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**Overview of kahikā Rangitāhua (*Metrosideros kermadecensis*) and  
rātā Moehau (*M. bartlettii*), taonga unique to the rohe of Ngāti Kuri**

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# Overview of rātā Moehau (*Metrosideros bartlettii*) and kahikā Rangitāhua (*M. kermadecensis*), taonga unique to the rohe of Ngāti Kuri

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Appendix 1 – Fungi recorded on *Metrosideros bartlettii* and *M. kermadecensis* by McKenzie et al. (1999), with some names updated from New Zealand Fungarium (PDD) Te Kohinga Hekaheka o Aotearoa (as indicated)..... 17



## 1 Introduction

*Metrosideros* contains 12 species indigenous to New Zealand, with five tree species in subgenus *Metrosideros*: *M. bartlettii*, *M. excelsa*, *M. kermadecensis*, *M. robusta* and *M. umbellata*. In addition, there are 7 species of mostly climbers in subgenus *Mearnsia*: *M. albiflora*, *M. carminea*, *M. colensoi*, *M. diffusa*, *M. fulgens*, *M. parkinsonii*, *M. perforata*. Several species occur in the rohe of Ngāti Kuri, including rātā Moehau (*M. bartlettii*) from Te Pahi and kahikā Rangitāhua (*M. kermadecensis*), restricted to Rangitāhua / Kermadec Islands. Rātā Moehau and kahikā Rangitāhua both have a conservation status of Threatened, Nationally Critical (de Lange et al. 2018).

In April 2017, the fungal pathogen myrtle rust (*Austropuccinia psidii* (G. Winter) Beenken; Beenkin 2017) was found on kahikā Rangitāhua trees on Raoul Island, the most northern of the New Zealand Kermadec Islands (Ho et al. 2019). A month later the pathogen was recorded on *Metrosideros excelsa* plants in Kerikeri, Northland (Ho et al. 2019). *Austropuccinia psidii* is an invasive pathogen that has now expanded its distribution and host range and threatens indigenous ecosystems rich in Myrtaceae. The rust has become widespread in the North Island and has been found from northern parts of the South Island (Ministry of Primary Industries Manatū Ahu Matua 2018). It has been recorded on 24 species and six hybrids of Myrtaceae in New Zealand, including eight species of *Metrosideros*: *M. bartlettii*, *M. carminea*, *M. diffusa*, *M. excelsa*, *M. fulgens*, *M. kermadecensis*, *M. perforata*, *M. robusta*, and several hybrids (Toome-Hellier et al. 2020). The New Zealand myrtle rust is recognised as the pandemic strain that also occurs in Australia, Colombia, Indonesia, and Singapore (du Plessis et al. 2019); it is represented in New Zealand by two genetic clusters, known as C1 and C4 (Stewart et al. 2018).

This report provides information on the botany, ecology and biology of rātā Moehau and kahikā Rangitāhua to assist Ngāti Kuri with decisions relating to the future management and conservation of these taonga.

## 2 Kahikā Rangitāhua – *Metrosideros kermadecensis*

### 2.1 Distribution

Kahikā Rangitāhua is restricted to the Kermadec Islands, where it occurs on Raoul Island and the main Herald Islets (except Nugent) (Sykes et al. 2000). It has not been recorded from other locations despite botanical surveys being undertaken, including surveys of Macauley Island (Barkla et al. 2008; de Lange 2015a), L'Esperance Rock (de Lange 2015b) and Cheeseman Island (de Lange 2015c) in the southern Kermadec Islands, and Egeria Rock in the northern Kermadec Islands (de Lange 2014a).

Kahikā Rangitāhua is naturalised on Maui, Hawai'i, where it is regarded as an environmental weed (Evenhuis & Eldredge 2004). A distribution modelling study was undertaken for 22 of the 29 Myrtaceae species occurring in New Zealand (McCarthy et al. 2019). Unfortunately, this study did not include kahikā Rangitāhua, as the modelling was

based on the Land Environments of New Zealand (LENZ; Leathwick et al. 2002) and this does not include the Kermadec Islands.

## 2.2 Habitats and associated species

Raoul Island is largely covered in forest dominated by kahikā Rangitāhua (Oliver 1910). In the drier forest below about 250 m the understorey of kahikā Rangitāhua is characterised by *Myrsine kermadecensis*, *Coprosma acutifolia*, and *Piper excelsum* subsp. *psittacorum*. In the wetter forest above 250 m elevation the understorey is formed by *Ascarina lucida* var. *lanceolata*, *Homalanthus polyandrus* and *Pseudopanax kermadecensis*, and to a lesser extent *Melicytis ramiflorus*. The wet forest, which lies within the cloud zone and collects moisture from the mist, is luxuriant with cryptogamic epiphytes. There is a narrow coastal zone where *Myoporum kermadecense*, *Cyperus insularis*, and *Isolepis nodosa* are common. Two indigenous epiphytic species, the shiny filmy fern (*Hymenophyllum flabellatum*) and hanging club moss (*Phlegmariurus varius*), can often be found growing on kahikā Rangitāhua. Thirty-five species of fungi have also been recorded from kahikā Rangitāhua (McKenzie et al. 1999; Appendix 1).

Oliver (1910) described two growth forms of kahikā Rangitāhua. The common form is a lofty forest tree, up to 20 m tall, with an erect, twisted trunk up to 1 m diameter at the base and with irregular branching. Aerial roots grow out from the lower part of the trunk and grow towards the ground where they eventually take root – the wetter the site the greater the mass of roots. In wet forest, the prostrate trunk may be 1 m above the ground, supported by hundreds of props formed from masses of aerial roots, and developing large upright branches each like a distinct tree. On ridges and in exposed places the larger trees have large, prostrate trunks and aerial roots form on the underside of the trunk with the base of the tree becoming a tangled mass of roots and branches of various sizes.

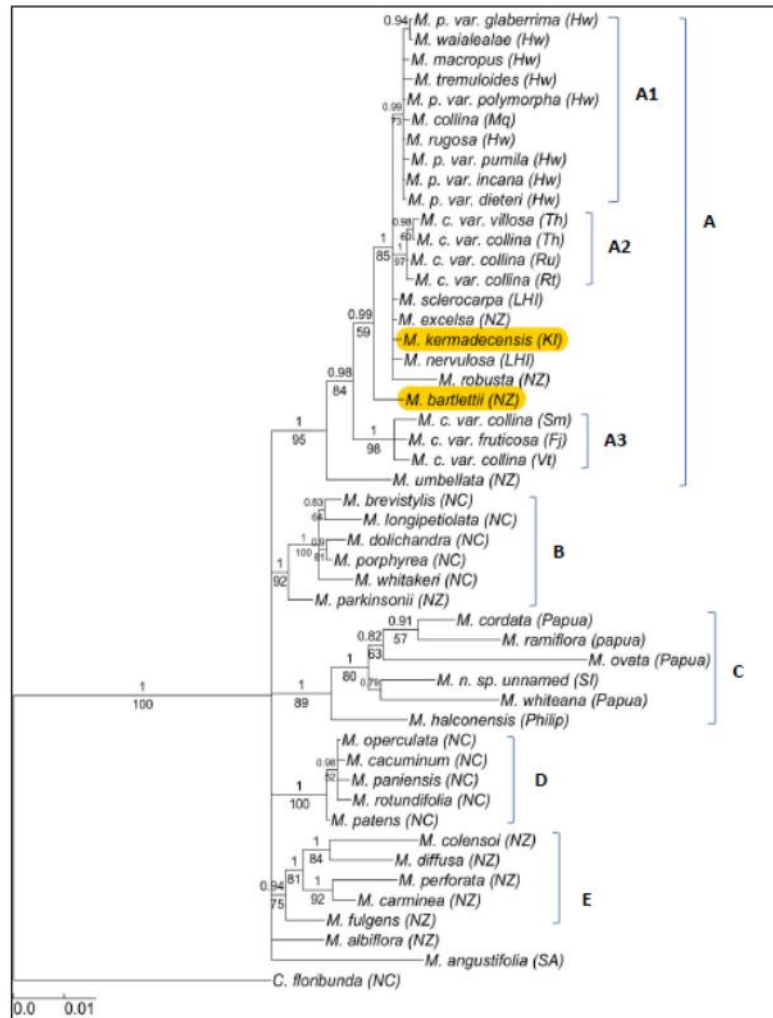
## 2.3 Phylogenetic relationships

Kahikā Rangitāhua belongs with pōhutukawa (*M. excelsa*) and northern rātā (*M. robusta*) in a widespread Pacific Island group of *Metrosideros* distributed from the main islands of New Zealand north to Kermadec Islands, Lord Howe Island, Tahiti, Rarotonga, and Hawai'i (Wright et al. 2000, 2001). This group is considered to have dispersed across the Pacific Ocean in the last 2 million years, during the Pleistocene. Melesse (2017) established similar relationships for kahikā Rangitāhua with *M. robusta* and *M. excelsa* (Fig. 1).

## 2.4 Genetic structure

A population genetic study showed that kahikā Rangitāhua has a genetic marker called 'haplotype b' that also occurs in pōhutukawa and rata populations in Northland, occupying





**Figure 1** Bayesian phylogenetic tree obtained from combined *nr*DNA ITS and ETS dataset showing the relationships of *M. kermadecensis* and *M. bartlettii* (reproduced from Melesse 2017, figure 2.10).

the area between Maunganui Bluff and Houhora Harbour and with an outlier on Mokohinau Island in the outer Hauraki Gulf (Gardner et al. 2004).

## 2.5 Myrtle rust – *Austropuccinia psidii*

In March 2017, myrtle rust (*Austropuccinia psidii*) was first identified in the New Zealand region on kahikā Rangitāhua growing on Raoul Island (Ho et al. 2019). A few months later, in May 2017, myrtle rust was found on pōhutukawa (*M. excelsa*) growing in a nursery at Kerikeri, North Island. While the initial focus of the Ministry for Primary Industries was on eradication of myrtle rust, the focus is now on effective long-term management of the disease. The most obvious symptoms of myrtle rust include red-purple lesions and masses of bright yellow pustules on young leaves. DNA analysis of myrtle rust

with ITS, TUB, and EF sequences showed that the Raoul Island and Kerikeri samples were identical; the DNA sequences have been deposited in the GenBank as MK014294 and MK020421 (ITS), MK015682 and MK015683 (TUB), MK017943 and MK017944 (EF). Herbarium specimens were deposited in the New Zealand Fungal Herbarium (Raoul Island: PDD 112332; Kerikeri: PDD 112289). Kahikā Rangitāhua growing in Hawai'i (Forest Health Highlights 2009) and Queensland and New South Wales (Australia) have also been observed with myrtle rust (Teulon et al. 2015).

There is no information on levels of infection and natural resistance in kahikā Rangitāhua. As a comparison, pōhutukawa is very susceptible to myrtle rust; seed collected from 31 pōhutukawa seed families from four provenances produced 570 plants, with over half (319, 56.5%) of the plants rated as highly susceptible and only a single resistant plant observed (Smith et al. 2020).

## 2.6 Biology

Oliver (1910) recorded tūi (*Prosthemadera novae zealandiae*) abundant on Sunday Island and visiting the flowers of kahikā Rangitāhua where they feed on the nectar, and with a yellow patch of pollen at the bases of their bills they will almost certainly be effecting cross-pollination. Flowering begins in October, peaks in November and December, and is tailing off in January (Oliver 1910).

Flower and fruit characters place *M. kermadecensis* as a member of *Metrosideros* Group A1, with the other tree species (e.g., *M. excelsa*, *M. umbellata*, *M. robusta*; Dawson 1968). Characters defining this group are technical botanical characters and include: inflorescence axillary and in pairs, of open form, and with deciduous bud scales; cymule bracts are broad and petals persistent, the flower ovary semi-superior and not bulging in fruit; style base and placentas in capsule become widely separated; the seeds are narrow with a length/width ratio of 7–10/1, and are released through the free part of the capsule; and the veins of the fruit are not persistent (Dawson 1968).

## 2.7 Weed Threats

To protect indigenous ecosystems on Raoul Island, a programme to eradicate exotic pest plants was initiated in 1972 (West 2002). By the early 2000s, 7 species that represented the greatest threat had been eradicated, and although some of these were difficult to control, none were widespread. Difficulties for the control programme include the rugged terrain, herbicide resistance, cryptic species, and long-lived seedbank. Another 22 species were targeted for eradication, with some of these being in the early stages of establishment. Each year an area equivalent to one quarter of Raoul Island is grid-searched twice; this is the area where alien plants are known to be present. The remainder of the island is checked during the recreational time of staff and volunteers and occasionally by air.

In anticipation of the planned eradication of rats (*Rattus norvegicus* and *R. exulans*) and cats (*Felis catus*) on Raoul Island in 2002, the exotic flora was evaluated to determine which species might become more invasive following the removal of rats and cats (West

2011). The interactions between the three mammal species targeted for eradication and the multiple weed species on the island were considered. A group of exotic plant species that had expanded their range vegetatively but had not been observed fruiting in the presence of rats were identified. This group included grape (*Vitis vinifera*), shore hibiscus (*Hibiscus tiliaceus*), rosy periwinkle (*Catharanthus roseus*) and airplant (*Bryophyllum pinnatum*). As a precaution, grape was targeted for eradication as this species would be dispersed effectively by native honeyeater tūi (*Prosthemadera novaeseelandiae*) and blackbird (*Turdus merula*) if it began to fruit after rats were eradicated. Grape proved difficult to control but by mid-2002 all nine known grape infestations were reduced to zero density. In 2008/2009, no grape sprouts were found during searches of all known infestation sites. Since the pest animal eradication, almost all species that did not fruit when rats were present are now fruiting.

Overall, eleven species have been eradicated during the 45 years the Raoul Island weed eradication programme has been active (West & Havell 2019). To complete the restoration of Raoul Island's unique ecosystems supporting significant seabird biodiversity and other endemic biota, nine further weeds that can adversely affect ecosystem function should be eradicated. Four species targeted for eradication are African olive (*Olea europaea* subsp. *cuspidata*), yellow guava (*Psidium guajava*), castor oil plant (*Ricinus communis*), and grape (*Vitis vinifera*). West & Havell (2019) recommended additional staff resources are required to eradicate four other pest plants as these are establishing faster than they are being eliminated: purple guava (*Psidium cattleianum*), black passionfruit (*Passiflora edulis*), Brazilian buttercup (*Senna septemtrionalis*), and Mysore thorn (*Caesalpinia decapetala*). The ninth species, Madeira vine (*Anredera cordifolia*), is being contained but presents logistical difficulties for effective control as it has herbicide resistant tubers and cliff locations requiring rope access in unstable terrain. Increasing the current resources for this programme to enable eradication of these transformer pest plants will reduce the total long-term cost. Eradication of rats, the 2006 eruption, recent increased cyclone frequency, increased tourism requiring biosecurity management, and staff reductions have impacted progress on weed eradication.

With the eradication of goats from Raoul Island in 1984 there have been changes to the vegetation associated with kahikā Rangitāhua. The exotic aroid lily (*Alocasia brisbanensis*) has decreased in abundance and dominance within the forest since the goats were eradicated, with the closing in of the pōhutukawa and nikau canopy possibly the principal reason, as the aroid lily is intolerant of low light levels (Sykes & West 1996). Very little spike-sedge (*Cyperus mindorensis*; formerly known as *Cyperus kyllingia*) now grows in the kahikā Rangitāhua understorey at Denham Bay because of the greater density of the indigenous understorey vegetation (Sykes & West 1996). The Mysore thorn (*Caesalpinia decapetala*) has been eradicated from the Denham Bay area, but where it once occurred several clumps of Indian shot (*Canna indica*) have grown in open kahikā Rangitāhua forest to the west of the Denham Bay swamp (Sykes & West 1996).

Myrtle rust is the latest invasive species establishing on Raoul Island, and its impact on the dominant canopy tree kahikā Rangitāhua and on the weed eradication programme is unknown at this point (West & Havell 2019). Damage to the kahikā Rangitāhua canopy will almost certainly impact the indigenous vegetation, as increased light will result in changes to the understorey and alter the balance between indigenous and pest plant species.

## 2.8 Herbivory and pest animals

Raoul Island was gazetted a Flora and Fauna Reserve in 1934 and attempts have been made to control or eradicate such introduced animals as pigs (*Sus scrofa*), feral goats (*Capra hircus*), and feral cats (*Felis catus*) (Parkes 1984a). Pigs, which were never abundant, were eliminated from Raoul Island in 1966 (Sykes 1977). Goats were liberated on the island before 1836 (Straubel 1954) and in 1908 it was noted they were damaging the vegetation by thinning the undergrowth, restricting the growth of some terrestrial seedlings and barking some trees so that certain plants that had been once common were restricted to inaccessible places (Oliver 1910). By 1966, there were few or no young plants kahikā Rangitāhua regenerating and it was predicted the species might eventually disappear from large parts of Raoul Island (Sykes 1969). Rumen samples from 103 goats shot in 1982–83 showed that at least 48 species of vascular plants, mostly indigenous species, were eaten. However, 7 plants made up 89% of the diet by dry weight. Kahikā Rangitāhua was the most important dietary item, comprising 35.0% of all samples, being eaten by most goats (90.3%), and forming 32% of their diet (Parkes 1984a).

Several other visitors confirmed Oliver's observations of the impact of goats (Merton 1968; Sykes 1969, 1977), and proposals were made to exterminate them. Government hunting campaigns began in 1937, with yearly hunting from 1972, and by 1983 the herd had been reduced from several thousand to the verge of extinction (Parkes 1984a, 1984b), with eradication in 1985 (Sykes & West 1996). The reduction of goat numbers and their eventual elimination has allowed most of the palatable species to regenerate. In 1982, terrestrial seedlings and young kahikā Rangitāhua trees were common, particularly in the crater and on cliffs at Denham Bay, and epicormic shoots were abundant on most trunks (Parkes 1984b). Goat eradication has seen recovery of parapara (*Ceodes brunoniana*), Kermadec five finger (*Pseudopanax kermadecensis*), Kermadec poplar (*Homalanthus polyandrus*), karo (*Pittosporum rangitahua*), and Kermadec nettle tree (*Pouzoizia australis*) (Sykes & West 1996). Kermadec koromiko (*Hebe breviracemosa*) also recovered the brink of extinction after goat removal (de Lange & Stanley 1999).

## 2.9 Cultivation

Kahikā Rangitāhua is often grown in frost-free parts of New Zealand as an ornamental shrub or small tree. Winter hardiness and lethal temperature for kahikā Rangitāhua is  $-3^{\circ}\text{C}$  before damage and  $-5^{\circ}\text{C}$  for death (Warrington & Stanley 1987); in summer, frost hardiness and lethal temperatures are  $-1^{\circ}\text{C}$ .

Twelve cultivars of kahikā Rangitāhua are grown in the nursery trade in New Zealand and Australia (Dawson et al. 2010a; Dawson 2011), and all except *M. kermadecensis* 'Platt's Form' have variegated or variously coloured leaves. These include *M. kermadecensis* 'Cream Ridge', *M. kermadecensis* 'Gala', and *M. kermadecensis* 'Variegata'. It is possible some of these selections have been renamed to enhance their marketability.

*Metrosideros kermadecensis* and *M. excelsa* are closely related and are considered to hybridise readily when grown together (Dawson et al. 2010a). A spontaneous hybrid

between *M. kermadecensis* and *M. excelsa* that is considered to have arisen in cultivation is *Metrosideros* ‘Red Haze’.

### **3 Rātā Moehau – *Metrosideros bartlettii***

#### **3.1 Distribution and plant numbers**

Rātā Moehau is an extremely rare tree, confined to three small forest fragments in the vicinity of North Cape (Dawson 1985; Drummond et al. 2001). These remnants are generally referred to as Radar Bush, Kohuronaki and Unuwahao. A recent distribution modelling study was undertaken by McCarthy et al. (2019) for 22 of the 29 Myrtaceae species occurring in New Zealand, but *M. bartlettii* was not included as it has too few records for the modelling to provide a meaningful result.

Since its first being brought to scientific attention, in 1976, very few plants of rātā Moehau have been located in its restricted geographic area. Table 1 is a chronological summary of the date, location and number of plants that have been documented. Plant numbers vary among the comments of the different observers.

#### **3.2 Habitats**

Rātā Moehau is usually found growing in or near damp habitats. For example, at Radar Bush a large tree is right beside the stream with a large root extending across it and, at Kohuronaki, a tree epiphytic on a pūriri (*Vitex lucens*) overhangs a deep pool in the stream. On giving the tree a scientific name and describing the species, Bartlett (1985) noted that one medium-sized tree in a valley-head bush patch at Radar Bush is epiphytic on a pūriri and at the head of the swamp below the bush patch three small trees are epiphytic on dead mamukū (*Cyathea medullaris*) with their roots growing down into the swamp.

#### **3.3 Associated species**

A range of fungi have been reported from *Metrosideros* species and most of these are saprobes, forming their fruiting bodies on dead leaf or woody tissue. Some of these fungi have been reported only from *Metrosideros*, and they may be host specific (McKenzie et al. 1999). Two fungi have been recorded from rātā Moehau: *Anthracoxyllum archeri* and *Cladobotryum* sp. (McKenzie et al. 1999; Appendix 1). The widespread root-rotting pathogen *Phytophthora cinnamomi* has been reported on *Metrosideros*, as have several fungi which cause leaf spots (McKenzie et al. 1999).

Two liverwort species have been recently described from rātā Moehau. *Siphonolejeunea raharahanehemiae* grows on the twigs of canopy branches of and is known from collections at Radar Bush and Unuwahao Forest (Renner & de Lange 2020). Rātā Moehau is also the only known host tree for *Frullania wairua* (von Konrat and Braggins 2005). The two known collections of *Siphonolejeunea raharahanehemiae* are mixed with *Frullania wairua*.

### 3.4 Chromosome number

Chromosome counts for rātā Moehau and all other New Zealand species of *Metrosideros* have revealed that they are diploid with a chromosome number of  $2n = 22$  (Dawson 1987).

**Table 1.** Chronological summary of the date, location and number of plants that have been documented for rātā Moehau. The numbers provided by de Lange (2016) will be the most accurate as he would have had access to DOC field survey and monitoring data

Date	Observation on plant numbers and reference
July 1976	Radar Bush 3 trees noted first in scientific literature
1977	Foliage, but no flowers or fruits, were obtained from another small tree that was blown over near to Radar Bush; it has since died (Dawson 1985)
1984	A second locality discovered by Peter Anderson near the beginning of the Spirits Bay road (Kohuronaki)
1985	7 trees known when the species was formally described by Dawson (1985): a small tree was found by Bartlett in 1976 but had not been relocated in 1985
1990	Ten trees had been found across two Te Paki sites – Radar Bush and Kohuronaki (de Lange 2016)
1991	Another population discovered in the Muriwhenua Incorporation’s Unuwahao Forest near Spirits Bay (de Lange 2016)
1992	34 wild trees were recorded from the three known sites (de Lange 2016)
2000	A total of 31 trees known. Radar Bush 2 trees; Kohuronaki 7 trees; Unuwahao 22 trees
2007	DOC staff found 7 trees at Unuwahao had died from possum browse and several more were seriously defoliated (de Lange 2016)
2010	29 adult plants in the wild (de Lange et al. 2010)
2012	25 adult trees left in the wild (de Lange 2014).
April 2015	The known trees at Radar Bush and Kohuronaki remain; at Unuwahao Forest field survey found only 1 tree in the original stand of 16, but 3 more plants discovered in a nearby catchment (de Lange 2016)
2017	Total 21 plants: Unuwahao 5 plants; Radar Bush 2 plants; Kohuronaki 14 plants (Melesse 2017)
2018	13 trees in three populations in the wild (Lehnebach & van der Walt 2018)

### 3.5 Phylogenetic relationships

Rātā Moehau is the closest relative and ‘sister’ species to a large group of species, comprising the New Zealand *M. excelsa*, *M. kermadecensis*, and *M. robusta* and Pacific Island species from Lord Howe Island, Tahiti, Rarotonga, and Hawai’i (Wright et al. 2000, 2001). Melesse (2017) established similar relationships of the phylogenetic distinctiveness of *M. bartlettii* from its close relatives, *M. robusta* and *M. excelsa* (Figure 1).

### 3.6 Genetic structure

The results of DNA fingerprinting’ studies with microsatellite and AFLP data demonstrate that rātā Moehau is a unique species, distinct from its New Zealand relatives *Metrosideros robusta*, *M. excelsa*, and *M. umbellata* (Drummond et al. 2000; Melesse 2017). Population structure of the AFLP loci varied between the three subpopulations sites. The Radar Bush (Te Paki) site with two trees formed a subgroup and showed some separation from the populations at Unuwahao and Kohuronaki; plants from these latter two sites overlapped and are mixed together in their AFLP population diversity profiles and are therefore genetically closely related (Drummond et al. 2000). Statistically, pairwise  $F_{ST}$  showed that the Te Paki population was significantly different from both the Unuwahao and Kohuronaki sites. An estimate of effective population size ( $N_e$ ) can be made from the levels of genetic variation in the existing populations.

A population estimate of  $N_e = 5,480$  plants is derived, which suggests that the 31 surviving trees are remnants of a much larger population that has recently suffered a quite dramatic collapse (Drummond et al. 2000). The restricted distribution and few plants evident today probably dates from the last glacial maximum (c. 18,000 years ago). At the time of that cooling, the frost-sensitive rātā Moehau was probably confined to the far north of New Zealand, where it appears to have remained during the subsequent warming of the Holocene. The arrival of Māori and more recently European settlers in New Zealand resulted in forest clearance and habitat disturbance, but it is unknown how this would have impacted the distribution and number of plants of rātā Moehau.

Melesse (2017) analysed the genetic structure of rātā Moehau by AFLP and SSR markers and showed that this species has lower genetic diversity (AFLP:  $H_e = 0.17$ , SSR:  $H_e = 0.48$ ) than the related *Metrosideros excelsa* and the average reported values for long-lived, outcrossing, and wind-dispersed tree species. Analyses of population genetic structure showed that, despite the proximity of the populations, these had significant genetic differentiation (AFLP:  $F_{st} = 0.22$ , SSR:  $F_{st} = 0.20$ ), confirming the results of Drummond et al. (2000). Structure analysis showed the assignment of individuals into two genetic populations: Kohuronaki and Unuwahao/Radar Bush. In a PCoA the Kohuronaki population formed a distinct group clearly separated from the Unuwahao and Radar Bush populations, which were grouped together. This suggests limited gene flow between populations, which could be expected, given the small number of trees and the resulting small pollen and seed production that is inadequate to attract many pollinators.

### 3.7 Herbivory and pest animals

Possum damage to rātā Moehau has been documented and is a serious threat to the species survival. In 2007, DOC staff found 7 trees at Unuwahao had died from possum browse and several more were defoliated (de Lange 2016).

*Metrosideros* are a preferred possum food plant and possum browse on *Metrosideros excelsa*, *M. robusta*, and *M. umbellata* can be severe (Payton 1983, 1987; Pekelharing & Batcheler 1990). Possums browse selectively and concentrate on individual plants of their preferred species, and their continued defoliation over several years can result in the death of the tree. At a local geographic scale, possums have made some plants rare or locally extinct, such as the loss of northern rātā from the Aorangi Range (Druce 1971). Following the possum control campaign on Rangitoto Island there was a very marked increase in flowering of pōhutukawa (Atkinson et al. 1995).

### 3.8 Myrtle rust – *Austropuccinia psidii*

Myrtle rust has been recorded from a single plant of rātā Moehau (Toome-Hellier et al. 2020), but no information was provided on where this occurred, whether from among the three wild populations or on a cultivated plant. Myrtle rust is known to affect leaves, shoots, buds, flowers, fruits, and new growth (Tommerup et al. 2003; Glen et al. 2007; Pegg et al., 2014). There is high probability that wild populations of rātā Moehau will be infected with myrtle rust because of its location in northern North Island in a geographic area where myrtle rust is known to be prevalent and with high risk of infecting Myrtaceae (Beresford et al. 2018; McCarthy et al. 2020).

### 3.9 Pollination, seed set and germination

The efficacy of hand pollination in producing viable seeds of rātā Moehau was examined by Nadarajan et al. (2020). One of the rātā Moehau trees cultivated at Otari Native Plant Museum, Wellington, was shown to be self-incompatible, and successful hand cross-pollinations using pollen obtained from different genotypes growing in the gardens at the University of Auckland resulted in seed production with c. 20% germination. Self-incompatibility means flowers of rātā Moehau will produce seeds only if they are pollinated by pollen from a genetically different plant to the mother plant; self-incompatibility is a strategy to promote outcrossing and genetic diversity. Earlier research on seed production in the New Zealand *Metrosideros* species has recorded 2% in rātā Moehau (Schmidt-Adam 1997), comparable to *M. robusta* (3.0%; Knightbridge 1993), *M. umbellata* (13.0%; Wardle 1971).

The ovaries of hand cross-pollinated flowers of rātā Moehau quickly swelled up after pollination, but the fruits took almost 5 months to mature (Nadarajan et al. 2020). A change in colour, from light green to dull brown, indicated the capsules were mature. The harvested capsules contained a mixture of filled (embryo present) and empty seeds, a



characteristic common of many Myrtaceae species. Mean seed germination of all seeds in a capsule was c. 21%, with all of the filled seeds germinating. The first germination was observed after 3 days, with germination completed within 7 days. Agamospermy, autonomous self-pollination, hand self-pollination and natural pollination all failed to develop fruits, indicating the failure of individual plants to set seed and form fruit with their own pollen (Nadarajan et al. 2020). Initial seed germination of rātā Moehau seeds was  $91\% \pm 1.2$  and germination was still high ( $>70\%$ ) for the seeds dried to around 2% moisture content; these results indicate the seeds are orthodox (Nadarajan et al. 2020).

Nadarajan et al. (2020) comment that their findings contradict reports of abundant fruit-set and the production of viable seeds observed in single rātā Moehau trees growing in some botanic gardens or private gardens. They consider that it is possible that, as with pōhutukawa (Schmidt-Adam et al. 1999), self-incompatibility in rātā Moehau is incomplete and self-compatible individuals may also exist. Alternatively, rātā Moehau trees may be capable of hybridising with other *Metrosideros* species growing nearby. Although the average germination of seed obtained from the controlled pollination of rātā Moehau was generally low, which is consistent with findings in other Myrtaceae species such as pōhutukawa (Schmidt-Adam et al. 1999), hand pollination is beneficial where trees are too far apart for pollination to occur and when no pollinators are present on site.

Another pollination experiment to determine whether rātā Moehau is able to form seeds using its own pollen or whether it requires pollen from a genetically distinct tree was conducted by Lehnebach & van der Walt (2018). They followed the development of the flowers from bud to anthesis (i.e., flower is fully open) and conducted several pollination experiments. This study also concluded rātā Moehau is a self-incompatible species.

### **3.10 In vitro culture**

Tissue culture protocols for initiation of seedlings and shoots into tissue culture and their propagation using in vitro and photo-autotropic micropropagation techniques were developed for various Myrtaceae, including rātā Moehau (Nadarajan et al. 2019). Through shoot tip culture of rātā Moehau we could achieve almost 100% sterile plants because the initial contamination in the agar plates was not high. Sterile seedlings were cultured on a medium consisting of Murashige and Skoog (MS) half-strength macro elements, full strength MS microelements, and B5 vitamins with 3% (w/v) sucrose solidified with agar (7.5% w/v); developing plantlets were transferred to NaDCC-free medium. Further, in vitro propagated rātā Moehau have been transferred to the greenhouse successfully with 100% acclimation success and can be grown on for eventual planting out.

### **3.11 Cultivation**

Rātā Moehau is sometimes grown in public gardens as an ornamental tree, and occasionally in private gardens. It apparently produces few flowers in cultivation as two trees growing at Otari Native Plant Museum flowered for the first time in November 2017, almost 25 years after they were planted (Lehnebach & van der Walt 2018). A 25-year-old

plant growing in a private garden in Port Hills, Canterbury, has not been observed flowering but has proved cold hardy as it is not damaged by winter frost or occasional snow falls (PBH, pers. obs.).

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## 5 References

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**Appendix 1** – Fungi recorded on *Metrosideros bartlettii* and *M. kermadecensis* by McKenzie et al. (1999), with some names updated from New Zealand Fungarium (PDD) Te Kohinga Hekaheka o Aotearoa (as indicated)

<i>Metrosideros bartlettii</i> (2 associated fungi)		
AGARICALES		
<i>Anthracoxyllum archeri</i> (Berk.) Pegler	Mushrooms gregarious to caespitose on fallen twigs of various trees in indigenous forest.	Auckland: PDD 60845.
MITOSPORIC FUNGI		
<i>Cladobotryum</i> sp.	On outer bark of living tree. Associated with a mushroom fruitbody.	Northland: PDD 60086.
<i>Metrosideros kermadecensis</i> (35 associated fungi)		
ASCOMYCOTA		
<i>Coccomyces limitatus</i> (Berk. & M.A.Curtis) Sacc.	Widespread and common on fallen leaves of many trees throughout the northern half of New Zealand. Known also from Australia, tropical Asia, and Central America.	Kermadec Islands: PDD 54665.
<i>Daldinia concentrica</i> (Bolton) Ces. & De Not.	Forms large, black fruiting bodies (cramp balls) on fallen wood of many trees in New Zealand. Cosmopolitan in distribution.	Kermadec Islands: PDD 54733.
<i>Lanzia</i> sp. " <i>aureus</i> " (in McKenzie et al. 1999 as <i>Hymenoscyphus</i> sp.)	Small, yellow discomycete found on fallen leaves and flower parts.	Kermadec Islands: PDD 54668.
<i>Meliolina novae-zealandiae</i> Hansf.	Causes large sooty blotches on the undersides of leaves. The fungus enters the leaves through stomata.	Kermadec Islands: PDD 54799.
<i>Plectania platensis</i> (Speg.) Rifai	A black cup fungus saprobic on dead wood.	Kermadec Islands: PDD 54737.
<i>Propolis emarginata</i> (Cooke & Masee) Sherwood	An immersed discomycete forming fruiting bodies on fallen leaves. It is common on <i>M. excelsa</i> , <i>M. robusta</i> , and <i>M. kermadecensis</i> ; rare on the other species.	Kermadec Islands: PDD 54664, 54666.

<i>Scorias spongiosa</i> (Schwein) Fr.	Sooty mould. A tropical and subtropical species known in New Zealand only from Kermadec Islands.	Kermadec Islands: PDD 16759.
<i>Torrendiella eucalypti</i> (Berk.) Spooner (in McKenzie et al. 1999 as <i>Torrendiella</i> sp.)	Discomycetes with black setae on the receptacle, <i>Torrendiella</i> spp. are common on fallen leaves of many plants throughout New Zealand.	Kermadec Islands: PDD 54660, 54667.
<i>Tubeufia helicoma</i> (W.Phillips & Plowr.) Piroz., anamorph <i>Helicosporium pannosum</i> (Berk. & M.A.Curtis) R.T.Moore	A saprobe on fallen leaves. Occurs throughout New Zealand on dead wood and leaves.	Kermadec Islands: PDD 54770, 54771.

#### BASIDIOMYCOTA AGARICALES

<i>Armillaria ?novae-zelandiae</i> (G.Stev.) Herink	This indigenous, pathogenic species is widespread in New Zealand on many woody hosts. It is a major cause of death of <i>Pinus radiata</i> in New Zealand.	Kermadec Islands: PDD 54731.
<i>Panellus pusillus</i> (Pers. ex Lev.) Burds. & O.K.Mill.	Polypore bracket fungus with white, cream, or pale yellow basidiocarps. On dead wood, associated with a white rot. In mainland New Zealand known only in Northland.	Kermadec Islands: PDD 17288, 39249, 55029, 55045.

#### APHYLLOPHORALES

<i>Antrodiella</i> sp.	This record is based on a single collection containing a somewhat deformed, yellow-brown, poroid basidiocarp.	Kermadec Islands: PDD 59469.
<i>Ganoderma applanatum</i> sensu Wakef. (in McKenzie et al. 1999 as <i>Ganoderma</i> cf. <i>applanatum</i> (Pers.) Pat.)	Polypore bracket fungus. Associated with a white heart rot of living trees. Widespread and common in New Zealand on many woody hosts.	Kermadec Islands: PDD 59463, 59464.
<i>Lenzites vespacea</i> (Pers.) Ryvarden, <i>Norweg.</i>	Polypore bracket fungus. Causing a white rot on standing dead trunks and stumps. The only other known host in New Zealand is <i>Pinus radiata</i> .	Kermadec Islands: PDD 55048.
<i>Phellinus senex</i> (Nees & Mont.) Imazeki	Recorded from dead standing and fallen trunks of several indigenous hosts, causing a white rot. Appears to be the most common species of <i>Phellinus</i> on <i>Metrosideros</i> .	Kermadec Islands: PDD 26137, 26138.



<i>Phellinus wahlbergii</i> (Fr.) D.A.Reid	Causing a white rot of several hardwood hosts, less often on conifers. Fruits on bark of standing and fallen dead trunks.	Kermadec Islands: NZFRI(M) 1251, PDD 59465.
<i>Trametes pubescens</i> (Schumach.) Pilát (in McKenzie et al. 1999 as <i>Trametes ?pubescens</i> (Fr.) Pilát)	Polypore bracket fungus. Saprobiic on dead wood. Worldwide in distribution, but not known from mainland New Zealand.	Kermadec Islands: PDD 55041, 55044.

#### AURICULARIALES

<i>Auricularia polytricha</i> (Mont.) Sacc.	Wood ear fungus. Widespread and common throughout New Zealand on dead wood of many different plants.	Kermadec Islands: PDD 55046.
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#### MITOSPORIC FUNGI

<i>Acrodontium crateriforme</i> (J.F.H.Beyma) de Hoog	Overgrowing and probably parasitic on <i>Meliolina novae-zealandiae</i> . In New Zealand known only from Kermadec Islands.	Kermadec Islands: PDD 54807.
<i>Chaetosticta</i> sp.	Hypophyllous on living leaves, forming discrete black colonies or more general black mould-like growth within the leaf tomentum.	Auckland: PDD 46690.
<i>Chloridium</i> sp.	A saprobe on dead, fallen leaves.	Kermadec Islands: PDD 59366.
<i>Codonaea</i> sp. (in McKenzie et al. 1999 as <i>Dictyochaeta</i> sp.)	A saprobe on dead, fallen leaves.	Kermadec Islands: PDD 59377.
<i>Conoplea</i> sp.	A saprobe on dead, fallen leaves.	Kermadec Islands: PDD 59372.
<i>Cryptophiale orthospora</i> McKenzie	A saprobe on dead, fallen leaves.	Kermadec Islands: PDD 59365.
<i>Ellisiopsis galesiae</i> Bat. & Nascim.	A saprobe on dead, fallen leaves. Widespread in tropical areas. In New Zealand known only from Kermadec Islands.	Kermadec Islands: PDD 54648.
<i>Gyrothrix</i> sp	A saprobe on dead, fallen twig.	Kermadec Islands: PDD 59367.
<i>Olidodendron</i> sp.	A saprobe on dead, fallen leaves.	Kermadec Islands: PDD

		59373.
<i>Pleurotheciopsis</i> sp.	A saprobe on fallen leaves.	Kermadec Islands: PDD 59374, 59375.
<i>Ramichloridium</i> sp.	Overgrowing <i>Meliolina novae-zealandiae</i> .	Kermadec Islands: PDD 54825.
<i>Septonema</i> sp.	A saprobe on dead, fallen leaves.	Kermadec Islands: PDD 59381.
<i>Spiropes</i> sp.	Overgrowing and probably parasitic on <i>Meliolina novae-zealandiae</i> .	Kermadec Islands: PDD 54810.
<i>Verticicladiella</i> sp.	A saprobe on dead, fallen leaves.	Kermadec Islands: PDD 59378, 59379.
<i>Wiesneriomyces</i> sp.	A saprobe on dead, fallen leaves.	Kermadec Islands: PDD 59363, 59376.

#### MYXOMYCOTA

<i>Fuligo septica</i> (L.) F.H.Wigg	Slime mould found on dead wood.	Kermadec Islands: PDD 54594.
<i>Trichia favoginea</i> (Batsch) Pers.	Slime mould found on dead wood.	Kermadec Islands: PDD 54595.