rivers, respectively. However, there are limitations in the use of this method and it is inherently risky to use these models alone to extrapolate from relictual vegetation patches. This is because these relicts often exist within steep or sheltered sites that are not necessarily representative of the wider landscape, and, in addition, such remnant populations are typically small and isolated, thus they suffer from edge effects and can be highly modified (Walker et al., 2004).

In order to make more accurate predictions of historical woody species distributions prior to human arrival, within Central Otago, Walker *et al.* (2004) utilised existing species distributions in conjunction with sub-fossil evidence (pollen spectra, log and charcoal remains) and the presence of plant life-forms within sites of environmental stress. Their analysis split Central Otago into 12 pre-settlement vegetation zones based upon environmental variables. According to the models, *Podocarpus cunninghamii* was expected to have dominated the more arid mid-elevation slopes between approximately 500-800 m above sea level (zones IV and V). *Nothofagus* spp., *Sophora microphylla, Leptospermum scoparium, Kunzea ericoides, Griselinia littoralis* and *Phyllocladus alpinus* would also have been important components with *Podocarpus cunninghamii* depending on local site conditions. *Podocarpus cunninghamii* would have been replaced by *Nothofagus* on moister sites and by *Sophora microphylla, Leptospermum scoparium* and *Kunzea ericoides* on the lower slopes and valley bottoms. It is likely that some of these predictions could be extrapolated to the Mackenzie Basin, given its similarity in dryness to Central Otago, although *Nothofagus* was largely absent.

Overall, these models and records provide a picture of the changing flora of the high country prior to human arrival, from the end of the last glacial maximum to approximately 1,000 years BP. This picture shows that at the arrival of Polynesians, the majority of the high country below tree line and above the valley bottoms was forested. *Nothofagus* forest covered the axial ranges, excluding the central part of the South Island where *Podocarpus cunninghamii* forest flourished. Further east from the Main Divide in the drylands of Central Otago, the Mackenzie Country and the Inland Kaikoura Range, *Podocarpus cunninghamii* communities continued to be the predominant vegetation type.

2.2 Human impacts on the vegetation

The arrival of humans to New Zealand brought massive changes to the country's vegetation. It is now well established that early Polynesian fires wrought large-scale destruction of forest areas, particularly within dry, fire-prone sites (McGlone, 1989, McGlone, 2004). These changes were soon followed by the arrival of European pastoralists, who cleared many the woody communities that remained in order to establish sheep runs.

In pre-human times, fires in New Zealand were rare events. Lightning strikes, which are the only likely source of natural fires in the South Island, are rare in New Zealand compared with other countries (McGlone, 2001). Lightning strikes that do occur are most commonly restricted to the west coast, which may receive at most 20 electric storms each year (Ogden et al., 1998). In addition, the return time of fire to the same site has been measured at between 1,500 and 2,000 years, in pre-human times (Ogden et al., 1998); meaning naturally burnt sites would have returned to forest before being re-burnt and would also have developed very large fuel loads. As a result of this fire rarity, the flora has not evolved adaptations to fire, and with few exceptions all of New Zealand's tree species are killed by fire (Ogden et al., 1998, Wardle, 1991). Radiocarbon dating of available charcoal remains has found a massive increase in South Island fires beginning circa 800 years BP (McGlone and Wilmshurst, 1999, Ogden et al., 1998, Rogers et al., 2007). This analysis puts the sudden change of fire regime within the period of Polynesian settlement (McGlone and Wilmshurst, 1999, Ogden et al., 1998). Furthermore, the increase in charcoal remains coincides with abrupt changes in palynological deposits. Sub-fossil evidence recovered from sites throughout the high country, from the Inland Kaikoura Range to Central Otago, shows a dramatic increase in Poaceae pollen and *Pteridium esculentum* spores between 700 and 500 years BP (c. 1300-1500 AD; Figure 5). These increases are concurrent with a marked decline in podocarp pollen (McGlone, 2001, Burrows et al., 1993, McGlone et al., 1997, McGlone and Basher, 1995, McGlone et al., 1995, McGlone and Moar, 1998, Rogers et al., 2007).

It has been suggested that these conflagrations, the "Fires of Tamatea", were the result of deliberate and repeated land clearances by Maori, most likely to improve ease of travel and to favour the regeneration of starch-rich species, e.g. *Pteridium esculentum* (McGlone, 2004). A combination of the flammability of the vegetation and the accumulated fuel load, particularly

within the dry eastern ranges, and the effect of the hot, dry föhn winds prevailing from the northwest, allowed the fires to spread rapidly, thus deforesting large areas of land. Repeated fires to maintain cleared areas would have exacerbated the loss of woody vegetation and allowed the grasslands, which responded rapidly to fire, to expand out of their pre-human habitats and become the dominant flora (McGlone, 2001, Rogers et al., 2007).

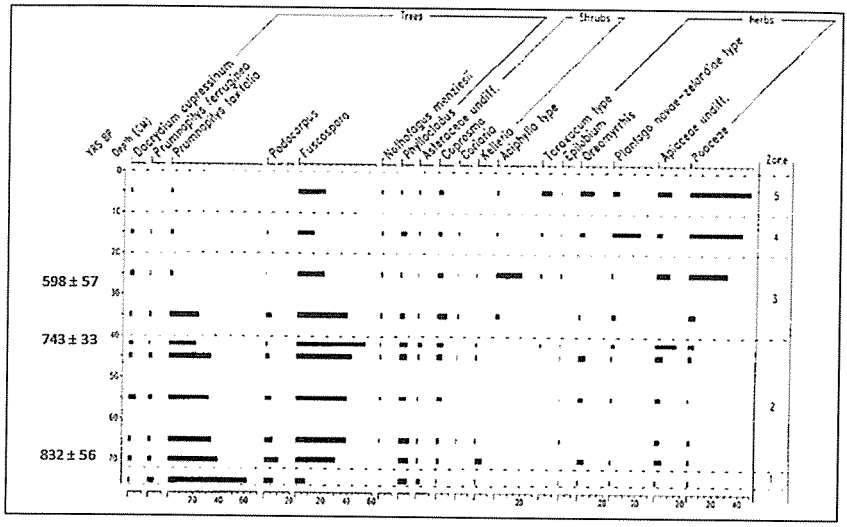

Figure 5 - Pollen diagram from Winterton Bog, Inland Kaikoura Range, Marlborough. Years before present are shown on the left (modified from McGlone and Basher, 1995).

This loss of forest, early in the history of human settlement in New Zealand, explains the descriptions of extensive tussock grasslands provided by early European explorers to the hinterland. The fragments of woody vegetation that remained were soon further diminished or destroyed on arrival of the European settlers in the late nineteenth century; woody vegetation was cleared to make way for sheep runs, or used as building material, for fencing or as firewood (Buchanan, 1868, Munro, 1868, Speight, 1910).

3. Current distribution and associations of *Podocarpus cunninghamii*

Podocarpus cunninghamii shows wide variation in its distribution and abundance across the high country. In wet, steep locations it can form extensive stands that must be reminiscent of its abundance prior to human settlement, while on dry, shallow slopes it occurs in small, isolated

populations or even as individual trees. The following descriptions of the distribution of plant communities characterised by the presence of *Podocarpus cunninghamii*, which has been drawn from numerous publications and the knowledge of various individuals, will begin in the north, in the Kaikoura Ranges, before moving southwards through Canterbury and ending in Central Otago. These descriptions are not intended as a final and authoritative account of the distribution of every stand across the high country; rather, they document all of the stands that I have been able to find information on. I feel confident that the majority of stands are included here, but it is unavoidable that some stands have inadvertently been missed. Eastern *Nothofagus* forests, especially those comprised of *Nothofagus solandri*, in which *Podocarpus cunninghamii* can occur, are not included in these descriptions. The descriptions are categorised firstly according to broad geographical location, and secondly more precisely, to Ecological Region (McEwan, 1978); the overall distribution is shown in Figure 6, page 82.

3.1 The Kaikoura Ranges

The Kaikoura Ranges are distinct from all other parts of the high country in that their rainfall gradient runs from east to west, rather than west to east. Greywacke is the predominant rock type (LRI, 1992).

3.1.1 Lowry Ecological Region

Within the steep, high precipitation (900-1,200 mm per annum) Seaward Kaikoura Range, *Podocarpus cunninghamii* forms extensive stands of tall forest, cloaking the mid-range mountain faces between 450-1,000 m altitude (Plate 1, page 83). *Nothofagus* becomes more important at the northern and southern ends of the range. Wardle (1971) surveyed the vegetation of the Seaward Kaikoura Range, and a summary of his descriptions of the *Podocarpus cunninghamii* vegetation association is provided here. *Podocarpus cunninghamii* is the dominant canopy tree, averaging 15 m in height, with *Griselinia littoralis*, *Pseudopanax crassifolius* and *Coprosma linariifolia* often forming a sub-canopy. The shrub layer is sparse, with only *Coprosma dumosa* considered important. The ground layer is also often sparse, with occasional small herbs, such as the exotic *Mycelis muralis*, or wide-leaved species of *Uncinia* present; otherwise *Polystichum vestitum* can form dense patches. *Rubus cissoides* is the only common liana. Several species of ungulate, including red deer, are present in high numbers, and are predicted to reduce the presence of *Griselinia littoralis, Coprosma linariifolia*,

Coprosma dumosa and *Polystichum vestitum* in the long-term. Possum use of these forests is also high, though Wardle does not discuss their potential impact on forest structure.

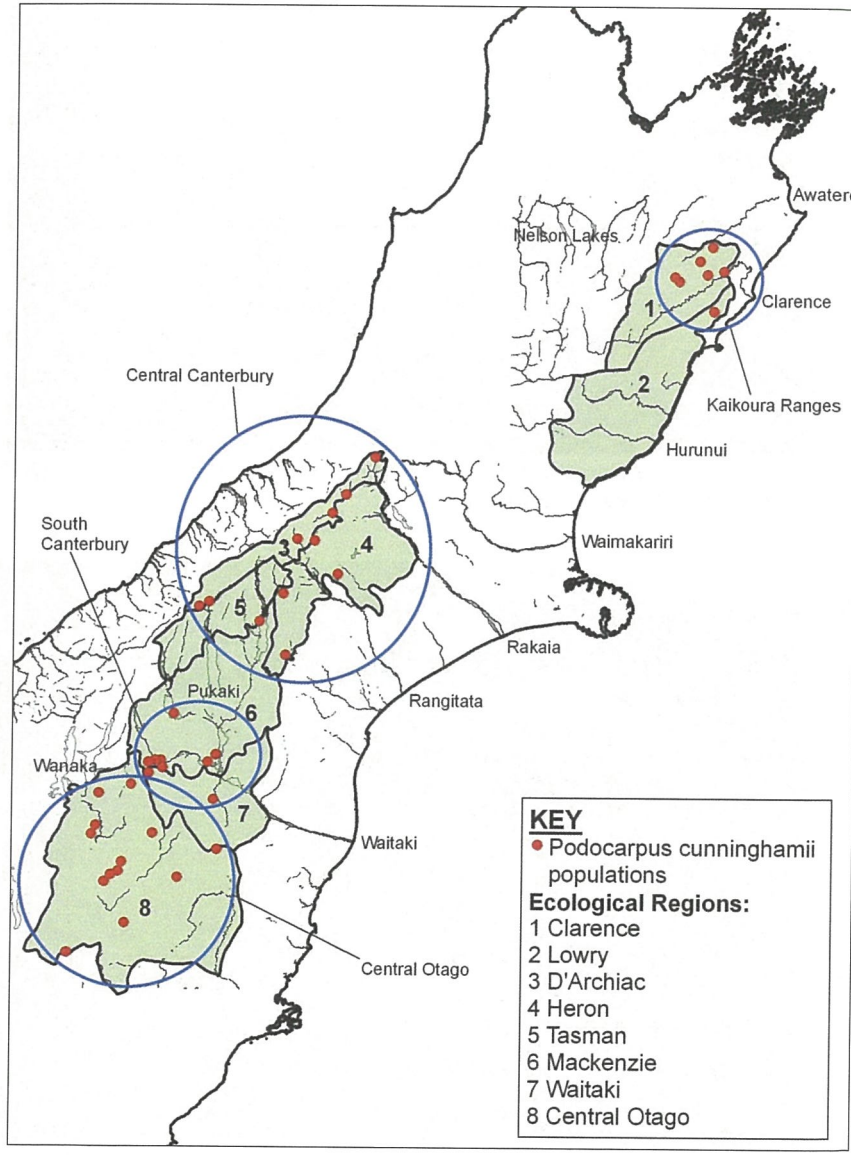

Figure 6 The distribution of *Podocarpus cunninghamii* communities throughout the high country

Plate 1 Extensive stands of *Podocarpus cunninghamii* forest in the upper Hapuku River catchment, Seaward Kaikoura Range.

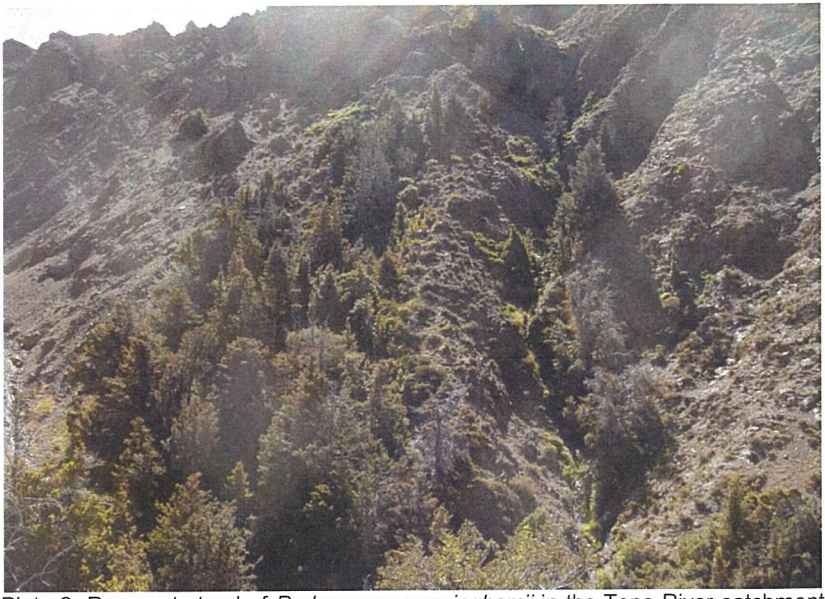

Plate 2 Remnant stand of *Podocarpus cunninghamii* in the Tone River catchment (Muller Station), Inland Kaikoura Range.

3.1.2. Clarence Ecological Region

The Inland Kaikoura Range differs markedly to the Seaward Range in terms of precipitation, receiving just 700 mm in its driest reaches (Pascoe, 1983, Williams, 1989). *Podocarpus cunninghamii* has a very fragmented distribution in the Inland Kaikoura Range, being restricted to remote and steep valleys. Charcoal deposits, pollen records, and evidence of recolonisation are all indicative of a historical cover far more extensive than that of today (McGlone and Basher, 1995, Williams, 1989).

Two forms of *Podocarpus cunninghamii* vegetation association were recorded by Williams (1989) in the Inland Kaikoura Range: *Podocarpus cunninghamii* forest and woodland, and *Podocarpus cunninghamii* scrub. Both associations occur mainly on very steep to precipitous slopes up to 1,250 m altitude. The forest and woodland association is most extensive in the southeast catchments of the Range, most notably at Muzzle and Branch Streams, while smaller, more fragmented remnants exist in the northwest catchments, particularly in Totara Stream, and the Hodder and Tone Valleys (Plate 2, page 83). *Podocarpus cunninghamii* forms the canopy, reaching 12 m in height, with *Griselinia littoralis*, *Phyllocladus alpinus* and *Hoheria lyallii* forming the sub-canopy. The shrub layer, like that of the Seaward Kaikoura Range, is sparse, with *Coprosma linariifolia, Coprosma propinqua*, *Myrsine divaricata,* and *Phyllocladus alpinus* most common. The herb layer is scattered with *Polystichum vestitum*, *Mycelis muralis,* and fine-leaved species of *Uncinia*. The scrub association constitutes a range of shrub communities that all share the presence of emergent *Podocarpus cunninghamii. Discaria toumatou*, *Rosa rubiginosa*, *Hoheria lyallii* and *Brachyglottis monroi* are the most common sub-components. These remnant populations are often located high above the valley floors, in the mouths of hanging valleys. On very steep south facing slopes and bluffs between 1,000-1,400 m, *Phyllocladus alpinus* becomes the main sub-component with *Hoheria lyallii* and *Podocarpus nivalis*.

3.2 Central Canterbury high country

This part of Central Canterbury, largely defined by the Heron Ecological Region but including the D'Archiac and Tasman Ecological Regions, is host to several populations of *Podocarpus cunninghamii*. These regions are all found south of the Hawdon and Puketeraki Ecological Regions, both of which are dominated by *Nothofagus* forest. Although *Podocarpus cunninghamii* can be often found growing in these *Nothofagus* forests, which inhabit the Waiau,

Hurunui and Waimakariri catchments, they form a relatively minor component of the flora. Conversely, *Podocarpus cunninghamii* communities that lack *Nothofagus* are either rare or absent from these catchments. The majority of *Podocarpus cunninghamii* populations exist within the beech gap; that is the high precipitation upper catchments of the Rakaia and Rangitata Rivers, as well as in Mt Cook National Park. Some isolated remnants are also present outside of these areas. The underlying rock for the majority of this region is greywacke, with alluvial rock types common in valley bottoms and basins (LRI, 1992).

3.2.1 D'Archiac, Heron and Tasman Ecological Regions

Within the climatic diversity of these three regions, annual rainfall is highest in the west, where it can be near 7,000 mm per annum close to the Main Divide, and range from c. 2,500-5,500 mm along the Mt Cook Range (Wilson, 1976). Away from the Main Divide, such as along the flanks of Lake Tekapo, precipitation declines to 800-1,000 mm per annum.

In the Rakaia catchment, *Podocarpus cunninghamii* is recorded as being abundant above 600 m in the upper reaches of the Wilberforce River, where it forms a canopy over *Phyllocladus alpinus, Griselinia littoralis, Pseudopanax crassifolius* and *Pittosporum tenuifolium*. Other common associates include *Brachyglottis buchananii, Ozothamnus vauvilliersii* and *Anaphalioides bellidioides*. *Rubus schmidelioides* is the only liana of note, while *Polystichum vestitum* is the dominant fern along with several species of *Blechnum* (McKelvey, 1984). *Podocarpus cunninghamii* is also recorded in association with *Griselinia littoralis, Hoheria lyallii, Pseudopanax crassifolius* and *Sophora microphylla* in Lake, Jellicoe and Washbourne Streams (Burrows and Russell, 1990). Nearby in Paddle Hill Creek catchment, which feeds into the South Branch Ashburton River, remnant *Podocarpus cunninghamii* trees are found in association with *Griselinia littoralis* and *Pittosporum tenuifolium* (Burrows et al., 1993).

In the Rangitata catchment, *Podocarpus cunninghamii* is present in the upper reaches of the Lawrence River, forming a canopy over *Phyllocladus alpinus, Griselinia littoralis, Podocarpus nivalis,* as well as various *Hebe* and *Coprosma* species (Plate 3). *Podocarpus cunninghamii* is also recorded as forming a remnant forest/scrub association with *Kunzea ericoides* on the cone and talus systems north of Lake Clearwater, at the southern tip of the Dogs Range, opposite Mt Guy. (Harrington et al., 1986). Annual rainfall in the

upper Lawrence is approximately 1,500 mm, which declines to 800-1,000 mm around Mt Guy (Ryan, 1987)

Plate 3 Extensive stand of *Podocarpus cunninghamii* forest in the upper Lawrence Valley.

Further south, *Podocarpus cunninghamii* is found along the Two Thumb Range. In the headwaters of Lake Tekapo, in the streams along the true left of the Macaulay River, *Podocarpus cunninghamii* forms shrub communities with *Aristotelia fruticosa* and numerous *Coprosma* species. At the southern extent of the same Range, *Podocarpus cunninghamii* forms a significant forest stand with *Pseudopanax crassifolius*, *Griselinia littoralis* and *Olearia avicenniifolia* (Plate 4, page 87). Just east of here, in the South Opuha River, several specimens of *Podocarpus cunninghamii* are recorded as being present amongst remnant stands of *Pseudopanax crassifolius, Griselinia littoralis* and *Pittosporum tenuifolium* (Harrington et al., 1986). Annual rainfall is high in the northwest of the Range, reaching 2,000 mm per annum. This declines rapidly further south, to 1,000 mm (Ryan, 1987).

Plate 4 *Podocarpus cunninghamii* forest at the southern end of the Two Thumb Range.

Plate 5 A stand of *Podocarpus cunninghamii* forest on the Sealy Range, near Mt Cook Village.

Several stands of *Podocarpus cunninghamii* forest are present within Aoraki/Mt Cook National Park (MCNP), on the Liebig, Mt Cook and Sealy Ranges (Plate 5, page 87). Here *Podocarpus cunninghamii* emerges above a canopy of predominantly *Griselinia littoralis* and *Phyllocladus alpinus*, with *Pseudopanax colensoi* var. *ternatus, Hoheria lyallii* and *Dracophyllum longifolium* also common (Wilson, 1976). Outside of MCNP, to the southeast, within the Tasman Ecological Region, small remnant stands of *Podocarpus cunninghamii* occupy the faces of the Hall Range, below Mistake Peak, overlooking the head of Lake Tekapo (D. Scott, pers. comm.), and in the upper reaches of the Cass River (D.A. Norton, pers. comm.).

3.3 South Canterbury high country

The south Canterbury high country is a dramatic and extremely varied landscape, covering the Mackenzie and Waitaki Ecological Regions. Close to the Main Divide rainfall can reach 2,000 mm per annum, while further east, along the flanks of Lakes Pukaki and Ohau, precipitation declines to 800-1,000 mm per annum. Further east again, at the southern tip of the Diadem Range, along the Ahuriri River, and along the Hawkdun Range, the climate becomes semi-arid, and annual rainfall can drop to below 600 mm. Greywacke is the most common underlying rock type on the mountain faces, with alluvial deposits forming the basins. The greywacke begins to intergrade with schist south of the Ahuriri River (LRI, 1992).

3.3.1 Mackenzie and Waitaki Ecological Regions

An extensive stand of *Podocarpus cunninghamii* is present on the boulderfields of the southwest face of Mt Ben Ohau, overlooking Lake Ohau (Plate 6). This particular stand is regarded as being the best example of a regenerating stand of *Podocarpus cunninghamii* in the Ben Ohau Ecological District (Espie et al., 1984), and may provide the most accurate picture of the dry *Podocarpus cunninghamii* forests that once covered the wider area (Molloy et al., 1976). Three lonesome individuals are also recorded in Lockharts Stream, east of the Dalgety Range.

Several stands are present in the drier areas of the Mackenzie Region, particularly on the hill slopes in and around the Ahuriri Valley, at the southern end of the Diadem Range (Plate 7). These form associations with *Podocarpus nivalis* and *Phyllocladus alpinus*, and occur mainly on boulderfields. *Podocarpus cunninghamii* populations in association with various *Coprosma* species are also recorded on the boulderfields within

Plate 6 *Podocarpus cunninghamii* on the southwest face of Mt Ben Ohau.

Plate 7 *Podocarpus cunninghamii* remnant at the southern end of the Diadem Range (Birdwood Station).

Totara and Coal Creeks, on the Benmore Range (Espie et al., 1984). A small stand of *Podocarpus cunninghamii* is also present further east, down the Waitaki River system, perched high on a south facing ledge in a deep gorge of Clear Stream (D.A. Norton, pers. comm.); annual rainfall here is less than 600 mm.

3.4 Central Otago

The Central Otago region is home to New Zealand's most continental climate, with annual rainfall levels dropping to as low as 400-500 mm in the driest places (De Lisle and Browne, 1968). The region is also distinct from the areas further north as the rock underlying the mountain ranges is almost entirely schist rather than greywacke (LRI, 1992).

3.4.1 Central Otago Ecological Region

There are numerous small population of *Podocarpus cunninghamii* within the Central Otago Ecological Region, many comprised of just a handful of trees. As Wardle (2001a) notes in his descriptions of the flora in the upper Clutha district, the drier mountains, down valley from the more extensive, predominantly *Nothofagus* forest areas, exist scattered and small *Podocarpus cunninghamii* communities. These typically include species such as *Podocarpus nivalis, Phyllocladus alpinus, Dracophyllum longifolium, Olearia nummularifolia, Olearia cymbifolia, Brachglottis cassinioides* and *Hebe subalpina.*

Podocarpus cunninghamii communities are present on the east side of the Lindis Pass Road, at the base of McLays Creek and on the steep, south facing slopes of Dip Creek, where it associates with *Olearia odorata, Coprosma propinqua* and *Discaria toumatou.* In the gorge area of Hospital Creek, near Lake Hawea, scattered *Podocarpus cunninghamii* trees form communities with *Olearia avicenniifolia, Coprosma propinqua* and *Helichrysum aggregatum.* Two remnant populations also occur further south, at Alfern Creek and the Lochar Burn, on the Pisa Range (Plate 8). These sites are rich with *Kunzea ericoides,* which shelter smaller numbers of *Podocarpus cunninghamii, Podocarpus nivalis, Phyllocladus alpinus, Dracophyllum longifolium, Corokia cotoneaster* and *Coprosma* species. Further east, at the northern and southern extents of the Dunstan Mountains, are additional *Podocarpus cunninghamii* populations. At Shepherd's Creek, *Podocarpus cunninghamii* has colonised rocky outcrops and rockfields with *Corokia cotoneaster, Griselinia littoralis* and *Phyllocladus alpinus*; at Scotts Creek, the

population is again confined to a rocky fire refuge, and here grows with *Phyllocladus alpinus, Dracophyllum longifolium* and *Podocarpus nivalis* (Ward et al., 1994). *Podocarpus cunninghamii* is also recorded as being present in the gorge of Near Undaunted Creek, on the south face of the Ida Range (Grove, 1994).

Further south in the Region, on the sheltered bluffs at the junction of Gorge Creek (formerly known as Blue Creek) and the West Branch Waikaia River, is an area of remnant forest containing *Podocarpus cunninghamii, Phyllocladus alpinus, Griselinia littoralis, Hoheria lyallii, Pittosporum tenuifolium* and *Dracophyllum longifolium* (McEwan, 1978, Brumley et al., 1986). Remnant patches of *Podocarpus cunninghamii* are also recorded in the gorge at the junction of the east and west branches of Little Valley Stream, near Alexandra, associated species include *Sophora microphylla, Myrsine divaricata,* and *Pittosporum tenuifolium*. On North Rough Ridge, overlooking Ranfurly, a group of 6-8 trees of *Podocarpus cunninghamii* clings to a rocky outcrop, along with *Myrsine divaricata, Dracophyllum longifolium* and *Gaultheria antipoda* (Fagan and Pillai, 1992).

Plate 8 Remnant stand of *Podocarpus cunninghamii* mixed with *Kunzea ericoides* at Alfern Creek Conservation Area.

4. Summary

The predominant vegetation types of the high country have not been constant through time. At the end of the last glacial maximum grasslands covered much of the landscape. At around 13-10,000- years BP, as the climate warmed, these were slowly succeeded by *Coprosma* type shrublands or *Phyllocladus* scrub below tree line. Eventually, about 10-8,000 years BP, as temperatures continued to rise, podocarp forest expanded into these woody communities and became the predominant vegetation type. Approximately 7-6,000 years BP the climate began to cool again, allowing *Nothofagus* to expand its range and replace podocarp forest along the vast majority of the axial ranges. *Podocarpus cunninghamii* forest remained the dominant forest type in the central part of the South Island, where *Nothofagus* was still largely absent. The absence of *Nothofagus* here most likely reflects its slow dispersal from refugia to the north and south of this region since end of the last glacial maximum. Moving eastwards from the Main Divide into the drylands, *Podocarpus cunninghamii* communities remained the dominant woody community below tree line and above the valley bottoms. For the most part, shrublands and tussock grasslands would have been confined to valley bottoms and alpine areas, respectively. This state is most likely what the first Polynesians to New Zealand would have encountered approximately 800 years ago. Vast swathes of the high country were deforested during the early stages of Polynesian settlement. This deforestation was greatest in the eastern dryland high country, and explains the predominantly grassland environment that early European explorers and pastoralists discovered. Pastoral farming has extended and maintained these grasslands over the last 150 years.

The large scale deforestation and conversion of the high country to grassland has severely depleted the former, pre-human range of *Podocarpus cunninghamii* communities. In the wetter valleys close to the Main Divide, such as in the headwaters of the Rakaia and Rangitata catchments, extensive tracts of tall *Podocarpus cunninghamii* forest can still be found. Species such as *Griselinia littoralis, Pseudopanax crassifolius* and *Coprosma linariifolia* are common and form a continuous canopy or sub-canopy, above which project emergent *Podocarpus cunninghamii*, at times frequent enough to form a canopy. However, as one moves eastwards, the remaining populations become increasingly scarce, small and isolated. These short statured, predominantly scrub-like communities cling to fire refugia and appear

highly degraded. Species of *Coprosma* are common, as is the invasive *Rosa rubiginosa*.

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Mahoe or whiteywood,
Melicytus reamiflorus.
Watercolour by Hugh Wilson