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Cover: Leaf of ramarama (*Lophomyrtus bullata*) infected with *Austropuccinia psidii*, the rust that causes myrtle rust disease, at the Awaroa Scenic Reserve, Kawhia. Photo: Peter J. de Lange.

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epress@unitec.ac.nz
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Unitec, Te Pūkenga
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CONTENTS

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It is an understatement to say that we have all been seriously affected by Covid-19-induced health concerns, lockdowns and travel restrictions over the past two years. From a biosecurity perspective, the lack of international travellers arriving in Aotearoa / New Zealand may have helped reduce the risk of unwanted organisms entering our country to some degree, but having our biosecurity personnel confined to barracks provided invasive species the opportunity to rebound in their absence. Reports of biosecurity issues throughout the Covid times are a sure indicator that invasive species are alive and well out there – for example the *Mycoplasma bovis* recurrence in Canterbury, pepino mosaic virus in Tāmaki Makaurau / Auckland, two marine pests (Asian seaweed *Undaria pinnatifida* and the carpet sea squirt *Didemnum vexillum*) at Rakiura / Stewart Island, and a too-close-to-home outbreak of foot-and-mouth disease in Southeast Asia.

As the general populace everywhere scrambled to survive in their day-to-day family and professional lives throughout the pandemic impacts, submission of academic manuscripts for publication clearly slipped (perhaps justifiably) to a low priority. As a result, only one paper was submitted to *Perspectives in Biosecurity* in 2021. This was published early in that year "ahead of print" as we felt that the myrtle rust subject matter was too important to wait for an end-of-year full issue (see Schmid et al. 2021). That early publication was a fortunate move given that no further papers materialised!

However, we are delighted to present three very different research papers in this year's issue of *Perspectives in Biosecurity*. The first paper describes the development of an intriguing mixed native–naturalised vegetation association on an island near urban Tāmaki Makaurau / Auckland. The second paper provides a preliminary assessment of the cyanobacteria, flora and lichenised associates of two endemic tree species (ramarama, *Lophomyrtus bullata* and rōhutu, *L. obcordata*) that are threatened by myrtle rust. The third paper covers some preliminary research on the efficacy of the Honshu white admiral butterfly (*Limenitis glorifica*) as a biological control against Japanese honeysuckle (*Lonicera japonica*).

We gratefully thank the authors for their contributions to this issue, and acknowledge their persistence and productivity over what has been a challenging time to complete research projects.

Mel Galbraith and Dan Blanchon
Editors

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The biota and geology of Ngārango Otainui: A mixed indigenous / naturalised vegetation association of the Māngere Inlet, Manukau Harbour

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Contact:
epress@unitec.ac.nz
www.unitec.ac.nz/epress/
Unitec, Te Pūkenga
Private Bag 92025
Victoria Street West, Auckland 1010
Aotearoa / New Zealand

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The biota and geology of Ngārango Otainui: A mixed indigenous / naturalised vegetation association of the Māngere Inlet, Manukau Harbour

Peter J. de Lange, Andrew J. Marshall, Luzie M. H. Schmid and Sharen Graham

Abstract

An account of the geology, vegetation associations, mycobiota, flora and avifauna of Ngārango Otainui, a 0.309 ha island located at the eastern end of the Māngere Inlet, Manukau Harbour, Tāmaki Makaurau / Auckland is provided. This appears to be the first comprehensive account of the island's geology, vegetation and biota. The island has been mapped by others as Puketoka Formation; our survey confirmed this, noting that the basal exposed portion of the island appears to be a distal, heavily weathered ignimbrite over which is deposited a series of tephras (Hamilton Ashes). The flora and mycobiota of the island, assessed over three visits (2009 and 2021) recorded 125 taxa from 57 families and 100 genera from Ngārango Otainui, and vouchers for 119 (95%) of these obtained. Fifty-two (54%) of the vascular plants and four (36%) of the bryophytes are naturalised to New Zealand and most of these dominate the island's vegetation. Earliest imagery (1940) available suggests that the island was then dominated by grassland, and that since then the island has developed a woody vegetation dominated by naturalised plants, mostly from dispersal from nearby Auckland City urban sources. Fourteen of these plants are regarded as pest species within the Auckland Council Region. During two visits (January and November 2021) 14 species of bird were noted on or around the island. While no nationally threatened taxa were found, one plant, *Bromus arenarius*, five lichens and three birds seen are listed as 'At Risk' by threat listing panels using the New Zealand Threat Classification System. Nine vegetation associations (and sparsely vegetated landforms) were recognised. These are described in this paper and their extent given and mapped. Since aerial imagery became available for the island, 55% of the island has been lost through erosion, which is ongoing.

Keywords

Ngārango Otainui; Māngere Inlet; Manukau Harbour; biota, vegetation associations; naturalised plants; erosion

Introduction

Ngārango Otainui (0.309 hectares, 4 m a.s.l., -36.938736°S 174.820305°E, Figures 1, 2) is the only island within the Māngere Inlet of the Manukau Harbour, Tāmaki Makaurau / Auckland. Ngārango Otainui is located at the eastern end of the Māngere Inlet, surmounting the southern end of a broad mudbank that is covered in c.1 m of water at high tide. The island is reasonably close to land; the nearest point of land, Norana Park, Māngere, to the south west of the island is c.513 m distant.

The first mention, or really depiction, of the island is that by Hochstetter (1859, published in 1864), who called it 'Hara nui', noting also that west of the island across a channel was a 'white shell bank'. This shell bank may already have been vegetated, though Hochstetter did not mention this; irrespective, the earliest aerial imagery we can find of Ngārango Otainui (1940) shows Hochstetter's 'white shell bank' as another, low-lying, vegetated island, which had almost completely vanished through coastal erosion by 1972, and which by 1985 had completely gone. The name 'Hara nui' is of interest; 'Hara' is a te reo Māori term used to denote placement of a stick, bent at the top to indicate the site where a rangatira died, thus designating the location tapu (Williams 2001: 36). Thus 'Hara nui' may indicate the site where a prominent rangatira died (T. White, pers. comm., 23 November 2021). Subsequently the island has been variously referred to as 'Otainui' or 'Ngārango Otainui', which could refer to a species of blowfly ('Ngāro rango' or 'Ngārango', see Williams 2001: 230),

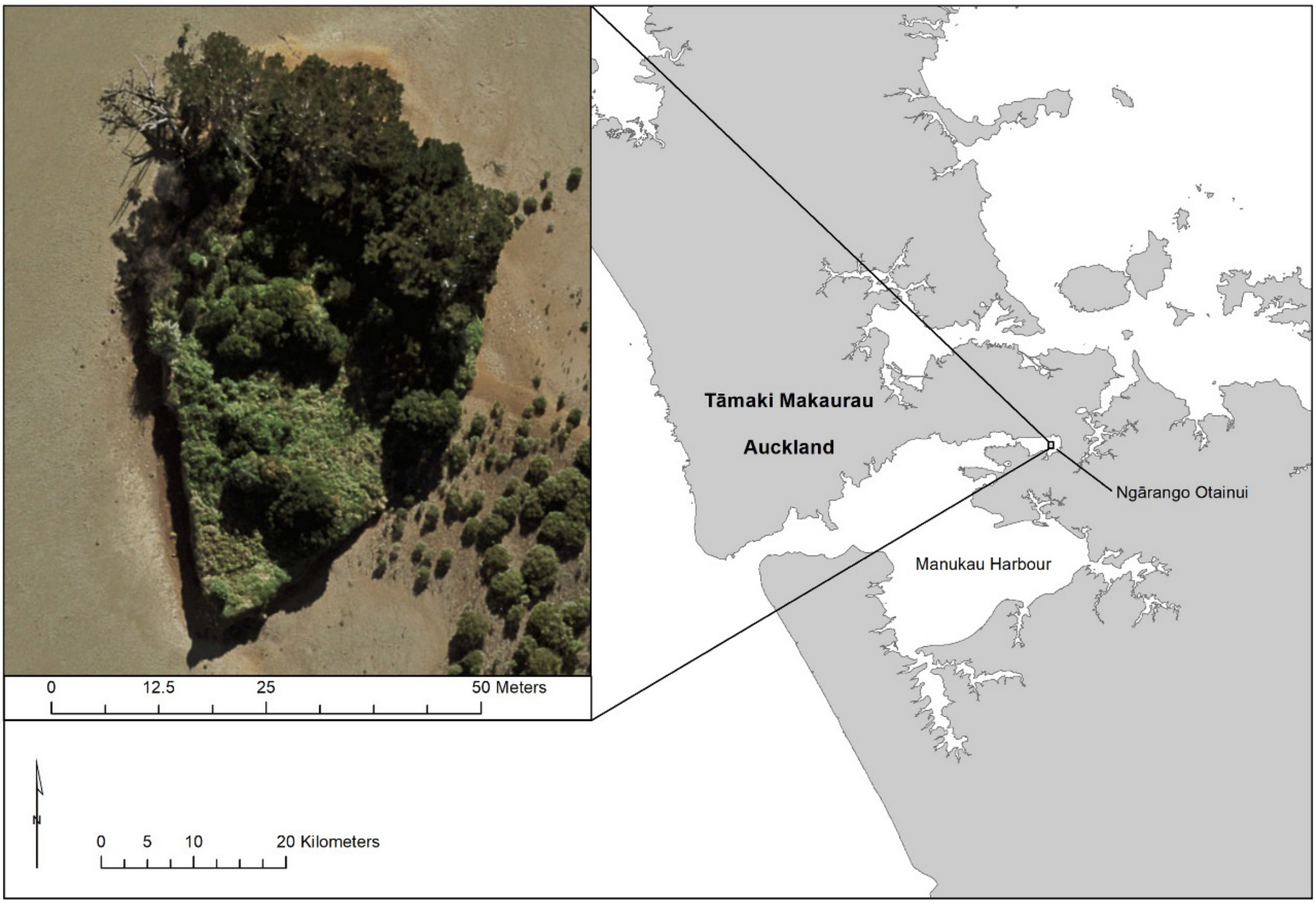

Figure 1. Location of Ngārango Otainui, Mangere Inlet, Manukau Harbour, Auckland. Aerial image courtesy of Land Information New Zealand (Eagle Technology, Land Information New Zealand).

while 'Otainui' may relate to the passage of the Tainui waka, which was hauled across the Tāmaki isthmus via Te Tō Waka and relaunched in the Māngere Inlet of the Manukau near the island (Rāwiri 2005); hence, the island name may in some way refer to a prophetic or spiritual blowfly associated with that waka, e.g, 'Ngārango o Tainui'. However, as with most Māori place names, the exact meaning without knowledge of the context in which it was given is open to speculation. We may never know the reason for the island's Māori name, nor why Hochstetter (1859, published in 1864) called it 'Hara nui' and it is now known as 'Ngārango Otainui'.

Ngārango Otainui captured public imagination when on 15 February 2016 the privately owned island was put up for sale, touted then as "one of New Zealand's smallest islands" (Gibson 2016), and soon purchased by Arzan Hajee and Arif Hajee who, it seems, then transferred it to the crown, who now hold the land "for roading purposes" (https://map.grip.co.nz/ [accessible cadastral information]).

Despite its proximity to land (Figure 1), it would seem that the island's vegetation and flora has never been documented. We can find no mention of it in the seminal works and notebooks of pioneering Auckland botanists Thomas Kirk, Thomas Cheeseman, Lucy Cranwell or Donald Petrie (who lived his last decade or so in Onehunga within sight of the island [Cockayne 1926]). Indeed, prior to our visits on 7 February 2009 (P.J. de Lange), 23 January 2021 (P.J. deLange & A.J. Marshall) and 6 November 2021 (P.J. deLange, A.J. Marshall, L.M.H. Schmid and S. Graham) we could find only one herbarium specimen, a collection of *Gladiolus ×hortulanus* made by Rhys O. Gardner from the island on 25 March 2001. We have seen no published observations about the island in regional botanical society literature either.

Ngārango Otainui, our field work and research soon disclosed, is an island that has developed from the open fernland / grassland evident in aerial imagery during the 1940s to an island supporting a flora and series of vegetation associations dominated by naturalised plants. This flora appears to have mostly colonised the island through dispersion from the adjacent urban landscape of Auckland. Despite this intriguing vegetation, we also discovered that the island is, as past owner Stan McCloskey stated, “slowly washing away” (Gibson 2016, see also discussion below). This paper is timely, then, as it brings together for the first time the geology, biota and vegetation of Ngārango Otainui, an island which, to quote Stan McCloskey, “won’t be there in 20, 30, 40 years’ time” (Gibson 2016).

Geology and physiography

Ngārango Otainui (Figure 2) is aligned north to south, almost in the shape of an inverted isosceles triangle, c.46 m wide at its widest point at the northern end of the island and 5 m wide at the southern end. The highest point on the island, on the cliffs at the north-western end, we estimated at 4 m a.s.l.; the lowest point, c. 1.5 m a.s.l., is located midway along the eastern side of the island. The margins of the island are mostly sharply delineated by cliff faces (Figure 3), with those on the western side actively eroding. Otherwise the surface of the island is more-or-less flat though gradually sloping south east from the high point on the western cliffs to the lowest point on the eastern side of the island. In fact, at the time of our last visit (November 2021), at the south-western end of the island, ongoing coastal erosion had nearly undermined the sole pōhutukawa (*Metrosideros excelsa*[1]) on the island (Figure 5), and sometime between 2007 and 2009 (based on aerial imagery), erosion had caused a massive pine (*Pinus radiata*) growing at the north-western end of the same cliffs to topple into the sea (Figure 4). Material eroded from this side of the island is in part what has built up the small beach and mangrove (*Avicennia marina* subsp. *australasica*) covered bar on the eastern side of the island (Figure 1).

Kermode (1992) mapped the island as Puketoka Formation, though it is not clear whether he surmised this or based his decision on an actual field inspection. The Puketoka Formation is part of the Holocene-aged Tauranga Group (Kear & Schofield 1978; Edbrooke et al. 2001), which as interpreted by Kermode (1992) encompasses a range of lithologies including lignite beds, rhyolitic ignimbrites, tephra, peat, conglomerates and carbonaceous mudstone (see comments by Hayward

Figure 2. Ngārango Otainui, as seen at low tide from the southern end looking north. Photo: Peter J. de Lange.

Figure 3. Western cliff face of Ngārango Otainui showing Hamilton Ash sequence overlying distal ignimbrite (Puketoka Formation). Photo: Peter J. de Lange.

Figure 4. Remains of two pines (*Pinus radiata*), probably originally planted ones that had fallen into the sea as a result of ongoing erosion of the western side of Ngārango Otainui. Photo: Peter J. de Lange.

[1] Authorities for all taxa present on Ngārango Otainui, unless otherwise mentioned, are provided in Appendices 1 and 2.

Figure 5. Coastal erosion of western cliff face, southern end of Ngārango Otainui, undermining the only known pōhutukawa (*Metrosideros excelsa*) on the island. Photo: Peter J. de Lange.

& Grenfell 2010). The western shoreline of the island is delineated by a prominent c.4 m high cliff face that exposes a complete sequence from low-tide mark to the vegetated island surface (Figure 3). The basal layer comprises c.1–1.2 m of heavily weathered, greyish, finely pumiceous / siliceous clay (Figures 6A, 6B), which is distinctly gritty in the hand (interpreted here as a heavily weathered distal ignimbrite). This layer is riddled with numerous vertical holes of varying diameter (some 30 mm diameter, others 10 mm diameter), the margins of which are stained brown or in places occluded with ligneous material (Figure 6A). These we suspect may be the remains of the roots of a former vegetated surface rather than mud crab (*Austrohelice crassa* [Dana, 1851]) burrows, as during all visits no mud crabs were seen either around the island or in any of the holes, several of which were dug out for critical inspection. Above this layer there is a c.1 m thick layer of blocky greyish-orange clay, which in turn is overlaid by a c. 1.5 m series of horizontally layered dark red, red-brown and pale yellow-white bands (Figure 3). This last layer has been identified by David J. Lowe (pers. comm. 2021) as Hamilton Ash. Above the Hamilton Ash a shallow, brown-black, friable soil has developed.

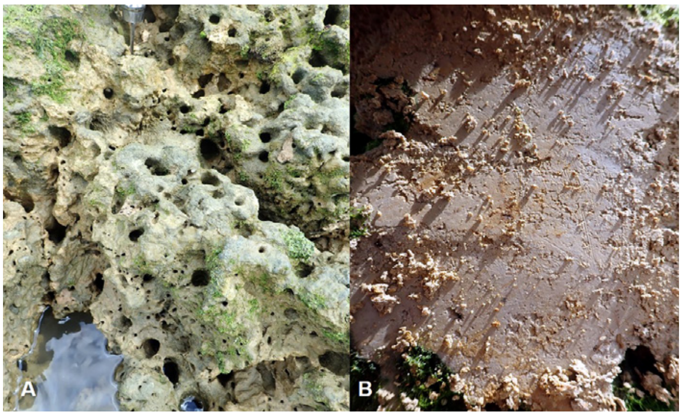

Figure 6. Basal geology of Ngārango Otainui, interpreted here as part of the Puketoka Formation showing **A**, the heavily weathered, siliceous clay assumed to be a distal ignimbrite, pitted with numerous larger vertical holes (former tree roots?) and covered with the green alga, *Ulva compressa*; **B**, portion cleared by knife to expose the unweathered pale greyish, siliceous clay. Photos: Peter J. de Lange.

Methods

Ngārango Otainui was visited by the authors on three occasions between 2009 and 2021 (see introduction above). Detailed observations of the geology, vegetation, fauna, flora, fungi and lichenised mycobiota were made during the two 2021 visits, and that data collated for this paper. Collections made were lodged in AK and UNITEC herbaria (herbarium acronyms follow Thiers 2008–onward). Taxa observed are arranged taxonomically by family as follows: Alga (Nelson 2013; Wilcox 2018), Bryophytes (Söderström et al. 2016 [hornworts, liverworts]; Crosby et al. 1999 [mosses]), Gymnosperms (World Flora online, http://www.worldfloraonline.org/), Pteridophytes and Flowering Plants (APG II-IV; PPG 1), Fungi (Mycobank, https://www.mycobank.org/page/Home), Lichenised Mycobiota (Kraichak et al. 2018) and Avifauna (Gill et al. 2010).

Vegetation associations were distinguished using the vegetation classification system of Atkinson (1985). The exception to his definitions is that the designation 'forest' is based on the height of the dominant plant (5 m tall or more) as well as the presence of a clear trunk devoid of branches.

Observations of vegetation succession and island erosion over time were made using images stored on Retrolens (https://retrolens.co.nz/) and a geospatial analysis performed using ArcMap 10.7 (https://www.esri.com/en-us/arcgis/products/arcgis-desktop/resources). To gauge the rate of erosion, a geospatial analysis was performed using a combination of historical imagery obtained from Retrolens (https://retrolens.co.nz/), LINZ (https://www.linz.govt.nz/) and Google Earth. The Retrolens imagery was orthorectified using ArcGIS (https://www.arcgis.com/index.html) to obtain a realistic view of the island's historical size so that the rate of erosion could be calculated.

Results

Flora and mycobiota

A total of 125 taxa from 57 families and 100 genera were recorded from Ngārango Otainui (Appendix 1). Fifteen of the families and 41 of the genera present on the island are also only represented by naturalised taxa. Three species appear to have been deliberately planted, e.g., pōhutukawa. Of these, naturalisation from plantings has occurred with pines. In total 119 (95%) of those taxa recorded here are supported by herbarium vouchers lodged in AK and UNITEC. The collections comprise: two seaweeds, 14 bryophytes (three liverworts and 11 mosses), one pteridophyte, one gymnosperm, 75 flowering plants, six fungi and 20 lichens.

Marine algae, as the unstable nature of the island substrate and turbidity of the surrounding water reflect, are poorly represented. We found three seaweeds on the ignimbritic material comprising the basal portion of the island's cliff faces. The most common of these is *Ulva compressa* (Figure 7), a species that coats the island's cliffs faces from where they make contact with the estuary surface to the high tide mark, and in shaded sites, on the eastern side of the island, admixes with saltmarsh vegetation, notably *Isolepis cernua* var. *cernua*. Along the southern portion of the island cliffs, often growing in 'root holes' (see Geology and Physiography above) we noted the red seaweed *Caloglossa vieillardii* (Figure 8). During the November 2021 visit we also noted small specimens of *Ulva* sp. 1 (Nelson 2013; Wilcox 2018), an as yet unnamed species that is seasonally common during the summer months around Onehunga, where, on account of its growth and smell when rotting, it often causes problems (see https://www.scoop.co.nz/stories/AK0509/S00112/techniques-trialled-to-clean-up-onehunga-bay.htm). Within the mangroves during the January 2021 visit, occasional specimens of Neptune's necklace (*Hormosira banksii*) were observed festooning the bases of mangrove pneumatophores.

A bryophyte flora of 14 taxa was noted on the island. Three liverworts – two corticolous species,

Figure 7. *Ulva compressa* growing on assumed distal ignimbrite at and below high tide mark. Photo: Peter J. de Lange.

Figure 8. *Caloglossa vieillardii,* a red seaweed commonly seen at and just below the high tide mark on the cliff faces of Ngarango Otainui. Photo: Peter J. de Lange.

Frullania fugax and *Siphonolejeunea nudipes* var. *nudipes*, and one terricolous species – *Chiloscyphus semiteres* var. *semiteres* (Figure 9) were noted. Of these, the *Chiloscyphus* was noted occasionally within open ground in grassland, whilst *Siphonolejeunea* was common on the bark of karo (*Pittosporum crassifolium*) and pine. Eleven mosses, four of these naturalised, were noted. None were common, and most grew on exposed soil or decorticated semi-decayed branches within open ground in grassland, or under pines. The naturalised species, *Eurhynchium praelongum*, *Fissidens bryoides*, *F. taxifolius* and *Pseudoscleropodium purum*, are common weedy species of urban habitats, lawns especially, and grassland (Beever 2014; Fife 2020). Two of them, *Fissidens taxifolius* and *Pseudoscleropodium purum*, spread solely by vegetative means (Beever et al 1992; Beever 2014; Fife 2020) so we assume their presence on the island relates to accidental introduction by island visitors, or possibly dispersal by birds, perhaps as nesting material.

The terrestrial flora and lichen composition of the island is typical of successional vegetation of urban Auckland, with 56 (59%) species of naturalised plants and 39 (40%) considered indigenous, and one indigenous species, pōhutukawa, planted. Of those naturalised species, onion twitch (*Arrhenatherum elatius* subsp. *bulbosum*), moth vine (*Araujia sericifera*) and tree privet (*Ligustrum lucidum*) are the main contributors to the island's vegetation associations. Pines, which have naturalised from what appears to have been five deliberately planted trees, by virtue of their size tower over the other vegetation and so dominate the skyline of the northern third of the island. Indigenous plants, with the exception of mangrove, are mostly uncommon on the island. Only bracken (*Pteridium esculentum*), plume grass (*Pentapogon crinitus*), tutu (*Coriaria arborea* var. *arborea*) (Figure 10) and tororaro (*Muehlenbeckia complexa* var. *complexa*) are common. One species, whau (*Entelea arborescens*), a specimen of which was collected in 2009, is now absent, a further 17 vascular plants are uncommon, and four species, wiwi (*Ficinia nodosa*), *Machaerina juncea*, pōhutukawa and *Suaeda novae-zelandiae*, are known from single plants.

Figure 10. *Coriaria arborea* var. *arborea*, one of the few common indigenous plants seen on Ngārango Otainui. Photo: Peter J. de Lange.

Figure 9. *Chiloscyphus semiteres* var. *semiteres*, the most common of three liverworts noted on Ngārango Otainui, was noted growing in open ground within onion twitch (*Arrhenatherum elatius* subsp. *bulbosum*) grassland. Photo: Peter J. de Lange.

The lichen mycobiota is by and large poorly developed. We noted only one terricolous lichen, *Cladonia confusa*, confined to one site of bare earth exposed on the north-western cliff top. The otherwise dense grassland probably prohibits the growth of *Cladia* Nyl. and other *Cladonia* P.Browne, genera that are common throughout

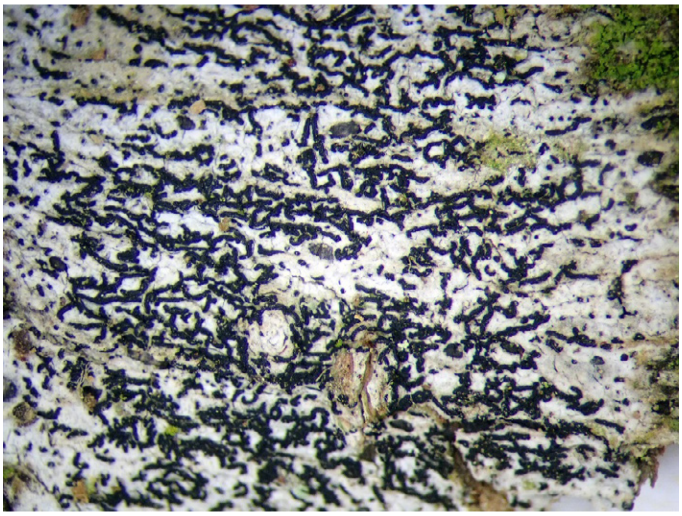

Figure 11. *Arthonia atra*, a common graphid lichen on privet (*Ligustrum lucidum*) and tutu (*Coriaria arborea* var. *arborea*) on Ngārango Otainui. Photo: Peter J. de Lange.

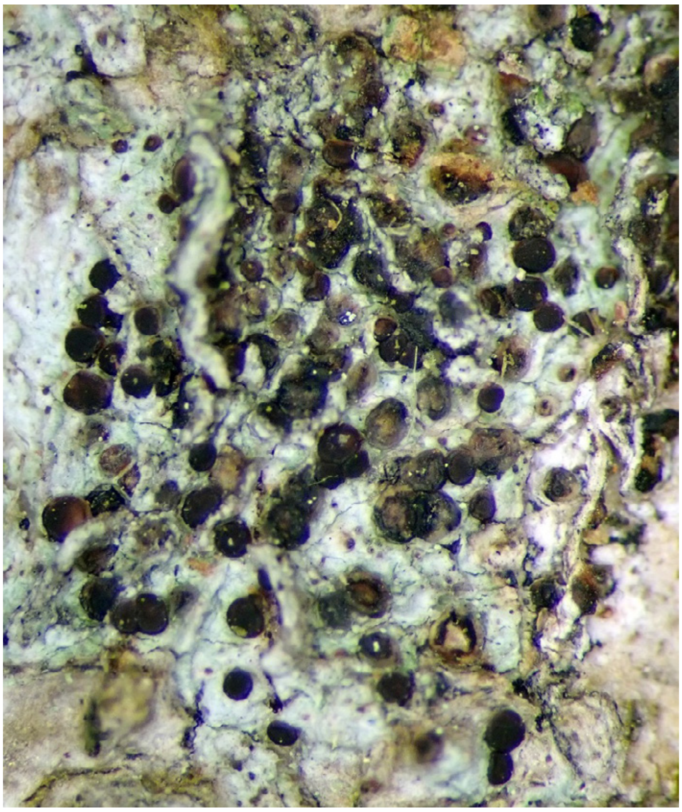

Figure 12. *Bacidia leucothalamia*, a common dot lichen on privet (*Ligustrum lucidum*) and tutu (*Coriaria arborea* var. *arborea*) on Ngārango Otainui. Photo: Peter J. de Lange.

Auckland on bare earth and rock, while the friable, easily eroded cliff faces seem to prevent the development of crustose taxa. Corticolous and foliicolous lichens are present, with corticolous taxa dominating; though even then, few are well developed, and conspicuous coastal-forest-, shrubland- and open-grassland-dwelling Auckland foliose genera such as *Crocodia* Link and *Pseudocyphellaria* Vain. are absent, while others such as *Parmotrema* are poorly developed. The most commonly seen corticolous lichens on Ngārango Otainui are those usually found on exposed bark in coastal situations around Auckland, e.g., *Heterodermia speciosa* and *Ramalina celastri*. Crustose lichens, though common on some phorophytes, are mostly poorly developed and sparingly fertile. Of those seen, only *Arthonia atra* (Figure 11), *Bacidia leucothalamia* (Figure 12) and *B. wellingtonii* were common, and these only on tree privet, tutu, pine bark and cones, while the mangroves, which colonised the eastern side of the island about 16 years ago (see below), are as yet too young to support the lichen diversity seen on older trees (Reynolds et al. 2017).

Non-lichenised mycobiota appear to be poorly represented on the island. However, we suspect a more dedicated survey during a range of seasons may find further fungi. Of the seven seen during our surveys, five are rust fungi, a group of fungi that while easily overlooked due to their diminutive size are often widespread and common; another, *Ramularia helminthiae*, is a leaf-spot fungus that is usually found where its host, oxtongue (*Helminthotheca echioides*), is established. The only other fungus, a species of *Russula* Pers., tentatively identified as *R. amoenolens* by J.A. Cooper (pers. comm., November 2021), was noted as a single, bird-damaged fruiting body emergent under a pine in the pine forest.

Avifauna

During the January and November 2021 visits to the island, observations were made of the near shore and island bird-life, recording 14 species over three hours on the island (Appendix 2). Of these, nine are indigenous, one of these migratory and the others naturalised. Karoro / black-backed gulls (*Larus dominicanus*) were the most commonly seen bird (13 individuals) flying around the island, but we saw no evidence of their using the island as a roost or nesting ground. The most commonly seen and heard bird on the island during the November 2021 visit were greenfinches (four seen).

The pines at the northern end of the island are used by matuku moana / white-faced herons (*Egretta novaehollandiae*), kāruhiruhi / pied shags (*Phalacrocorax varius*) and kōtuku ngutupapa / royal spoonbills (*Platalea regia*) for roosting, and in the case of the herons, nesting. We noted a few kotare / kingfisher (*Todiramphus sanctus*) nest holes near the apex of the north-western cliffs and one bird was seen near these. At the north-western end of the island near where a large pine had fallen into the sea, amidst a tangle of tororaro and pine branches, we also observed two mallard ducks (*Anas platyrhynchos*) resting up amongst the vegetation.

Despite the youth of the mangrove shrubland, the sole riroriro / grey warbler (*Gerygone igata*) noted during the November 2021 visit was observed moving across the island and then consistently out some 70 metres to the same area of mangrove. We suspect that the bird either had a nest there or was using the shrubland as a feeding habitat. Interestingly, the single pīpīwharauroa / shining cuckoo (*Chrysococcyx lucidus*) noted on the November 2021 visit was also noted in the mangrove shrubland site being frequented by the riroriro, also suggesting the mangrove was a nesting site.

Vegetation associations

Nine vegetation associations (and sparsely vegetated landforms) (Figure 13) were distinguished on the island. Seven of these are confined to the island, and two, sandy beach and mangrove shrubland, occupy the lee of the island. The extent of each association and landform is also provided.

1. Mangrove shrubland (10,668 m2) – indigenous vegetation association (Figure 14)

A low monospecific shrubland of mangrove, ranging from 1–2.5 m in height, c.20–100 mm dbh has developed since 2005 (based on aerial imagery) on the eastern side of Ngārango Otainui. In places, mangrove cover reaches 100%, though on the western flank cover drops to c.80%, leaving patches of mud and/or sparse Pacific oyster (*Magallana gigas* [Thunberg, 1793]) encrusted ground. As noted above, the trunks and branches of the mangroves, presumably because of their age (see Reynolds et al. 2017) support few lichens, and of those seen most had underdeveloped thallii. The most common lichens, which were confined to the branches and trunks of the older, taller, exposed mangrove only, are *Athallia cerinelloides* and *Lecanora carpinea*, otherwise lichen cover on the mangroves was sparse.

Figure 13. Vegetation associations and landforms of Ngārango Otainui as discussed in text. Coastal cliff vegetation is omitted from this figure because it is vertical and therefore cannot be seen in the base image. Base image courtesy of Land Information New Zealand (Eagle Technology, Land Information New Zealand).

2. Sandy beach (73 m2) – mixed indigenous / naturalised vegetation (Figure 15)

A small sandy beach of reddish pumiceous sand and yellow clay, which developed following the expansion of mangroves after c.2005, now delineates the north-western margin of the mangrove shrubland and island. The beach sand at high tide lies almost at water level, and in king tides would be completely immersed. Growing along the high tide mark within the sand were a few plants of orache (*Atriplex prostrata*), ureure (*Salicornia quinqueflora* subsp. *quinqueflora*) and one *Suaeda novae-zelandiae*. Mangroves are now rapidly colonising the beach margin to the extent that we expect this feature will soon vanish.

Figure 14. Mangrove (*Avicennia marina* subsp. *australasica*) shrubland. Photo: Peter J. de Lange.

3. Saltmarsh (71 m2) – indigenous vegetation association (Figure 16)

On the eastern side of the island, in places where a small wave-cut terrace has developed or colluvium or clay / sand has accumulated, there is a narrow band of sparse halophytic vegetation that we collectively refer to here as 'saltmarsh'. This vegetation varies with the degree of exposure, shade and, presumably, the stability of the substrate. In the open, most exposed, and actively eroding south-eastern point of the island, this vegetation is dominated by coastal immorality grass (*Austrostipa stipoides*), a species that also occurs as isolated tussocks higher upslope on the friable Hamilton Ash sequence overlying the carbonaceous clay (see Geology and Physiography above). Further along this shoreline in more sheltered sites, this grass is replaced by mākoako (*Samolus repens* var. *repens*) and *Isolepis cernua* var. *cernua*, and in one place a small patch of ureure. In one site, just above the high tide mark, a few tussocks of *Carex flagellifera* are also present. It is notable that, with the exception of coastal immorality grass, the other species are so scarce on the island, when on the adjoining shore of the Manukau they are extremely common. Unusual, too, is the absence of *Goodenia radicans* (Cav.) Pers. and *Apium prostratum* subsp. *prostratum* var. *filiforme* (A.Rich.) Kirk., which are commonly seen in association with mākoako and the *Isolepis* and common saltmarsh plants of the nearby shoreline.

Figure 15. Portion of sandy beach seen here during extreme high tide (6 November 2021). Photo: Peter J. de Lange.

4. Coastal cliffs (235 m) – mixed indigenous / naturalised vegetation (Figure 3)

Cliffs encircle the island, and as they are the product of ongoing erosion they are only sparsely vegetated, by coastal immorality grass (south-eastern and southern

Figure 16. Saltmarsh vegetation, eastern side of Ngārango Otainui, showing in this case patches of mākoako (*Samolus repens* var. *repens*), *Isolepis cernua* var. *cernua*, and *Ulva compressa* are threaded. Photo: Peter J. de Lange.

Figure 17. Onion twitch (*Arrhenatherum elatius* subsp. *bulbosum*) grassland. Photo: Peter J. de Lange.

end of island only), and at their tops with dense tangles of tororaro, pōhuehue (*Calystegia sepium* subsp. *roseata*) and, in places, moth vine. At the south-western end of the island a single 2 m tall pōhutukawa, which seems to have been planted sometime around 2014 (based on aerial imagery), grows at the cliff apex.

5. Onion twitch grassland (486 m2) – naturalised vegetation association (Figure 17)

Judging by image coverage, grassland of unknown composition has covered at least 70% of the island and was the dominant vegetation until sometime after 2014, when tree privet, tutu and bracken increased their extent. Onion twitch grassland is in places up to 1.5 m tall. Other than onion twitch, other, usually minor, associates include prairie grass (*Bromus catharticus*), cocksfoot (*Dactylis glomerata*), *Carex divulsa*, oxtongue, scotch thistle (*Cirsium vulgare*) and occasional *Carex flagellifera*. In places, notably along the south-western cliff face, plume grass can be locally abundant, such that it almost warrants recognition as a further vegetation association, i.e., onion twitch / plume grass grassland. Along the eastern side of this grassland, other minor associates include *Gladiolus* spp., pōhuehue, *Haloragis erecta* subsp. *erecta*, three species of lotus (*Lotus angustissimus*, *L. pedunculatus* and *L. suaveolens*), narrow-leaved plantain (*Plantago lanceolata*), herb Robert (*Geranium robertianum*), sowthistle (*Sonchus oleraceus*) and young vines of blackberry (*Rubus ulmifolius*). In the southern third of the island, onion twitch grassland grades into bracken / onion twitch fern / grassland described below.

6. Bracken / Onion twitch fern / grassland (463 m2) – mixed indigenous / naturalised vegetation association (Figure 18)

The main vegetation association in the southern third of the island is one in which almost equal amounts of bracken and onion twitch grow, forming tangles up to 1 m tall. Judging from aerial imagery, it seems that bracken is in the process of outcompeting onion twitch, and that given time it will replace the onion twitch grassland described above. This vegetation has a similar assemblage of associated species to onion twitch grassland except for the local dominance of Buffalo grass (*Stenotaphrum secundatum*), especially toward the southern end of the island, and presence of tororaro and King Island melilot (*Melilotus indicus*) near the eastern cliffs.

7. Tree privet forest (1044 m2) – naturalised vegetation association (Figure 19)

Tree privet forest occurs as two bands running northwest to southwest across the middle of the island, in places forming a canopy 5 m tall. Although dominated by tree privet, karo (*Pittosporum crassifolium*) and tutu are a local component of this forest, especially toward the western cliffs where tutu is more common. Near the eastern margin of the privet forest are two 3 m tall loquat (*Rhaphiolepis bibas*), a third, a sapling, grows under the privet near the western side of the island. On the eastern side of the southern-most privet forest association, there grow as canopy emergents a single monkey apple (*Syzygium smithii*), and scattered karamu (*Coprosma robusta*), coastal karamu (*Coprosma macrocarpa* subsp. *minor*) and hybrids between them. This forest has a dense subcanopy of privet, karo and occasional karamu. Threaded through this, and sometimes reaching the canopy, are tangles of moth vine and tororaro. These vine tangles are especially well developed along the southern and western fringes of this forest association, where they sometimes extend out into the bracken / onion twitch fern / grassland. The ground layer is usually devoid of plant cover; however, in a few places *Microlaena stipoides* may be present, and other occasional associates include *Geranium homeanum* and herb Robert.

8. Pine forest (1109 m2) – naturalised vegetation association (Figure 20)

Pine trees, undoubtedly the majority planted, are a feature of the island. There are two very large, multi-trunked trees c.10–14 m or so in height, with a canopy spread of 10 or more metres and trunk diameters up to 85 cm dbh. Aside from these two, and in association with them, there are a further 29 smaller trees, saplings and seedlings, and collectively they form a forest occupying about a third of the island. The canopy of the trees is a major nesting site for matuku moana / white-faced heron and a roost for kōtuku ngutupapa / royal spoonbill, resulting in a guano build-up around some of the larger trees. Structurally, this forest is less dense than the adjoining tree privet forest, the subcanopy comprising scattered tree privet, karo saplings and trees up to 6 m tall. Through these trees and forming scrambling tangles on the forest floor are occasional patches of moth vine, blackberry and tororaro, and sparse patches of prairie grass, *Bromus sterilis*, *Microlaena stipoides*, and *Fumaria muralis*. However, much of the ground layer is devoid of vegetation, being mostly covered in dense

Figure 18. Bracken (*Pteridium esculentum*) / Onion twitch fern / grassland. Photo: Peter J. de Lange.

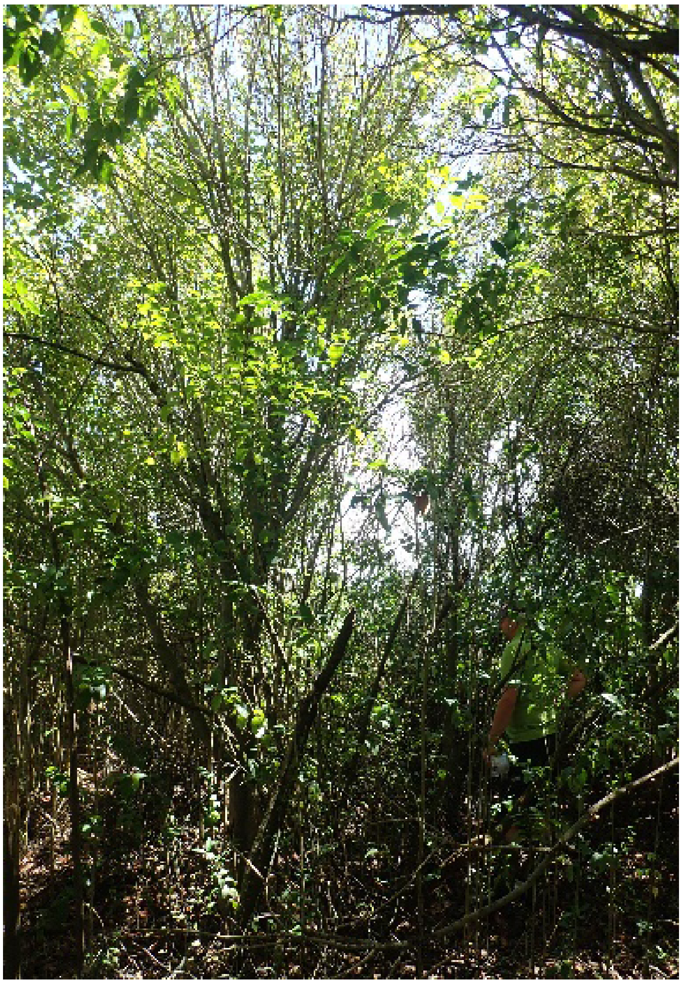

Figure 19. Tree privet (*Ligustrum lucidum*) forest. Photo: Peter J. de Lange.

Figure 20. Pine (*Pinus radiata*) forest. Photo: Peter J. de Lange.

Figure 21. Sand brome (*Bromus arenarius*) growing with *Microlaena stipoides*. Photo: Peter J. de Lange.

drifts of pine needles but also open because of deliberate cutting of saplings by people. We assume people camp here from time to time, as we found hidden away in a series of black plastic bags a carefully folded tent, and a large plastic bottle of fresh water. Though sheltered, the guano rain from the nesting herons and other roosting birds would make for an interesting camping site.

Discussion

There are 13 islands and islets within the Manukau Harbour. Prior to this investigation, the flora and vegetation of only three, Kauritutahi (Cameron 1996), Orona (Cameron 2008) and Kopuahingahinga (Hall 2011) have been documented. Ngārango Otainui, the fourth to be so covered, is in our view remarkable in that, unlike the others, it is located adjacent to a major metropolitan area (Onehunga, Mangere, Southdown) and yet we could find no documentation of the island's biodiversity prior to this publication.

Below we provide some summary points about notable taxa, vegetation succession and patterns, pest species and the ongoing rate of erosion of Ngārango Otainui.

Threatened and At-Risk Species

None of the biota recorded from Ngārango Otainui qualify as 'Threatened' using the New Zealand Threat Classification System (Townsend et al. 2008). However, nine are listed as 'At Risk' using that system and these are noted as follows.

Flora

From our combined visits we report a Flora of 80 vascular plants, 14 bryophytes, four seaweeds, six fungi and 19 lichenised mycobiota. Fifty-two (65%) of the vascular plants and four (36%) of the bryophytes are naturalised to New Zealand and most of these dominate the island's vegetation.

Only one plant recorded from Ngārango Otainui, sand brome (*Bromus arenarius*) (Figure 21), has a national conservation status of 'At Risk / Naturally Uncommon' (de Lange et al. 2018a). A strict annual, this species has a close association with sea-bird nesting sites in the northern North Island and the Chatham Islands, where it is usually found on small offshore islands. On Ngārango Otainui, a few plants were found growing in guano, under pines associated with *Microlaena stipoides*. Sand brome, though locally common on many of the islands of the Hauraki Gulf (de Lange & McFadden 1995; de Lange & Crowcroft 1996), has hitherto not been collected from the western coastline of Auckland or the coastline, islands and islets of the Manukau Harbour.

Lichenised mycobiota

Five lichens found on Ngārango Otainui have been listed by de Lange et al. (2018b); four (*Arthonia atra* [Figure 11], *Bacidia leucothalamia* [Figure 12], *Fissurina inquinata* [Figure 22] and *Graphis elegans*) as 'At Risk / Naturally Uncommon', and one, *Chrysothrix xanthina* (Figure 23), as 'Data Deficient'. Of these, the *Arthonia* and *Bacidia* are common on the island, as, judging by recent collections lodged in UNITEC, seems also to be the case elsewhere around New Zealand. Both species would probably be more appropriately listed as 'Not Threatened' using the New Zealand Threat Classification System (Townsend et al. 2008). The *Fissurina* and *Graphis* are also more widespread than had been believed, but probably still warrant their current conservation status. Similarly, *Chrysothrix xanthina* at the time the current lichen threat listing was being prepared (2017) was then known from just one New Zealand collection (Elix & Kantvilas 2007); since 2018, dedicated collecting of the genus throughout New Zealand has found that species to be the most common of the five *Chrysothrix* Mont. species now believed to be in the country (P.J. de Lange, unpublished data).

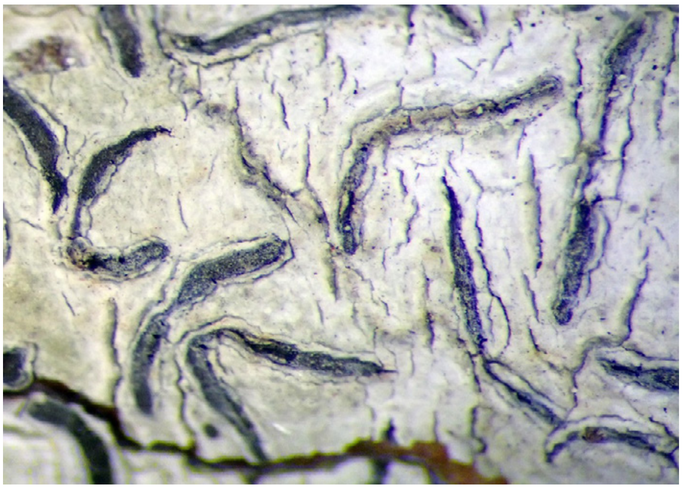

Figure 22. *Fissurina inquinata*, a graphid lichen, and one of four lichens listed as 'At Risk / Naturally Uncommon' (de Lange et al. 2018b) found on Ngārango Otainui. Photo: Peter J. de

Figure 23. *Chrysothrix xanthina,* a yellow powder lichen listed as 'Data Deficient' (de Lange et al. 2018b), was noted only on the bark of pine (*Pinus radiata*) on Ngārango Otainui. Photo: Peter J. de Lange.

The presence of these species on Ngārango Otainui is not in itself singular or especially noteworthy; rather it reflects the fact that there are still very few active field-based lichenologists collecting throughout New Zealand. Our knowledge of the extent of our lichenised mycobiota, and abundance of taxa within that, is still in its infancy, and this hampers accurate conservation assessments (de Lange et al. 2018b).

Avifauna

Three indigenous birds seen on or near Ngārango Otainui are listed by Robertson et al. (2017) using the New Zealand Threat Classification System (Townsend et al. 2008): kāruhiruhi / pied shags ('At Risk / Recovering'), kōtuku ngutupapa / royal spoonbill ('At Risk / Naturally Uncommon) and tara / white-fronted tern ('At Risk / Declining'). None of these birds are confined to the island, though the shag and spoonbill use the vegetation of the island as a roost.

Vegetation assemblage, succession and patterns

Aerial imagery dating back to 1940 indicates that the island was once covered in low grass and bracken fernland, a state in which it remained until sometime between 1988 and 1994 (aerial imagery is absent between these years), when pines, initially probably planted, appeared on the island. As judged by past aerial imagery the island is now better vegetated than it was in 1940, notably now supporting forest and shrubland. We suspect this development was driven by the ongoing erosion of the island's western side causing landowners to undertake plantings (Gibson 2016).

On 25 March 2001, when the island was visited by Rhys Gardner and Brent Maxwell, they noted that pines, onion twitch grassland and bracken fernland (through which they recorded tangles of *Muehlenbeckia*), dominated the island vegetation, collectively estimated by them to cover   of the island. Scattered through this vegetation they observed 1–1.2 m tall tutu. Nearer the coast and on the cliffs, they observed masses of moth vine, and in places considered pōhuehue to be abundant. Notably, they reported a few small bushes of tree privet (these up to 2 m tall), and recorded local occurrences of tree tobacco (*Solanum mauritianum* Scop.), and a *Brassica* L. sp. – two taxa not seen in the 2009 and 2021 visits. They saw no mangroves around the island. Unfortunately, their listing for the island, though detailed, was not sufficiently comprehensive to allow us to undertake meaningful species composition and vegetation association between visits.

Nevertheless, the 2021 situation, 20 years later, is drastically different. Grassland now covers 29% of the island, while privet has coalesced to form a distinct forest association. This forest merges at the northern end of the island into the pine forest and collectively these two forest associations now occupy 66% of the island, the rest being saltmarsh and beach (mangroves omitted). Mangroves now dominate the mudflats immediately east of the island.

Despite the improved forest cover, the youth of the island's woody vegetation is reflected by the island's flora and mycobiota, which has a low diversity and near absence of a range of taxa typical of Auckland coastal habitats. For example, the presence of just one pteridophyte, bracken, is notable, especially as the adjacent coastline, though highly modified, supports a range of ferns, including the terrestrial species *Doodia australis* (Parris) Parris, *Pellaea rotundifolia* (G.Forst.) Hook., *Polystichum neozelandicum* Fée, and *Pteris tremula* R.Br., all 'weedy' species common on the adjacent coastline that one would expect to see on the island. Notable, too, is the absence of *Pyrrosia eleagnifolia* (Bory) Hovenkamp and *Zealandia pustulata* (G.Forst.) Testo et A.R.Field subsp. *pustulata*, common epiphytic ferns of coastal forest and urban Auckland tree plantings. A similar pattern is evident in the bryophytes, only one liverwort, *Siphonolejeunea nudipes* var. *nudipes*, was considered common. This is a corticolous species preferring open successional woody vegetation, and which is abundant on urban trees throughout the Auckland Region. The lack of diversity in, and overall scarcity of, *Frullania* Raddi is also unusual; for example, one species common throughout Auckland, *F. pentapleura* Taylor, is absent from the island, we assume because of the lack of hard rock substrates – its preferred habitat in the region. Even *Frullania fugax*, common on pōhutukawa trees on the adjacent shoreline, is extremely uncommon on the island; we only saw it on pine trees, in places it would usually dominate elsewhere in the region. We can only assume, then, that it is a recent arrival to the island. Of the mosses seen, none were common, and most were confined to open ground within the onion twitch grassland. The absence of genera from the Bryaceae and Pottiaceae, which are common in similar habitats on the adjacent shoreline and Auckland City, is especially puzzling, as suitable habitat is common on the island, and these families are well represented on the adjacent shoreline.

The same paucity is evident in the lichenised mycobiota. Of the 20 species recorded, eight are considered abundant or common. The two abundant species, *Ramalina celastri* and *Xanthoria parietina*, are common throughout the Auckland Region, especially in coastal and urban habitats. On Ngārango Otainui, though abundant, *Xanthoria parietina* was restricted to the branches of dead or dying privet and the exposed trunks of pine. *Ramalina celastri*, while more widespread, was mostly present as small under-developed thalli. *Heterodermia speciosa*, though recorded as common, only formed large colonies on the larger privet and older pine trees. Other lichens, that are a feature of coastal and urban Auckland trees, such as species of *Amandinea* M.Choisy ex Scheird. et H.Mayrhofer, *Buellia* De Not., *Flavoparmelia* Hale, *Lepraria* Ach., *Pertusaria* DC., and *Usnea* Dill. ex Adans., were not seen. Lirelliate lichens, though present, were also mostly noted as small or poorly developed thalli. It has already been noted that the mangrove shrubland has a low diversity of lichens, with only two species, *Athallia cerinelloides* and *Lecanora carpinea*, common. Terricolous lichens, with the exception of a small colony of *Cladonia confusa*, are completely absent, which is unusual when compared with similar substrates and habitats on the adjacent shoreline, where species of *Cladia*, *Stereocaulon* Hoffm. and other *Cladonia* are common, if not abundant.

Collectively, we assume that these absences might be explained by the historical, probably human-induced, disturbance of the vegetation of Ngārango Otainui, the relatively recent development of woody vegetation and the ongoing erosion of the island cliffs (see below). We assume such disturbance has been considerable. As noted above, from 1940, when aerial images of the island

Pest plant (this paper)	Name used in Te kimi kīrearea Pest search (Tiaki Tāmaki Makaurau Conservation Auckland)
Allium triquetrum	*Allium triquetrum*
Araujia sericifera	*Araujia sericifera*
Asparagus asparagoides	*Asparagus asparagoides*
Carex divulsa	*Carex divulsa*
Gladiolus undulatus	*Gladiolus undulatus*
Ligustrum lucidum	*Ligustrum lucidum*
Osteospermum moniliferum subsp. moniliferum	*Chrysanthemoides monilifera*
Phytolacca octandra	*Phytolacca octandra*
Pinus radiata	*Pinus spp.*
Rhaphiolepis bibas	*Eriobotyra japonica*
Rubus ulmifolius	*Rubus fruiticosus agg.*
Stenotaphrum secundatum	*Stenotaphrum secundatum*
Syzygium smithii	*Syzygium smithii*
Watsonia meriana 'Bulbillifera'	*Watsonia meriana var. bulbillifera*

Table 1. Pest plants of the Auckland Region present on Ngārango Otainui. Taxa listed are those documented by the Auckland Council as pest plants (Tiaki Tāmaki Makaurau Conservation Auckland 2020).

are first available, the island has retained grass and fernland for close to 48 years before woody vegetation appeared on the island sometime around 1988.

What is notable about the islands is that the majority of the species forming the vegetation associations are naturalised to Aotearoa / New Zealand. Further, with the exception of three species that have been planted (and have spread or not), the other naturalised plants have colonised the island by natural dispersal from the adjacent mainland. Of these, it would seem that the majority (22 [42%]) of vascular plants present on the island are derived from bird dispersed (e.g., tree privet, bone seed [*Osteospermum moniliferum* subsp. *moniliferum*], *Carex divulsa*) or wind dispersed seed (e.g., moth vine, flea bane [*Erigeron sumatrensis*], sow thistle), with 12 vascular plants (23%), one moss and four fungi reaching the island in this way. At least two mosses, *Fissidens bryoides* and *F. taxifolius*, owe their origin to accidental transport to the island, either in soil or as a contaminant on footwear. It is also likely that one fungus, *Russula amoenolens*, an ectomycorrhizal species associated with pines (Cooper et al. 2022), was introduced when the pines were planted. Only a few species, notably wild gladiolus (*Gladiolus undulatus*) are likely to have colonised the island through saltwater dispersal. In a similar way, the majority of the indigenous plants are also derived from bird- and wind-dispersed seed. Only one indigenous plant, pōhutukawa, may have been deliberately planted, though it could also have naturally arrived from wind-dispersed seed, as this tree is common along the foreshore of the adjacent coast. Our supposition that it was planted is based on its 'sudden' appearance in aerial imagery after 2007.

Pest species

Fourteen of the plants currently present on the island (Table 1) are regarded as regional pest species in urban Auckland (Auckland Council 2020). Their presence on Ngārango Otainui is not considered singular, rather it reflects their abundance on the adjacent coastline and metropolitan area. In our view, as the vegetation of the island is helping reduce erosion, their control without carefully considered and well-timed replanting of other less invasive or indigenous plants would be unwise.

Two animal pest species were noted: a single rat – *Rattus* sp., black with a long tail so probably *R. rattus* (Linnaeus, 1758) – was noted running through the onion twitch grassland during the November 2021 visit, and a few garden snails (*Cornu aspersum* [O.F. Müller, 1774]) were seen. Considering the island's proximity to land, and the extent to which mudflats are exposed at low tide, the presence of rodents on the island is not unexpected. Similarly, as the island has undoubtedly been subjected to some plantings, the presence of garden snails, eggs and juveniles of which are common pot and soil contaminants, is not surprising either (see discussion on *Fissidens* mosses above).

Erosion

Our analysis of the rate of erosion revealed this to be very rapid, with the island losing over half (55%) its footprint between the first available image (1940) and the present day (Figure 24). The island has eroded at a roughly constant rate (Figure 25), although there was little change between 1962 and 1972, so 1972 imagery was not included in the analysis, which demonstrates the rate and location of erosion over the time of the analysis. Most of the material lost from Ngārango Otainui has been from its southwest coast, and as previously mentioned this has been deposited to the east, where a mangrove shrubland has since developed and is now rapidly expanding. Historical imagery reveals that mangroves were largely absent from the inlet where the island is situated, but have appeared in the past c. 40 years and will continue to spread as more material is deposited as a result of surrounding catchment land use

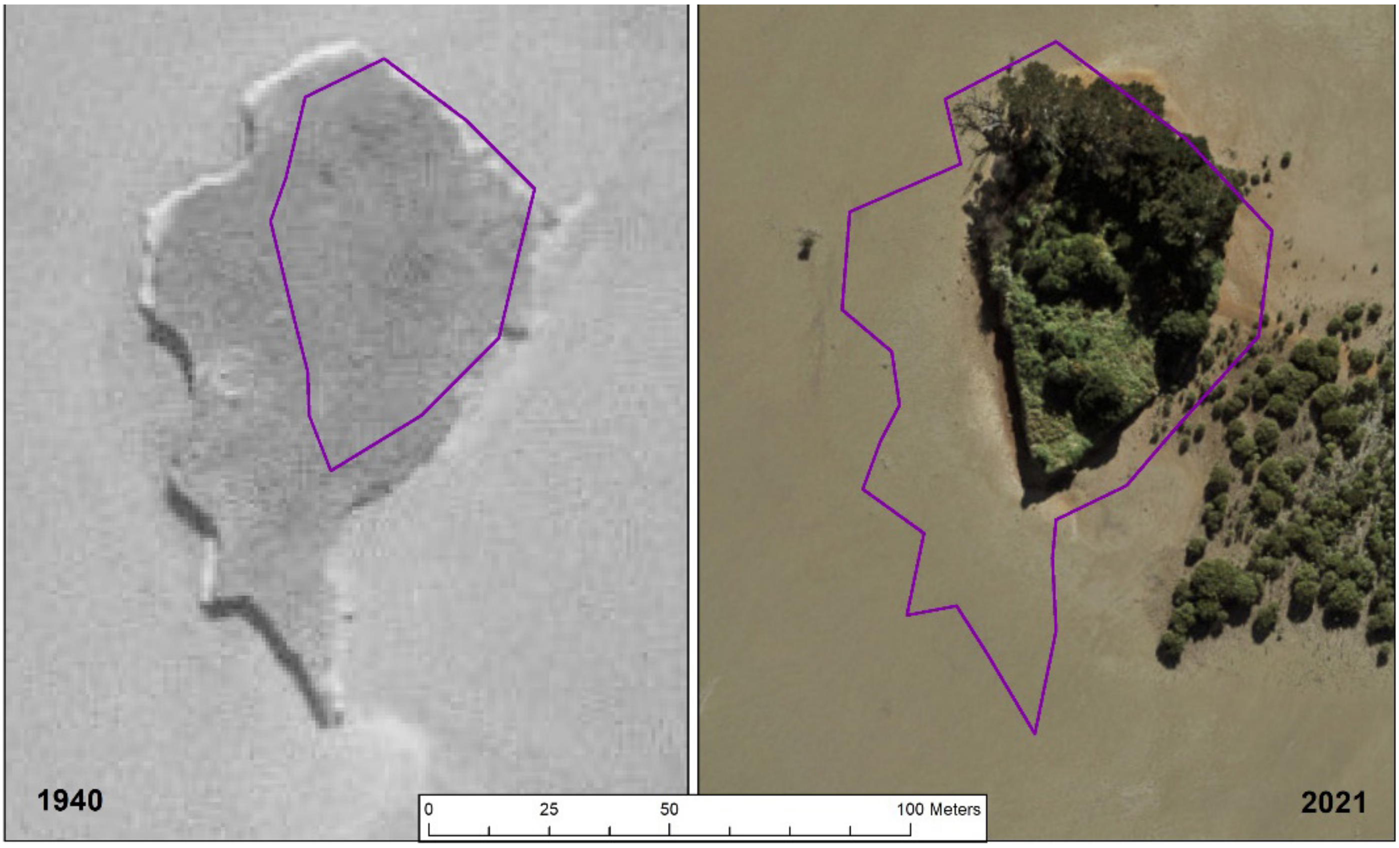

Figure 24. Extent of erosion of Ngārango Otainui gauged from when aerial images of the island first became available 1940. Base image courtesy of Land Information New Zealand (Eagle Technology, Land Information New Zealand).

Figure 25. Extent of erosion of Ngārango Otainui from 1940–2021. Base image courtesy of Land Information New Zealand (Eagle Technology, Land Information New Zealand).

and erosion of the island. Assuming the island continues to erode at the rate at which it has over the past 79 years, it will cease to exist by 2083, although there are myriad factors likely to affect the rate of erosion, so this estimate is vague at best.

While performing this analysis, the historical extent of the second island to the northwest was also calculated. In 1942 its footprint was larger than that of Ngārango Otainui (0.96 ha compared with 0.67 ha), although shadows on the imagery suggest it was much lower lying, and being – we assume – comprised of shells, more easily eroded, which may explain why this island had largely disappeared by 1972 (and had vanished altogether by 1985) while Ngārango Otainui has remained.

Acknowledgements

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APPENDIX 1: Flora and mycobiota recorded from Ngārango Otainui

*	denotes taxa naturalised to New Zealand
AK	Auckland War Memorial Museum Herbarium
UNITEC	Unitec Herbarium

	Family	Abundance	Voucher
Chlorophyta (2)			
Ulva compressa L.	Ulvaceae	abundant	
Ulva L. sp. 1.	Ulvaceae	uncommon	UNITEC 12921
Rhodophyta (1)			
Caloglossa vieillardii (Kützing) Setchell	Delesseriaceae	common	UNITEC 12922
Bryophytes (14)			
Liverworts (3)			
Frullania fugax (Hook.f. et Taylor) Gottsche. Lindenb. et Nees	Frullaniaceae	uncommon	UNITEC 12737
Siphonolejeunea nudipes (Hook.f. et Taylor) Herzog var. *nudipes*	Lejeuneaceae	common	UNITEC 12738
Chiloscyphus semiteres (Lehm.) Lehm. et Lindenb. var. *semiteres*	Lophocoleaceae	uncommon	UNITEC 12923
Mosses (11)			
Brachythecium rutabulum (Hedw.) Schimp.	Brachytheciaceae	uncommon	UNITEC 12931
**Eurhynchium praelongum* (Hedw.) Schimp.	Brachytheciaceae	uncommon	UNITEC 12924
**Pseudoscleropodium purum* (Hedw.) M.Fleisch.	Brachytheciaceae	uncommon	UNITEC 12927
**Fissidens bryoides* Hedw.	Fissidentaceae	uncommon	UNITEC 12925
**Fissidens taxifolius* Hedw.	Fissidentaceae	uncommon	UNITEC 12926
Hypnum cupressiforme Hedw. var. *cupressiforme*	Hypnaceae	uncommon	UNITEC 13007

Ptychomnion aciculare (Brid.) Mitt.	Ptychomniaceae	uncommon	UNITEC 12739
Ptychomitrium australe (Hampe) A.Jaeger	Ptychomitriaceae	uncommon	UNITEC 12928
Racopilum cuspidigerum var. *convolutaceum* (Müll.Hal.) Zanten et Dijkstra	Racopilaceae	uncommon	UNITEC 13008
Rhaphidiorrhynchium amoenum (Hedw.) M.Fleisch.	Sematophyllaceae	uncommon	UNITEC 12930
Sematophyllum homomallum (Hampe) Broth.	Sematophyllaceae	uncommon	UNITEC 12932
Pteridophytes (1)			
Pteridium esculentum (G.Forst.) Cockayne	Dennstaedtiaceae	common	UNITEC 12933
Gymnosperms (1)			
**Pinus radiata* D.Don	Pinaceae	common	UNITEC 12934
Spermatophytes (78)			
Monocots I (7)			
**Allium triquetrum* L.	Alliaceae	uncommon	UNITEC 12935
**Nothoscordum gracile* (Aiton) Stearn	Alliaceae	1 seen (2021)	UNITEC 12936
**Asparagus asparagoides* (L.) Druce	Asparagaceae	uncommon	UNITEC 12937
Phormium tenax J.R.Forst. et G.Forst.	Asphodelaceae	uncommon	UNITEC 12938
**Gladiolus undulatus* L.	Iridaceae	uncommon	UNITEC 13014
**Gladiolus ×hortulanus* L.H.Bailey	Iridaceae	uncommon	AK 254446
**Watsonia meriana* (L.) Mill. 'Bulbillifera'	Iridaceae	uncommon	UNITEC 13001
Monocots II – Commelinids (16)			
**Carex divulsa* Stokes	Cyperaceae	abundant	UNITEC 12939
Carex flagellifera Colenso	Cyperaceae	uncommon	UNITEC 12716
Ficinia nodosa (Rottb.) Goetgh., Muasya et D.Simpson	Cyperaceae	1 seen (2021)	UNITEC 12940

Isolepis cernua (Vahl.) Roem. et Schult. var. *cernua*	Cyperaceae	uncommon	UNITEC 12941
Machaerina juncea (R.Br.) T.Koyama	Cyperaceae	1 seen (2021)	
**Arrhenatherum elatius* subsp. *bulbosum* (Willd.) Schübl. et G.Martens	Poaceae	abundant	UNITEC 12942
Austrostipa stipoides (Hook.f.) S.W.LJacobs et J.Everett	Poaceae	uncommon	UNITEC 12943
Bromus arenarius Labill.	Poaceae	uncommon	UNITEC 12944
**Bromus catharticus* Vahl	Poaceae	uncommon	UNITEC 12945
**Bromus diandrus* Roth	Poaceae	uncommon	UNITEC 12946
**Bromus sterilis* L.	Poaceae	uncommon	UNITEC 12996
**Dactylis glomerata* L.	Poaceae	common	UNITEC 12947
Pentapogon crinitus (L.f.) P.M.Peterson, Romasch. et Soreng	Poaceae	common	UNITEC 12948
**Ehrharta erecta* Lam.	Poaceae	1 seen (2021)	UNITEC 12949
Microlaena stipoides (Labill.) R.Br.	Poaceae	uncommon	UNITEC 12950
**Stenotaphrum secundatum* (Walter) Kuntze	Poaceae	abundant	UNITEC 12951
Core Eudicots (55)			
Avicennia marina subsp. *australasica* (Walp.) J.Everett	Acanthaceae	abundant	UNITEC 12724
Salicornia quinqueflora Bunge ex Ung.-Sternb. subsp. *quinqueflora*	Amaranthaceae	uncommon	UNITEC 12952
Suaeda novae-zelandiae Allan	Amaranthaceae	1 seen (2021)	UNITEC 12953
**Araujia sericifera* Brot.	Apocynaceae	abundant	UNITEC 12954
Cotula coronopifolia L.	Asteraceae	uncommon	UNITEC 12955
**Cirsium vulgare* (Savi.) Ten.	Asteraceae	uncommon	UNITEC 12956
**Crepis capillaris* (L.) Wallr.	Asteraceae	1 seen (2021)	
**Erigeron sumatrensis* Retz.	Asteraceae	1 seen	UNITEC 13010
**Helminthotheca echioides* (L.) Holub	Asteraceae	uncommon	UNITEC 12957
**Hypochaeris radicata* L.	Asteraceae	uncommon	UNITEC 12958

**Osteospermum moniliferum* L. subsp. *moniliferum*	Asteraceae	common	UNITEC 12959
**Senecio elegans* L.	Asteraceae	1 seen (2021)	UNITEC 12960
**Senecio skirrhodon* DC.	Asteraceae	1 seen (2021)	UNITEC 12961
**Sonchus oleraceus* L.	Asteraceae	uncommon	UNITEC 12962
**Taraxacum sahlinianum* Dudman et A.J.Richards	Asteraceae	uncommon	UNITEC 12963
**Brassica* L.	Brassicaceae	1 seen (2001)	
**Lepidium didymium* L.	Brassicaceae	1 seen (2021)	UNITEC 12964
Calystegia sepium subsp. *roseata* Brummitt	Convolvulaceae	uncommon	UNITEC 12965
Coriaria arborea Linds. var. *arborea*	Coriariaceae	common	UNITEC 12717
**Lotus angustissimus* L.	Fabaceae	uncommon	UNITEC 12966
**Lotus pedunculatus* Cav.	Fabaceae	uncommon	UNITEC 12967
**Lotus suaveolens* Pers.	Fabaceae	uncommon	UNITEC 12968
**Medicago nigra* (L.) Krock.	Fabaceae	uncommon	UNITEC 12969
**Melilotus indicus* (L.) All.	Fabaceae	common	UNITEC 12970
**Trifolium dubium* Sibth.	Fabaceae	uncommon	UNITEC 13006
**Vicia sativa* subsp. *nigra* (L.) Ehrh.	Fabaceae	uncommon	UNITEC 12971
**Vicia sativa* L. subsp. *sativa*	Fabaceae	1 seen (2021)	UNITEC 12972
Geranium homeanum Turcz.	Geraniaceae	5 seen (2021	UNITEC 12973
**Geranium robertianum* L.	Geraniaceae	uncommon	UNITEC 12974
**Geranium gardneri* de Lange	Geraniaceae	uncommon	UNITEC 13383
Haloragis erecta (Banks ex Murray) Oken subsp. *erecta*	Haloragaceae	uncommon	UNITEC 12718
Entelea arborescens R.Br.	Malvaceae	1 seen (2009)	AK 304290
Metrosideros excelsa Sol. ex Gaertn.	Myrtaceae	1 seen (2021)	UNITEC 12975
**Syzygium smithii* (Poir.) Nied.	Myrtaceae	1 seen (2021)	UNITEC 13000
**Fumaria muralis* W.D.J.Koch	Papaveraceae	common	UNITEC 13019

**Fumaria capreolata* L. subsp. *capreolata*	Papaveraceae	common	UNITEC 12976
**Phytolacca octandra* L.	Phytolaccaceae	1 seen	UNITEC 13009
Pittosporum crassifolium Banks et Sol. ex A.Cunn.	Pittosporaceae	uncommon	UNITEC 12977
**Ligustrum lucidum* W.T.Aiton	Oleaceae	abundant	UNITEC 12978
Epilobium cinereum A.Rich.	Onagraceae	uncommon	UNITEC 12979
**Plantago lanceolata* L.	Plantaginaceae	uncommon	UNITEC 12980
Muehlenbeckia complexa (A.Cunn.) Meisn. var. *complexa*	Polygonaceae	abundant	UNITEC 12981
Muehlenbeckia australis (G.Forst.) Meisn. × *M. complexa* (A.Cunn.) Meisn. var. *complexa*	Polygonaceae	uncommon	UNITEC 12982
**Rumex conglomeratus* Murray	Polygonaceae	1 seen (2021)	UNITEC 13003
**Lysimachia arvensis* (L.) U.Manns et Anderb. subsp. *arvensis*	Primulaceae	abundant	UNITEC 12983
Samolus repens var. *repens*	Primulaceae	common	UNITEC 12984
**Rhaphiolepis bibas* (Lour.) Galasso et Banfi	Rosaceae	3 seen (2021)	UNITEC 12985
**Rubus ulmifolius* Schott	Rosaceae	uncommon	UNITEC 12986
Coprosma macrocarpa subsp. *minor* A.P.Druce ex R.O.Gardner et Heads	Rubiaceae	uncommon	UNITEC 12987
Coprosma robusta Raoul	Rubiaceae	uncommon	UNITEC 12988
Coprosma macrocarpa subsp. *minor* A.P.Druce ex R.O.Gardner et Heads × *C. robusta* Raoul	Rubiaceae	uncommon	UNITEC 12989
**Galium aparine* L.	Rubiaceae	uncommon	UNITEC 12990
**Sherardia arvensis* L.	Rubiaceae	uncommon	UNITEC 12991
**Solanum mauritianum* Scop.	Solanaceae	1 seen (2001)	
**Solanum nigrum* L.	Solanaceae	1 seen (2021)	UNITEC 12992
Chromista – Ochrophyta (Phaeophyceae) (1)			
Hormosira banksii (Turner) Dcne.	Hormosiraceae	uncommon	

Mycobiota (27)			
Fungi (7)			
**Ramularia helminthiae* Bremer et Petr.	Mycosphaerellaceae	uncommon	UNITEC 12995
Puccinia coprosmae Cooke	Pucciniaceae	uncommon	UNITEC 12993
**Puccinia coronata* Corda	Pucciniaceae	uncommon	UNITEC 12999
**Puccinia myrsiphylli* (Thüm.) G.Winter	Pucciniaceae	uncommon	UNITEC 12994
Uromyces ehrhartae McAlpine	Pucciniaceae	uncommon	UNITEC 13002
**Uromyces tranasversalis* (Thüm.) G.Winter	Pucciniaceae	common	UNITEC 13015
**Russula amoenolens* Romagn.	Russulaceae	1 seen (2021)	
Lichens (20)			
Arthonia atra (Pers.) A.Schneid.	Arthoniaceae	common	UNITEC 12728
Arthonia peraffinis Nyl.	Arthoniaceae	uncommon	UNITEC 12727
Chrysothrix xanthina (Vain.) Kalb	Chrysothricaceae	uncommon	UNITEC 12730
Cladonia confusa R.Sant.	Cladoniaceae	uncommon	UNITEC 12726
Fissurina inquinata C.Knight et Mitt.	Graphidaceae	uncommon	UNITEC 12744
Graphis elegans (Borrer ex Sm.) Ach.	Graphidaceae	uncommon	UNITEC 12726
Lecanora carpinea (L.) Vain.	Lecanoraceae	common	UNITEC 12735
Opegrapha agelaeoides Nyl.	Opegraphaceae	uncommon	UNITEC 12740
Parmotrema crinitum (Ach.) M.Choisy	Parmeliaceae	uncommon	UNITEC 12745
Parmotrema perlatum (Huds.) M.Choisy	Parmeliaceae	uncommon	UNITEC 12736
Dirinaria applanata (Fée) D.D.Awasthi	Physciaceae	uncommon	UNITEC 13013
Heterodermia speciosa (Wulfen) Trevis	Physciaceae	common	UNITEC 12731
Physica adscendens (Fr.) H.Olivier	Physciaceae	uncommon	UNITEC 13005
Bacidia leucothalamia (Nyl.) Hellb.	Ramalinaceae	common	UNITEC 12729
Bacidia wellingtonii (Stirt.) D.J.Galloway	Ramalinaceae	common	UNITEC 13004
Ramalina celastri (Spreng.) Krog et Swinscow	Ramalinaceae	abundant	UNITEC 12996

Ramalina peruviana (Ach.)	Ramalinaceae	uncommon	UNITEC 12735
Athallia cerinelloides (Erichsen) Arup, Frödén et Søchting	Teloschistaceae	common	UNITEC 12742
Teloschistes chrysophthalmus (L.) Beltr.	Teloschistaceae	uncommon	UNITEC 12732
Xanthoria parietina (L.) Beltr.	Teloschistaceae	abundant	UNITEC 12734

APPENDIX 2: Avifauna recorded from Ngārango Otainui (January and November 2021 observations)

* denotes taxa naturalised to New Zealand

Scientific Name	Family	Abundance and comments
**Anas platyrhynchos* Linnaeus, 1758	Anatidae	2 seen
Phalacrocorax varius (Gmelin, 1758)	Phalacrocoracidae	2 seen
Egretta novaehollandiae (Latham, 1790)	Ardeidae	Primary and secondary feathers on ground. Nests present in taller pines on the island.
Platalea regia Gould, 1838	Ardeidae	Primary and secondary feathers on ground. High tide roost.
Sterna striata Gmelin, 1789	Sternidae	2 seen
Larus dominicanus Lichtenstein, 1823	Laridae	13 seen
Chrysococcyx lucidus Gmelin, 1788	Cuculidae	1 heard
Todiramphus sanctus Vigors et Horsfield, 1827	Halcyonidae	1 seen
Gerygone igata (Quoy et Gaimard, 1830)	Acanthizidae	1 seen
Zosterops lateralis (Latham, 1802)	Zosteropidae	1 seen
**Turdus merula* Linnaeus, 1758	Turdidae	1 seen
**Passer domesticus* (Linnaeus, 1758)	Passeridae	1 seen
**Fringilla coelebs* Linnaeus, 1758	Fringillidae	1 seen
**Carduelis chloris* (Linnaeus, 1758)	Fringillidae	4 seen

Authors

Peter J. de Lange is a Professor teaching at the School of Environmental and Animal Sciences, Unitec, Te Pūkenga. A biosystematist, Peter regularly publishes on plant taxonomy, conservation, threat listing, and the flora of South Pacific and outlying New Zealand islands. A recipient of the New Zealand Botanical Society Allan Mere Award (2006) and Loder Cup (2017), Peter is a Fellow of the Linnean Society and a lifetime member of the New Zealand Plant Conservation Network. pdelange@unitec.ac.nz

Andrew J. Marshall is a graduate of the Bachelor of Applied Science programme and now a Research Associate at the School of Environmental and Animal Sciences, Unitec, Te Pūkenga. He is an author of seven papers, has broad interests in botany and especially crustose lichens, and is engaged in a study of the lichenised mycobiota of northern New Zealand. Andrew is the director of an ecological consultancy specialising in surveying and mapping the indigenous native and naturalised flora of the Auckland region. eco@lgm.kiwi

Luzie Schmid has completed the Bachelor of Applied Science programme at the School of Environmental and Animal Sciences, Unitec, Te Pūkenga. With interests in botany, genetics and taxonomy, she has been working in the Unitec Herbarium for two years, curating specimens and helping with research on *Lagenophora*, *Leptospermum* and *Muehlenbeckia*. Luzie has published three papers and undertaken field work on the Chatham Islands. lschmid@unitec.ac.nz

Sharen Graham is a retired ecologist and keen amateur botanist and ornithologist. Once a resident of Auckland, she now resides in Nelson. grahamsharen@gmail.com

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Contact:
epress@unitec.ac.nz
www.unitec.ac.nz/epress/
Unitec, Te Pūkenga
Private Bag 92025
Victoria Street West, Auckland 1010
Aotearoa / New Zealand

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Abstract

The invasive rust *Austropuccinia psidii*, responsible for myrtle rust disease, poses a serious threat to the New Zealand Myrtaceae. Since the 2017 detection of *Austropuccinia psidii* in Aotearoa / New Zealand, the rust has spread rapidly, resulting in the decline and death of a range of indigenous Myrtaceae, most notably the two species of the endemic genus *Lophomyrtus*, ramarama (*L. bullata*) and rōhutu (*L. obcordata*). While the threat *Austropuccinia psidii* poses to *Lophomyrtus* is now widely recognised, the indirect impact the rust has on the associated biota is poorly understood. Very little has been documented about the biota found in association with *Lophomyrtus*. To rectify this, we undertook a survey of the specimens held in three of the key Aotearoa / New Zealand herbaria that had been collected from *Lophomyrtus*. This was supplemented by field work in eight sites in western Te Ika a Maui / North Island, and north-western Te Wai Pounamu / South Island of Aotearoa / New Zealand. Although the herbarium searches located few specimens, and field work was limited to a few sample points within the range of *Lophomyrtus*, we found 221 taxa associated with *Lophomyrtus*, 176 taxa on ramarama, 81 on rōhutu and one on the naturally occurring hybrid between these two species *Lophomyrtus* ×*ralphii*. Of the 176 taxa found on ramarama, 59 are bryophytes (one hornwort, 33 liverworts and 25 mosses), five pteridophytes, 16 spermatophytes and 96 are lichenised mycobiota. Rōhutu supported 81 taxa: comprising one cyanobacterium, one alga, twenty-nine bryophytes (17 liverworts and 12 mosses), four pteridophytes, two spermatophytes and 44 lichenised mycobiota. Wild populations of *Lophomyrtus* ×*ralphii* were not investigated, and herbarium searches only disclosed one plant, the mistletoe *Korthalsella lindsayi*, associated with it. Several lichens and liverworts collected from *Lophomyrtus* represent potentially new species, and *Lepra erythrella* is a new addition to the lichenised mycobiota of Aotearoa / New Zealand. None of the putative new species are endemic to *Lophomyrtus*.

Introduction

Aotearoa / New Zealand has 29 indigenous Myrtaceae in five genera (de Lange & Schmid 2021; de Lange & Rolfe 2010; de Lange 2014; Schönberger et al. 2021); all are endemic, with the possible exception of *Leptospermum scoparium* J.R.Forst. et G.Forst., which, as currently circumscribed (Thompson 1989; Sykes 2016), extends to Australia and Rarotonga (Cook Islands), though de Lange & Schmid (2021), on the basis of genetic analyses published by Buys et al. (2019), treated it as endemic to Aotearoa / New Zealand. Of the five indigenous genera, two, *Lophomyrtus* Burret and *Neomyrtus* Burret in tribe Myrteae, are endemic to Aotearoa / New Zealand (de Lange & Rolfe 2010).

Lophomyrtus is a genus of two species, ramarama (*Lophomyrtus bullata* Burret) (Figure 1) and rōhutu (*Lophomyrtus obcordata* (Raoul) Burret) (Figure 2). These two species were originally described as either species of *Myrtus* L. or *Eugenia* L., *L. bullata* as *Myrtus bullata* Sol. ex A.Cunn. *nom. illeg.* (Cunningham 1839), and *L. obcordata* as *Eugenia obcordata* Raoul (Raoul 1844). *Eugenia obcordata* was transferred to *Myrtus* nine years after Raoul placed it in *Eugenia* as *M. obcordata* (Raoul) Hook.f. by Hooker (1853). Both species were then transferred by Burret (1941) to his new genus *Lophomyrtus*, where they have remained, as one of the few endemic genera left in the Aotearoa / New Zealand flowering plant flora (Govaerts et al. 2010; Garnock-Jones 2014; Schönberger et al. 2021). A third species, *Lophomyrtus ralphii* (Hook.f.) Burret, described by Hooker (1855) as *Myrtus ralphii* Hook.f., following the conclusions of Leonard Cockayne (Cockayne 1918)

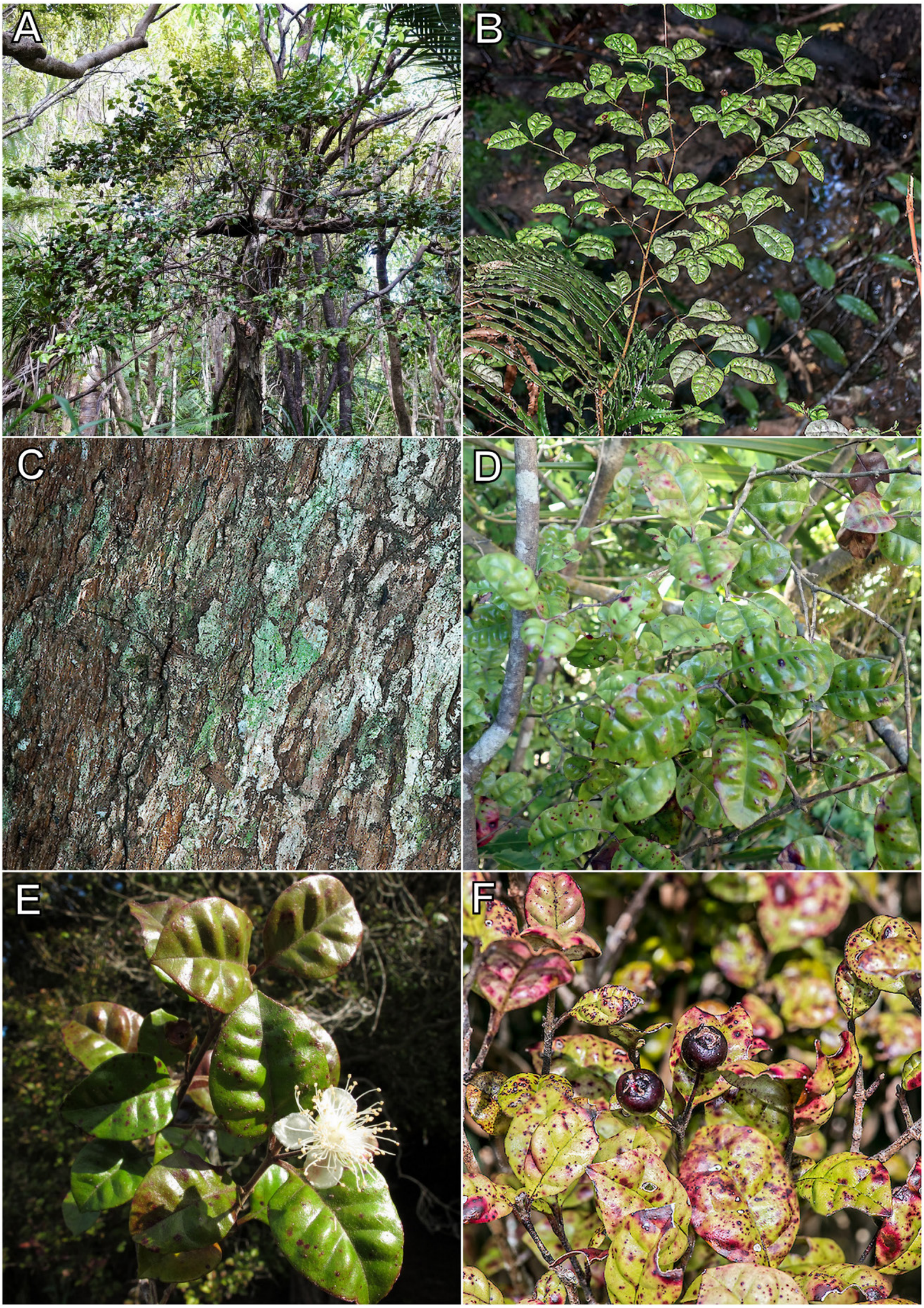

Figure 1. Ramarama (*Lophomyrtus bullata*). (**A**) Growth habit, Waitākere Ranges. Photo: J. Knight. (**B**) Sapling, Stokes Valley. Photo: J.R. Rolfe. (**C**) Bark, Boulder Hill, Lower Hutt. Photo: J.R. Rolfe. (**D**) Branchlet and foliage, Awaroa Scenic Reserve, South Kawhia. Photo: P.J. de Lange. (**E**) Flowers, ex cultivated Dunedin Botanic Garden. Photo: J.W. Barkla. (**F**) Fruits, Western Hutt Hills. Photo: J.R. Rolfe.

Figure 2. Rōhutu (*Lophomyrtus obcordata*). (**A**) Growth habit, Southland. Photo: J. Bythell. (**B**) Bark, Upper Hutt. Photo: J.R. Rolfe. (**C**) Branchlets and fruits, Broad Bay, Otago Peninsula. Photo: C. Knox. (**D**) Flowers, Aorere Delta. Photo: S. Walls. (**E**) Flowers, Stevenson's Island, Lake Wanaka. Photo: J.W. Barkla. (**F**) Fruits, Taita. Photo: J.R. Rolfe.

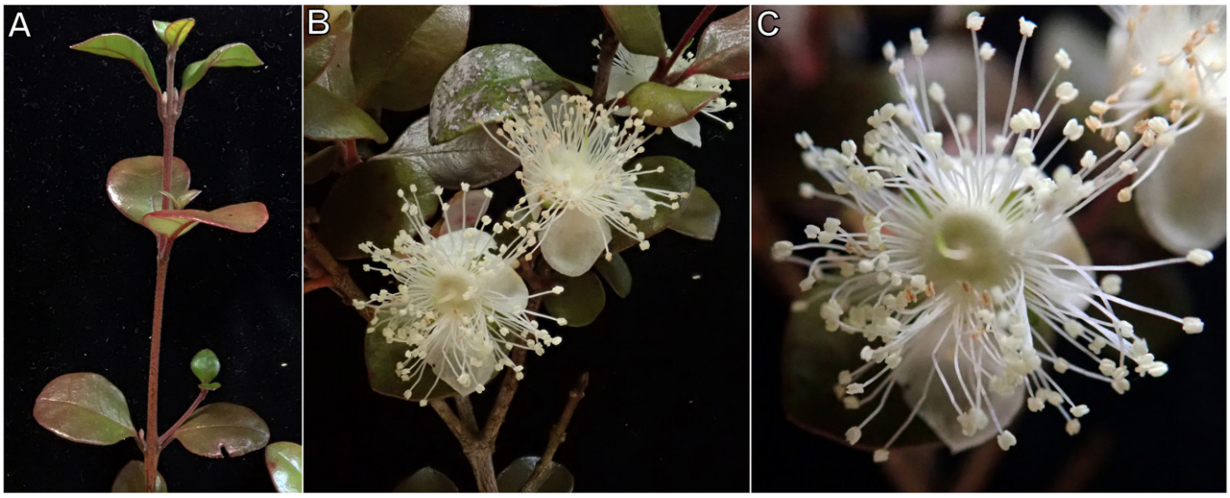

Figure 3. *Lophomyrtus ×ralphii,* a widespread, polymorphic hybrid plant found wherever the ranges of ramarama and rōhutu overlap. Selections of it with darkly pigmented leaves are popular in cultivation. (**A**) Branchlet. (**B**) Flowering branchlet. (**C**) Flowers, ex cultivated Unitec Institute of Technology, Mt Albert, Tāmaki Makaurau / Auckland. Photos: P.J. de Lange.

is now treated as the nothotaxon *Lophomyrtus ×ralphii* (Figure 3).

Ramarama occurs throughout Te Ika a Maui / North Island, where it is found in coastal, lowland to lower montane indigenous forest and associated shrubland (de Lange 2022a). In Te Wai Pounamu / South Island it is confined to the northern portion of that island to as far south as Greymouth in the west and north Canterbury in the east (de Lange 2022a). Rōhutu is more wide-ranging, occurring through both Te Ika a Maui / North Island and Te Wai Pounamu / South Island, though it is often regionally scarce particularly in the northern portion of Te Ika a Maui / North Island (de Lange 2022b).

The rust, *Austropuccinia psidii* (G. Winter) Beenken, which causes myrtle rust disease, was first reported from Aotearoa / New Zealand in May 2017. Following its detection, it has spread rapidly throughout Te Ika a Maui / North Island and the northern portion of Te Wai Pounamu / South Island (Galbraith & Large 2017; Beresford et al. 2018) reaching Rēkohu / Chatham Islands in April 2022 (see https://inaturalist.nz/observations/109933128). Although the full impact of myrtle rust on Aotearoa / New Zealand Myrtaceae is still unknown, based on the Australian experience it may be a decade or more before the full impact of this novel pathogen becomes evident (Carnegie et al. 2015; Carnegie & Pegg 2018; Fensham et al. 2020).

Since its 2017 detection in Aotearoa / New Zealand *Austropuccinia* Beenken has been frequently recorded infecting ramarama, rōhutu, white rata (*Metrosideros diffusa* Sol. ex Gaertn), pōhutukawa (*Metrosideros excelsa* Sol. ex Gaertn.) and maire tawake (*Syzygium maire* (A.Cunn.) Sykes et Garn.-Jones (Toome-Heller et al. 2020; Schmid et al. 2021). Of these species, *Austropuccinia* will cause the death of maire tawake, ramarama and rōhutu both in cultivation and in natural habitats (Beyond Myrtle Rust 2020; authors' pers. obs.), and in some parts of the northern range of these hosts it is now uncommon to find specimens not infected by this rust. These observations support the current threat assessment of 'Threatened / Nationally Critical', which had been given as a precautionary measure to these three species by de Lange et al. (2018a) on the advice of Australian experts researching the impact of *Austropuccinia* on their indigenous Myrtaceae.

The arrival of myrtle rust has prompted the urgent need to better understand the ecological communities of our indigenous Myrtaceae (Blanchon et al. 2020; Jo et al. 2022). At present, information on the associates of Aotearoa / New Zealand Myrtaceae is limited, and skewed toward vascular plants (Blanchon et al. 2020). For example, Bylsma et al. (2014), noted 16 fern and flowering plant taxa epiphytic on pōhutukawa. McKenzie et al. (1999) also published an annotated list of non-lichenised fungi known from *Metrosideros* Banks et Gaertn, and an account of the non-lichenised fungi of *Kunzea* Richb. and *Leptospermum* J.R.Forst. et G.Forst. (McKenzie et al. 2006).

To help rectify that apparent knowledge gap, we provide here a preliminary contribution to that need by listing the flora and mycobiota that utilise *Lophomyrtus* as a phorophyte. This contribution is not intended to be comprehensive, as we have only examined herbarium holdings in four Aotearoa / New Zealand herbaria, AK, CHR, UNITEC and WELT (Thiers 2020–onwards) and examined eight locations supporting *Lophomyrtus* (see below); nevertheless, this paper constitutes the first freely available compendium of the associates of

Lophomyrtus formally published for this genus. It is to be hoped that this contribution stimulates further investigation into the flora and mycobiota that utilise *Lophomyrtus*.

Methods

Herbarium searches

Records mentioning either *Lophomyrtus bullata*, *L. obcordata* or the hybrid *L.* ×*ralphii* (Hook.f.) Burret as the phorophyte / 'host' were collated in a spreadsheet from the herbarium databases of the herbaria AK, CHR, UNITEC and WELT. The records were arranged by their taxonomic groups and their threat status according to the New Zealand Threat Classification System (Townsend et al. 2008) noted.

Study sites

In addition to herbarium specimens, we undertook field work at eight locations in Te Ika a Maui North Island and Te Wai Pounamu / South Island (Figure 4). Field collection was mostly opportunistic, in part being hindered by access to locations due to concerns over the spread of *Austropuccinia*. However, in a few Waikato locations, Department of Conservation assistance from Dr C. Beard enabled more comprehensive sampling. The sample sites are as follows:

Lophomyrtus bullata **sites sampled (Figure 4)**

Te Ika a Maui / North Island, South Auckland, Waikato, South Kawhia, Awaroa Scenic Reserve

Vegetation Association: Riparian, lowland kahikatea (*Dacrycarpus dacrydioides* (A.Rich.) de Laub.) Forest. Understorey dominated by *Lophomyrtus bullata*.

Latitude: -38.147495°*S*, Longitude: 174.938993°*E*.

Te Ika a Maui / North Island, South Auckland, Waikato, Te Anga, Mangapohue Natural Bridge Scenic Reserve

Vegetation Association: Riparian vegetation developed along margins of limestone canyon. *Lophomyrtus bullata* uncommon component of understorey vegetation.

Latitude: -38.259607°*S*, Longitude: 174.900449°*E*.

Te Ika a Maui / North Island, Taranaki, North Taranaki, Waitaanga

Vegetation Association: Silver beech (*Lophozonia menziesii* (Hook.f.) Heenan et Smissen) forest. *Lophomyrtus bullata* occasional component of forest understorey.

Latitude: -38.841526°S, Longitude: 174.822548°E.

Lophomyrtus obcordata **sites sampled (Figure 4)**

Te Ika a Maui / North Island, South Auckland, Āwhitu Peninsula, Lighthouse Bush

Vegetation Association: *Lophomyrtus obcordata / Leptospermum* aff. *scoparium* (a) shrubland.

Latitude: -37.052617°S, Longitude: 174.545833°E.

Te Ika a Maui / North Island, South Auckland, Āwhitu Peninsula, Signal Station Bush

Vegetation Association: Mixed coastal forest of tawa (*Beilschmiedia tawa* (A.Cunn.) Benth. et Hook. ex Kirk) with porokaiwhiri (*Hedycarya arborea* J.R.Forst. et G.Forst.), and rewarewa (*Knightia excelsa* R.Br.). *Lophomyrtus obcordata* occasional as small trees and shrubs within understorey.

Latitude: -37.051440°S, Longitude: 174.552683°E.

Te Wai Pounamu / South Island Nelson, Motueka, Riuwaka Valley Road

Vegetation Association: Matai (*Prumnopitys taxifolia* (Sol. ex D.Don) de Laub.) / kahikatea (*Dacrycarpus dacrydioides*) forest. *Lophomyrtus obcordata* common understorey tree.

Latitude: -41.047754°S, Longitude: 172.924232°E.

Te Wai Pounamu / South Island, Nelson, Brooklyn, Brooklyn Reserve

Vegetation Association: Totara (*Podocarpus totara* D.Don var. *totara*) forest remnant. *Lophomyrtus obcordata* occasional understorey tree.

Latitude: -41.0548°*S*, Longitude: 172.5732°*E*.

Te Wai Pounamu / South Island, Nelson, Barnicoat Range, Richmond, Easby Reserve

Vegetation Association: Scattered *Lophomyrtus obcordata* in reverting manuoea (*Kunzea ericoides* (A.Rich.) Joy. Thomps.) forest.

Latitude: -41.2010°S, Longitude: 173.1510°*E*.

Results and discussion

Collectively we found 221 taxa associated with *Lophomyrtus*, 176 taxa on ramarama, 81 on rōhutu and one on *Lophomyrtus ×ralphii* (authorities for these taxa are given in Appendix 1). Thirty-six taxa were common to the two *Lophomyrtus* species. Our figures, with the exception of lichenised mycobiota, excluded mycobiota as we lacked the expertise to undertake family or lower-rank determinations. However, when possible, specimens were sent to PDD where it is to be hoped they will be identified in due course. The following summarises the associates by broad taxonomic group.

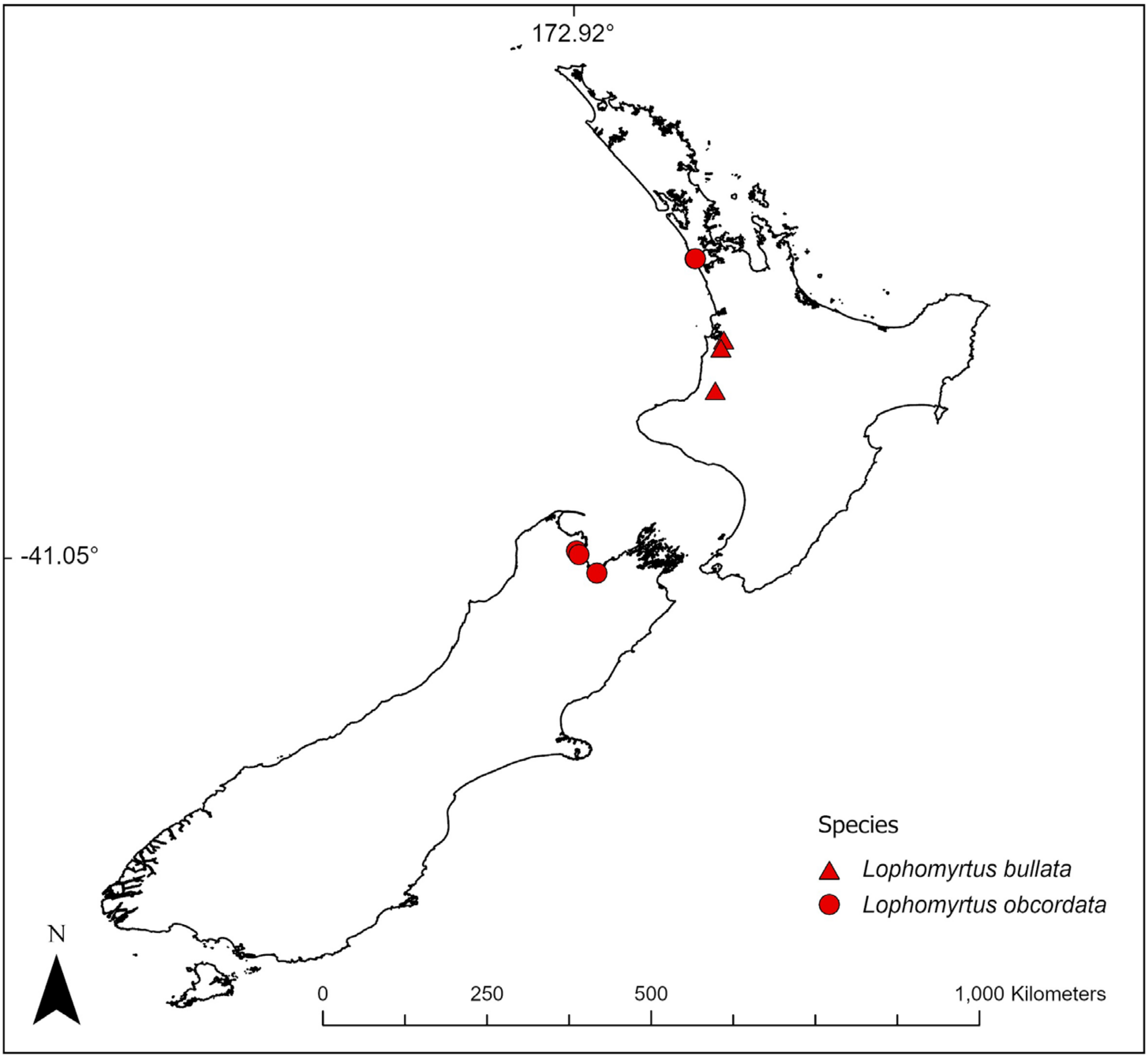

Figure 4. Locations from where *Lophomyrtus* species were sampled. Triangles – ramarama (*Lophomyrtus bullata*), circles – rōhutu (*Lophomyrtus obcordata*).

Lophomyrtus

Both species of *Lophomyrtus* and their hybrid form shrubs to small trees 6 (–7) m tall (de Lange 2022a, 2022b). Branching is well developed in specimens growing in exposed sites but those within shaded locations such as growing under a dense forest canopy are often sparingly branched. The bark of *Lophomyrtus* decorticates in larger flakes, that of rōhutu especially shedding, such that the trunks are often bare of epiphytic growth. However, ramarama, which attains a greater stature and breadth than rōhutu usually does, may have portions of decorticated trunk – often in sites where a former branch had been, leaving holes or crevices – and it is in these sites that fungi, bryophytes and other plants often establish.

The micro-niches of *Lophomyrtus* are notably less than those documented for pōhutukawa (Blanchon et al. 2020). However, the branch and branchlet forks of *Lophomyrtus* and the bullate leaves of ramarama provide a range of habitats suitable for colonisation, while the greater altitudinal range and habitat tolerances of the genus are less limiting than the strict coastal / lakeside often seral habitat favoured by pōhutukawa. A direct comparison is not possible for any taxonomic groups other than the lichenised mycobiota, however, as Blanchon et al. (2020) only reported on this group, finding 187 taxa utilising pōhutukawa, whereas this study found 95 lichenised mycobionts on ramarama and

44 on rōhutu. The greater number of lichens reported from pōhutukawa is not surprising, especially as this phorophyte, as a much larger tree, offers a greater range of microniches (see Blanchon et al. 2020). It is also likely that the iconic status of pōhutukawa has ensured that it is better studied and collected than *Lophomyrtus* (Bylsma et al. 2014; Simpson 2005).

Ramarama (*Lophomyrtus bullata*)

Ramarama had the greatest diversity of associates, most of which are corticolous taxa. Whilst the bark of ramarama sheds readily, the branches and branchlets, notably the forks, provide a suitable habitat for colonisation. Also, the trunk base, especially in older specimens where fallen bark has accumulated, provides a secure site for the establishment of a range of plants and lichens which over time will grow up the trunk (Figure 5). The coriaceous bullate and presumably long-lived leaves of ramarama (Figure 1D–F) also provide a suitable habitat for foliicolous liverworts, notably *Cololejeunea laevigata* and *Siphonolejeunea nudipes* var. *nudipes*, to colonise.

Figure 5. Bryophyte and Lichen growth on the lower trunk and branches of ramarama (*Lophomyrtus bullata*), Awaroa Scenic Reserve, South Kawhia. The dominant species visible in this image are the mosses *Leptostomum macrocarpon*, *Macromitrium longipes* and *Papillaria flavolimbata*; liverworts *Lepidolaena taylorii*, *Porella elegantula*; and the lichens *Cladonia darwinii*, *Dictyonema*, *Pannaria araneosa*, and *Pannaria delicata*. Photo: P.J. de Lange.

Our study found 176 taxa on ramarama. These taxa are broken down by taxonomic group as follows: 59 bryophytes (one hornwort, 33 liverworts and 25 mosses), five pteridophytes, 16 spermatophytes and 96 lichenised mycobiota.

Of the liverworts (see Figure 6 for examples), the Lejeuneaceae Rostovzev were the dominant family found on ramarama, with 12 species from seven genera noted. None of those found are listed as threatened (de Lange et al. 2020) though one, *Lopholejeunea* (a), treated as an unnamed species by de Lange et al. (2020), requires formal taxonomic assessment. Five species of *Radula* Dumort. (Radulaceae) were also recorded from ramarama; of these, one, *Radula marginata,* is listed as 'At Risk / Declining' due to indiscriminate harvesting of plants for their hallucinogenic properties (Toyota et al. 2003; de Lange et al. 2020).

Of the 25 mosses recorded from ramarama (see Figure 7 for examples), mosses from the Orthotrichaceae Arn. (3 genera, 3 species) and Ptychomniaceae M.Fleisch. (3 genera, 3 species) were the most commonly noted. None of these are listed as threatened by Rolfe et al. (2016). In some situations, notably in the upper branches and branchlets of ramarama, copious growths of *Papillaria crocea* and *P. flavolimbata* may be found, while the branch forks are a favoured habitat for *Cryphaea dilatatus* and *C. tenella*, pin cushion moss (*Leptostomum macrocarpon*) and species of *Macromitrium* Brid. Otherwise, the trunk base and damaged portions of trunk were often colonised by *Cladomnion* Hook. f. et Wilson (Figure 7A), *Ptychomnion aciculare* (Figure 7C) and *Rosulabryum* J.R. Spence. Despite the tendency of ramarama bark to shed, growths of the *Orthorrhynchium elegans* (Figure 7B) were often found in this habitat; presumably this moss can rapidly recolonise portions of trunk from which it has been shed.

Of the six pteridophytes recorded from ramarama, the most commonly encountered family was the Polypodiaceae J.Presl et C.Presl with *Pyrrosia elaeagnifolia* found in three ramarama field sites investigated, and *Zealandia pustulata* subsp. *pustulata* at two. In both species, growth had commenced on the forest floor, with the ferns managing to retain partial purchase on the flaking trunk bark, so reaching the branches and branchlets where a firmer attachment

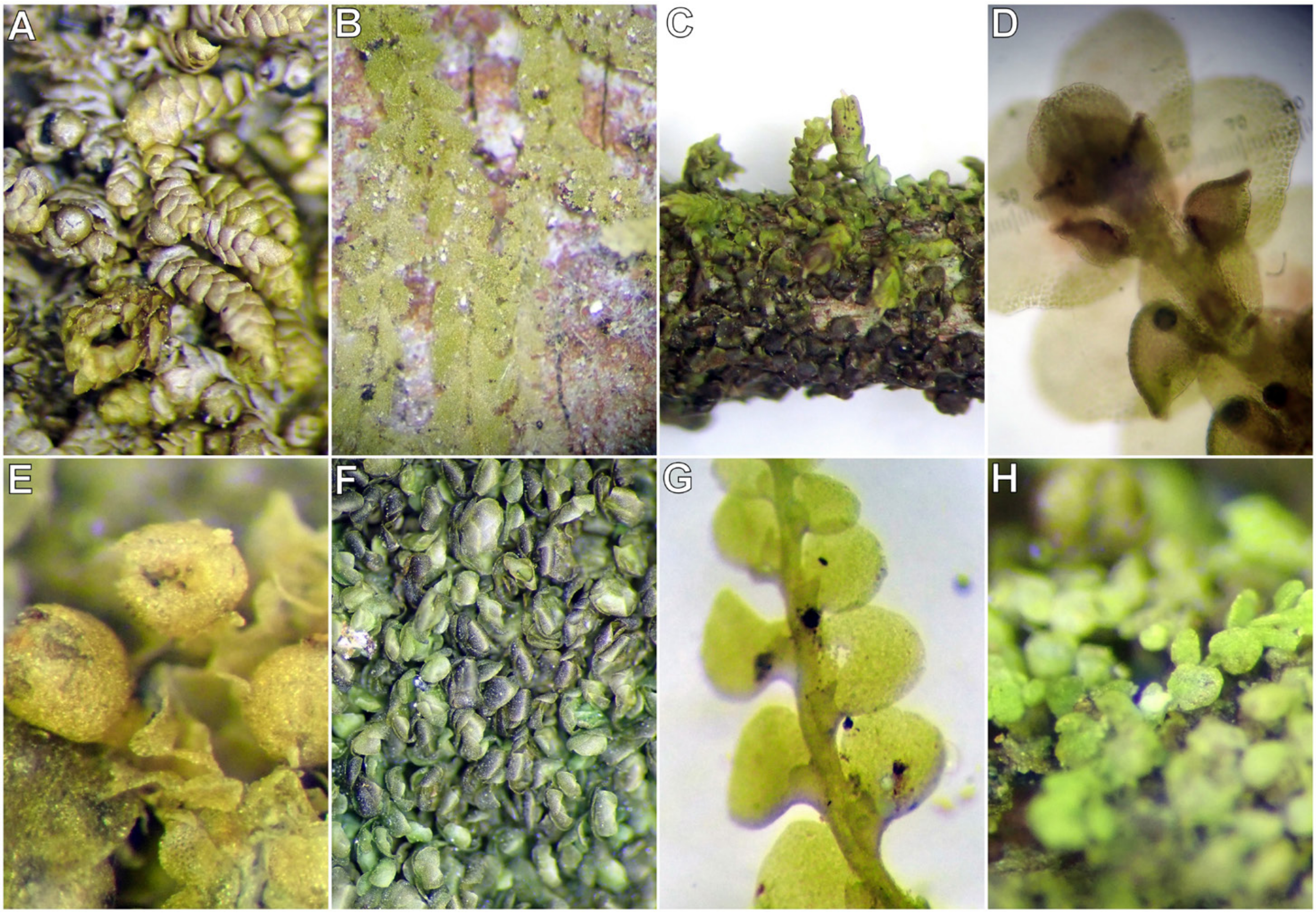

Figure 6. Liverworts associated with ramarama (*Lophomyrtus bullata*). (**A**) *Cheilolejeunea comittans*, Awaroa Scenic Reserve, South Kawhia. (**B**) *Chiloscyphus muricatus*, Awaroa Scenic Reserve, South Kawhia. (**C**) *Frullania incumbens*, Awaroa Scenic Reserve, South Kawhia. (**D**) *Frullania pycnantha*, Awaroa Scenic Reserve, South Kawhia. (**E**) *Lejeunea oracola*, Awaroa Scenic Reserve, South Kawhia. (**F**) *Lopholejeunea*, Awaroa Scenic Reserve, South Kawhia. (**G**) *Radula strangulata*, Awaroa Scenic Reserve, South Kawhia. (**H**) *Siphonolejeunea nudipes* var, *nudipes*, Awaroa Scenic Reserve, South Kawhia. Photos: P.J. de Lange.

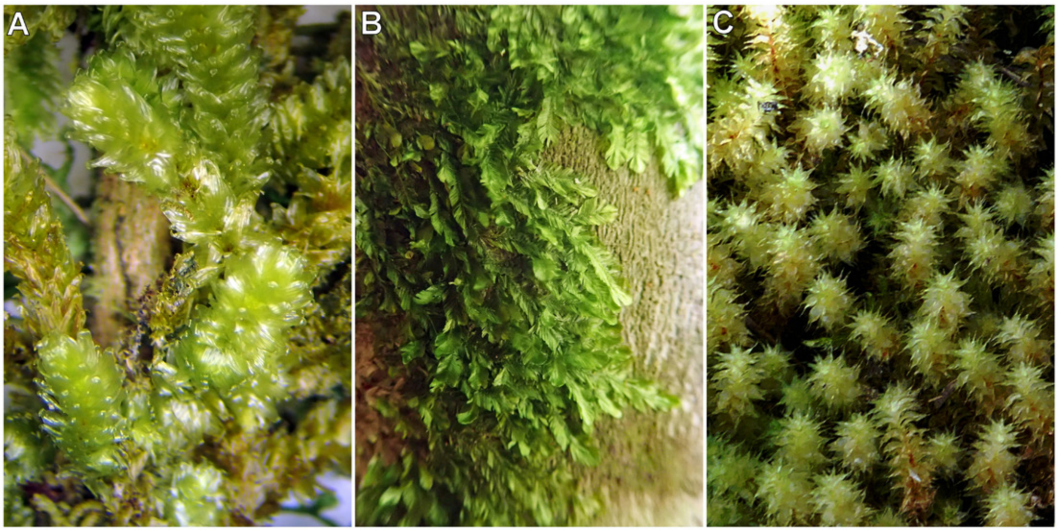

Figure 7. Mosses associated with ramarama (*Lophomyrtus bullata*). (**A**) *Cladomnion ericoides*, Mangapohue Natural Bridge Scenic Reserve, Te Anga. (**B**) *Orthorrhynchium elegans*, Awaroa Scenic Reserve, South Kawhia. (**C**) *Ptychomnion aciculare*, Awaroa Scenic Reserve, South Kawhia. Photos: P.J. de Lange.

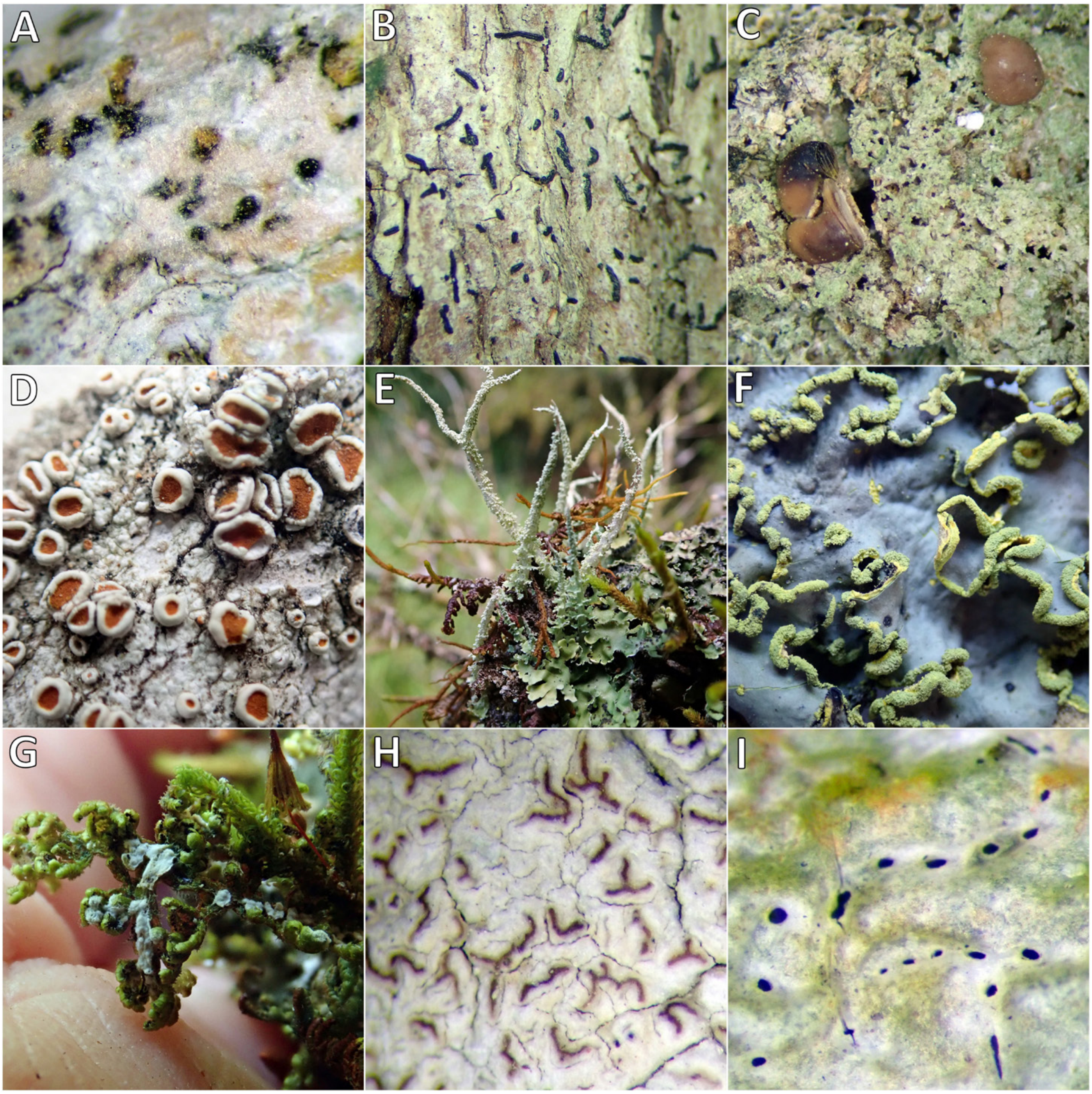

Figure 8. Lichenised mycobiota associated with ramarama (*Lophomyrtus bullata*). (**A**) *Arthonia indistincta*, Awaroa Scenic Reserve, South Kawhia. (**B**) *Arthonia epiodes*, Awaroa Scenic Reserve, South Kawhia. (**C**) *Bapulmia buchananii*, Awaroa Scenic Reserve, South Kawhia. (**D**) *Brigantiaea chrysosticta*, Awaroa Scenic Reserve, South Kawhia. (**E**) *Cladonia darwinii*, Awaroa Scenic Reserve, South Kawhia. (**F**) *Crocodia aurata*, Awaroa Scenic Reserve, South Kawhia. (**G**) *Dictyonema*, Awaroa Scenic Reserve, South Kawhia. (**H**) *Enterographa pallidella*, Awaroa Scenic Reserve, South Kawhia. (**I**) *Fissurina*, Mangapohue Natural Bridge Scenic Reserve, Te Anga. Photos: P.J. de Lange.

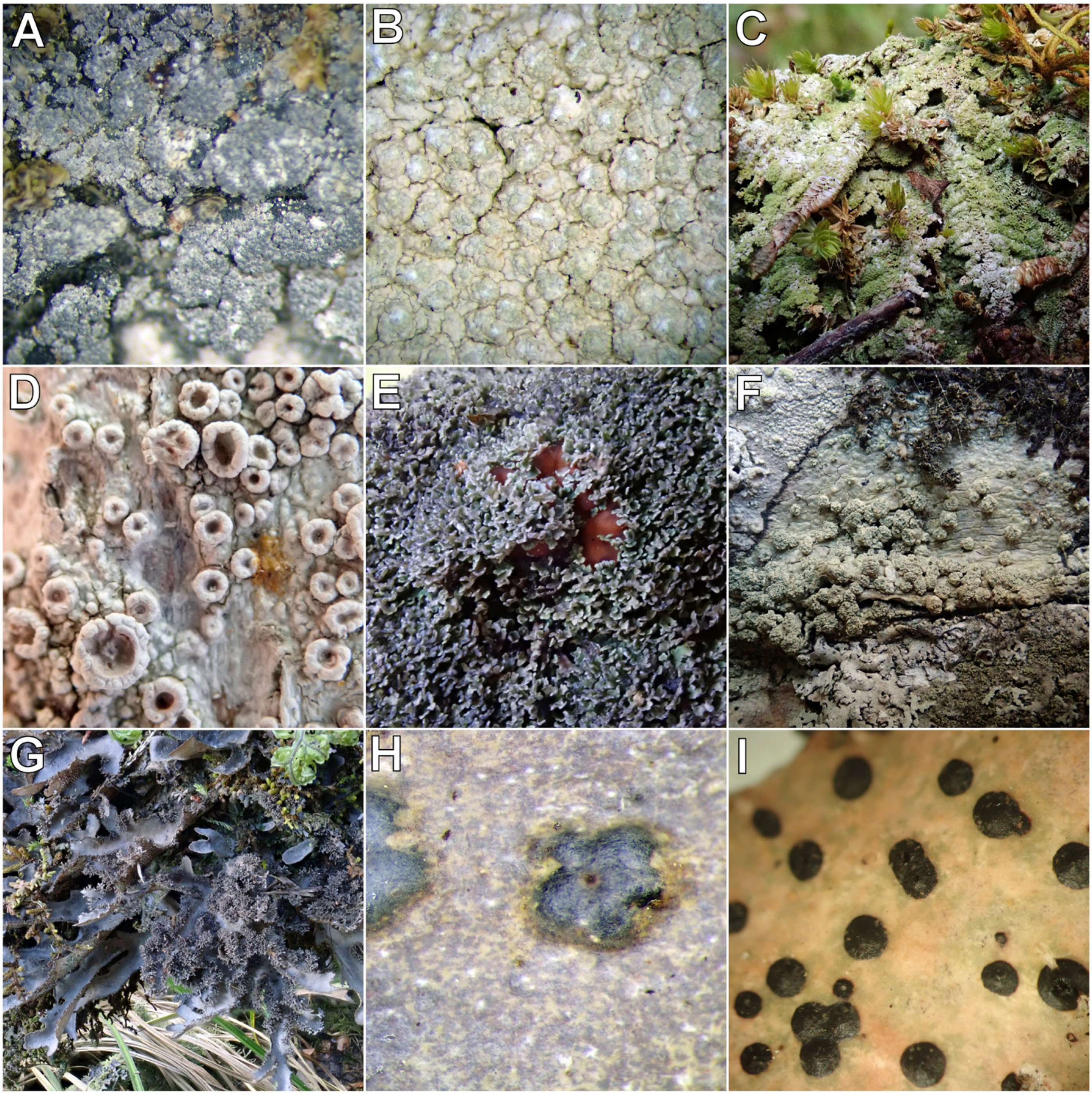

Figure 9. Lichenised mycobiota associated with ramarama (*Lophomyrtus bullata*). (**A**) *Fuscopannaria granulans*, Awaroa Scenic Reserve, South Kawhia. (**B**) *Lepra erythrella*, Awaroa Scenic Reserve, South Kawhia. (**C**) *Megalaria* aff. *orokonuiana*, Awaroa Scenic Reserve, South Kawhia. (**D**) *Orcholechia pallescens*, Awaroa Scenic Reserve, South Kawhia. (**E**) *Pannaria delicata*, Awaroa Scenic Reserve, South Kawhia. (**F**) *Pertusaria puffina*, Awaroa Scenic Reserve, South Kawhia. (**G**) *Pseudocyphellaria dissimilis*, Awaroa Scenic Reserve, South Kawhia. (**H**) *Pyrenula leucostoma*, Awaroa Scenic Reserve, South Kawhia. (**I**) *Pyrenula nitidula*, Mangapohue Natural Bridge Scenic Reserve, Te Anga. Photos: **A–H**, P.J. de Lange; **I**, A.J. Marshall.

could be made. This was also the way *Icarus filiformis*, another climbing fern, appears to have succeeded in establishing on ramarama. The other pteridophytes noted, *Asplenium flaccidum* and *Hymenophyllum sanguinolentum,* were noted growing at the trunk base, within decorticated rotted portions of trunk or, more commonly, within the branch forks.

Fifteen spermatophytes were noted on ramarama; these included two naturalised species, cocksfoot (*Dactylis glomerata*) and *Sison amomum*, which had colonised ramarama growing on a forest margin abutting rough pasture. At Awaroa Scenic Reserve, the upper branch forks were often colonised by *Astelia hastata* and *Earina mucronata*. One occurrence of a seedling *Ripogonum scandens* was also noted, in this case a plant that germinated within a pin cushion moss growing on ramarama. Of the indigenous species, seven are lianes, which had grown through ramarama in the same way the lianoid ferns had; two, the hemiparasitic *Korthalsella clavata*, and *K. lindsayi,* are listed as 'At Risk / Declining' (de Lange et al. 2018a). While *Korthalsella lindsayi* has been reported for ramarama by Sultan et al. (2018), *K. clavata* has not, so this is a new record for this host association. Two species, the rata vines (*Metrosideros diffusa* and *M. fulgens*) are listed as 'Threatened / Nationally Vulnerable' because of the risk posed by *Austropuccinia psidii,* which infects them (de Lange et al. 2018a; authors' pers. obs.).

The most diverse group of ramarama associates are lichenised mycobiota (see Figures 8 and 9 for examples); we report here 96 species, of which the Peltigeraceae Willd. (21 species from 4 genera) were the main contributing family, followed by the Pannariaceae Tuck., Parmeliaceae Zenker and Ramalinaceae C.Agardh, which each contributed 9 species, followed by the Collemataceae Zenker (8 species from two genera). Eleven of the lichens recorded are listed as 'At Risk' or 'Data Deficient' (de Lange et al. 2018b) and 14 lichens are either unresolved to species level (e.g., *Dictyonema* C.Agardh ex Kunth, Figure 8G), require taxonomic assessment (e.g., *Megalaria* aff. *orokonuiana* (Figure 9C), and a potentially new species of *Fissurina* Feé (Figure 8I), or are new additions to the lichenised mycobiota of Aotearoa / New Zealand so have no conservation listing yet, e.g., *Lepra erythrella* (Figure 9B) and *Pyrenula leucostoma* (Figure 9H), the latter discussed by Marshall et al. (2020). No clear patterns are evident in the lichen assemblages collected, beyond that where ramarama grew on forest margins it supported more lichen diversity, of photophilous species, and when growing in shaded sites less diversity of shade-tolerant taxa, e.g., *Bacidia* De Not. spp., *Collema* Weber ex F.H.Wigg. spp., *Coenogonium luteum* and *Leptogium* (Ach.) Gray spp., than we had anticipated. Eleven lichens have been listed as 'Data Deficient' by de Lange et al. (2018b); their discovery on ramarama therefore adds to our scant knowledge of them and will help improve our knowledge for further threat assessments.

Rōhutu (*Lophomyrtus obcordata*)

Rōhutu, the wider ranging of the two *Lophomyrtus* species, based on our admittedly limited sampling, seems to support fewer associates than ramarama. This may be because rōhutu bark sheds more readily than ramarama (Figure 2B). In this species, co-associates were mostly confined to branch forks, especially in those forks where shed bark had accumulated. The leaves, though non-bullate and smaller than ramarama, supported a range of cyanobacterial growths not noted in ramarama. While we were unable to identify the majority of these, based on the diversity of shape and form, further investigation of them may prove rewarding.

Our study found 81 taxa on rōhutu, comprising of one cyanobacterium, one alga, twenty-nine bryophytes (17 liverworts and 12 mosses), four pteridophytes and two spermatophytes. As with ramarama, lichenised mycobiota were the most prolific (44 species).

Cyanobacteria and algae are common on the leaves and branchlets of rōhutu. One of the cyanobacteria we found on the leaves of rōhutu plants sampled at Āwhitu (Figure 3) has been provisionally identified as a species of *Tolypothrix* Kützing ex Bornet et Flahault, *T.* c.f. *pseudodoxia* by Dr P. Novis of Landcare Research (pers comm, 20 July 2020). Aside from cyanobacteria, *Trentepohlia* was also commonly seen in shaded or humid habitats, growing on leaves, petioles and especially the upper branchlets. We were unable to obtain species-level determinations but on the basis of growth habit we suspect that there is more than one species present on rōhutu. Further investigation is needed.

Of the 17 liverworts recorded (see Figure 10 for examples), 15 are listed as 'Not Threatened' (de Lange et al. 2020) and two, a suspected undescribed species belonging to the *Porella elegantula* complex (Figures 10G, 10H) and the newly described *Lejeunea demissa* (Figures 10A–C; Renner et al. 2021), have yet to receive a formal conservation assessment (note, though that *Lejeunea demissa* was awarded a provisional status of 'Not Threatened' by Renner et al. 2021). Aside from species of *Frullania* Raddi, *Metzgeria furcata* and *Siphonolejeunea*

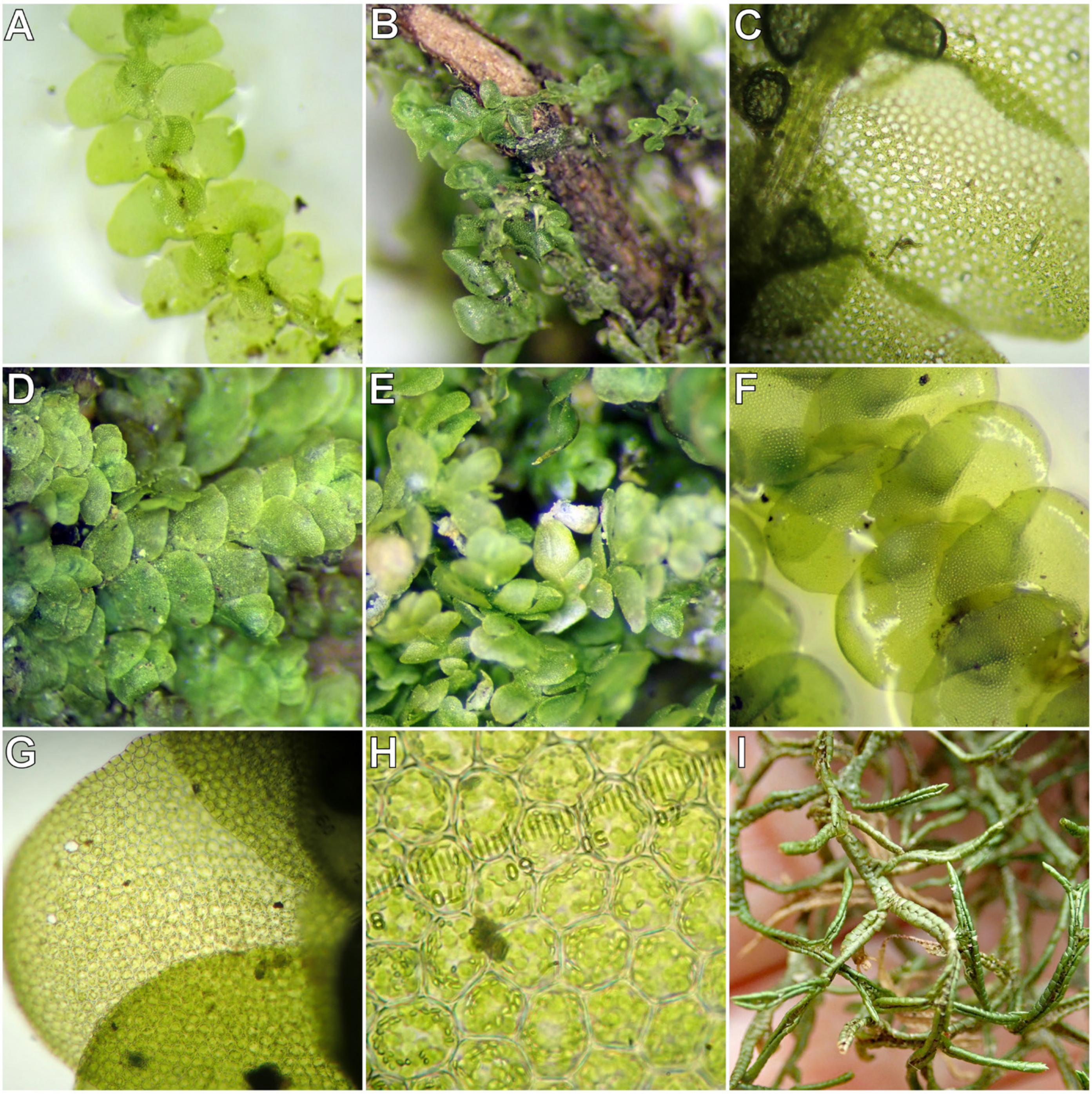

Figure 10. Liverworts associated with rōhutu (*Lophomyrtus obcordata*). (**A–C**) *Lejeunea demissa*, Riuwaka Valley Road, Motueka. (**D**) *Lejeunea hodgsoniana*, Signal Station Bush, Āwhitu Peninsula. (**E**) *Lejeunea oracola*, Signal Station Bush, Āwhitu Peninsula. (**G, H**) *Porella*, Riuwaka Valley Road, Motueka. (**I**) *Porella elegantula*, Riuwaka Valley Road, Motueka. Photos: P.J. de Lange.

nudipes var. *nudipes*, none of the liverworts recorded were common on rōhutu. With respect to liverwort families, the Lejeuneaceae was, as was also the case with ramarama, the largest contributing family to the liverwort assemblage on rōhutu with nine species from five genera, and with *Lejeunea* (four species) the most commonly encountered genus of that family. Members of the Lejeuneaceae were most commonly found on the branchlets just above the forks, in which places they often grew interdigitated with species of *Frullania*. In high light situations, *Frullania pycnantha* and *F. fugax* were the most common of the 17 liverworts reported, and easily the most conspicuous on account of their darkly pigmented foliage – often appearing black in the field. In shaded sites, *Metzgeria* sp. (possibly *M. howeana* Steph., previously attributed to a *M. furcata* (L.) Corda, a species now thought to not occur in Aotearoa / New Zealand – see Bechteler et al. [2021]) was often well developed, with large specimens mostly noted at the trunk base, where bark shedding is less of an issue.

We found 12 species of mosses on rōhutu (Appendix 1). At Lighthouse Bush, Āwhitu, where rōhutu grows in an exposed coastal shrubland, mosses were uncommon; there were two species of *Syntrichia* Brid., *S. laevipilia* and *S. papillosa*, while over the ridge at Signal Station Bush, where rōhutu grows within a mature coastal forest remnant, pin cushion moss was the most commonly encountered species. However, in shaded, humid habitats, such as those sites sampled within the riparian forest on the sides of the Riuwaka River, the upper branchlets of rōhutu were typically festooned in *Weymouthia cochlearifolia*, *W. mollis*, *Papillaria crocea* from the Lembophyllaceae Broth., and *Alleniella hymenodonta* from the Neckeraceae Schimp.

Pteridophyte associates of rōhutu were not evident in our herbarium searches, and our limited sampling only found four species from three families (Appendix 1). At Āwhitu, *Arthropteris tenella*, *Pyrrosia elaeagnifolia* and *Zealandia pustulata* subsp. *pustulata* were locally common at Signal Station Bush, growing on the taller rōhutu trees exposed along the western side of a coastal forest remnant.

Herbarium searches and field sampling only recorded two spermatophytes from rōhutu, the orchid *Drymoanthus adversus*, commonly seen on the upper trunk and branches of rōhutu at Signal Station Bush, and the hemiparasitic dwarf mistletoe *Korthalsella lindsayi*. Sultan et al. (2018) noted that rōhutu is an important secondary host for *Korthalsella lindsayi* (Figure 11).

Figure 11. The dwarf mistletoe Korthalsella lindsayi parasitic on rōhutu (*Lophomyrtus obcordata*), High Bare Peak, Little River, Horomaka Banks Peninsula. Photo: Alice Shanks.

As with ramarama, the greatest diversity of co-associates were lichenised mycobiota (see Figure 12 for some examples), with our herbarium searches and field sampling recording 44 taxa, 42 determined to species level and two (*Calicium* Pers., *Pyrenula* Ach.) to genus level. The largest contributing lichen families on rōhutu are the Parmeliaceae (six species from four genera), Ramalinaceae (six species from two genera) and the Collemataceae (six species from one genus, *Leptogium*). Of the 44 lichenised mycobiota documented here (Appendix 1) six are listed as 'At Risk / Naturally Uncommon', four as 'Data Deficient' and three are not assessed either because we were unable to obtain a species rank determination, or, as is the case for *Usnea dasaea*, it is a new addition to the lichenised mycobiota of Aotearoa / New Zealand (Bannister et al. 2020) and so does not as yet have a formal conservation assessment (c.f. de Lange et al. 2018b). As with the 'Data Deficient' lichens found on ramarama, the discovery of four 'Data Deficient' lichens found on rōhutu is an improvement on our poor knowledge of them, and their documentation here will help clarify their status in future

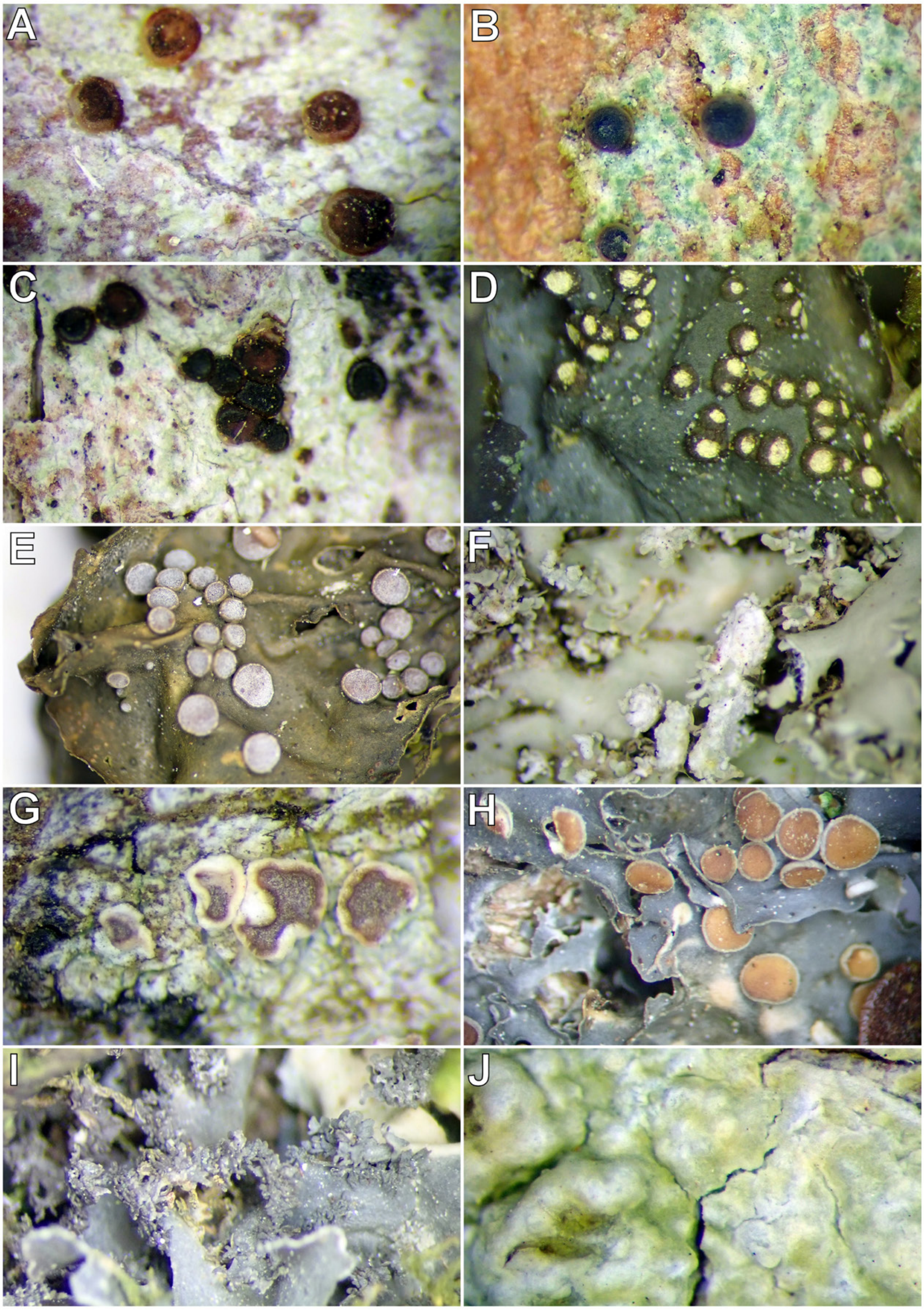

Figure 12. Lichenised mycobiota associated with rōhutu (*Lophomyrtus obcordata*). (**A**) *Bacidia laurocerasi*, Lighthouse Bush, Āwhitu Peninsula. (**B**) *Bacidia leucocarpi*, Riuwaka Valley Road, Motueka. (**C**) *Bacidia wellingtonii*, Lighthouse Bush, Āwhitu Peninsula. (**D**) *Collema laeve*, Riuwaka Valley Road, Motueka. (**E**) *Collema leucocarpum*, Waitaanga, North Taranaki. (**F**) *Heterodermia spathulifera*, Signal Station Bush, Āwhitu Peninsula. (**G**) *Lecanora flavopallida*, Signal Station Bush, Āwhitu Peninsula. (**H**) *Leptogium aucklandicum*, Riuwaka Valley Road, Motueka. (**I**) *Leptogium oceanianum*, Riuwaka Valley Road, Motueka. (**J**) *Pertusaria thiospoda*, Signal Station Bush, Āwhitu Peninsula. Photos: P.J. de Lange.

threat assessments. The most commonly encountered lichens on rōhutu were crustose species of the following genera: *Arthonia* Ach., *Arthopyrenia* A.Massal, *Bacidia*, *Coenogonium* Ehrenb. (*C. luteum* only) and *Pertusaria*. A species of *Calicium*, unfortunately only seen as sterile specimens, was extremely common in the windswept rōhutu growing at Lighthouse Bush, Āwhitu.

One *Pertusaria* DC., *P. puffina*, first recognised for Aotearoa / New Zealand by Er et al. (2015) from specimens collected off the trunks of manawa / mangrove (*Avicennia marina* subsp. *australasica* (Walp.) J.Everett) at Mataia, near Glorit, Kaipara Harbour, we found on rōhutu at the two sites sampled on the Āwhitu Peninsula. *Pertusaria puffina* was also recorded on ramarama sampled at the Awaroa Scenic Reserve, South Kawhia. This species, though much more widespread than initially believed, probably still merits the current threat listing of 'At Risk / Naturally Uncommon' as it remains biological sparse and occurrences are widely scattered.

Lophomyrtus ×ralphii

This hybrid is widespread wherever the ranges of ramarama and rōhutu overlap. For our study we were unable to sample a hybrid swarm. Herbarium searches located only one associate, the dwarf mistletoe *Korthalsella lindsayi*.

Conclusion

Although the decline of *Lophomyrtus* as a consequence of the spread of *Austropuccinia psidii* was predicted (de Lange et al. 2018a), ramarama and rōhutu as widespread species have suffered the fate common to many abundant species suddenly tipped into serious decline – ignorance. When de Lange et al. (2018a) listed ramarama and rōhutu as 'Threatened / Nationally Critical' they did so as a precautionary measure in response to the detection of *Austropuccinia* in Aotearoa / New Zealand. It was hoped that that listing would prove unwarranted. At the time of writing (April 2022), some four years later it is evident that this high listing was warranted; ramarama is now in serious decline throughout its range. Regional extinctions are now being witnessed, notably in Tairāwhiti / East Cape and the western Waikato (G. Atkins, pers. comm, 6 November 2021; authors' pers. obs.). Rōhutu, being more widespread, is so far less threatened, though the species is declining over a large part of its northern range (authors' pers. obs).

With these declines there is an urgent need to find effective conservation-management strategies to ensure the survival of both species. With that need comes the realisation of how little we know about the autecology and microbiome of ramarama and rōhutu.

This study, therefore, is an attempt to start the process of documenting the microbiome of ramarama and rōhutu. While our study is still preliminary, and we stress that a much wider sampling of both species, including their associated fungi and encompassing their full altitudinal and latitudinal spread, is needed, we found that *Lophomyrtus* support a diverse array of plants and lichenised mycobiota. In this paper we report on 221 taxa found from a sampling of eight *Lophomyrtus* populations (three *L. bullata*, five *L. obcordata*). While none of the taxa we found are confirmed as endemic to ramarama and rōhutu, the discovery of 15 lichens listed as 'Data Deficient' by de Lange et al. (2018b) highlights how the deliberate targeting of a phorophyte for lichens can help resolve the status of poorly known taxa. This was also noted by Blanchon et al. (2020), who reported similar results from their investigation of pōhutukawa. Further, at least one lichen, a *Fissurina,* has yet to be determined to species rank but a preliminary investigation and consultation with experts (A. Aptroot, R. Lücking, pers. comm. 28 January 2022) suggests it may be a new species, or a new record for Aotearoa / New Zealand.

As with Blanchon et al. (2020), we urge that more comprehensive sampling of *Lophomyrtus*, especially of non-lichenised mycobiota and cyanobacteria, is undertaken. We see this as high priority, considering the rapid decline, especially of ramarama, due to the ongoing spread of *Austropuccinia*.

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Appendix 1. List of flora and lichenised mycobiota found in association with *Lophomyrtus bullata, L. obcordata*, and *L. ×ralphii*

Lophomyrtus bullata

Taxon	Family	Threat Status	Voucher
Bryophytes (59)			
Hornworts (1)			
Dendroceros validus Steph.	Dendrocerotaceae	Not Threatened	CHR 633103
Liverworts (33)			
Chandonanthus squarrosus (Hook.) Schiffn.	Anastrophyllaceae	Not Threatened	UNITEC 13071
Hymenophyton leptopodum (Hook.f. et Taylor) Steph.	Hymenophytaceae	Not Threatened	CHR 657705
Frullania incumbens Mitt.	Frullaniaceae	Not Threatened	UNITEC 13167
Frullania patula Mitt.	Frullaniaceae	Not Threatened	UNITEC 13161
Frullania pycnantha (Hook.f. et Taylor) Taylor	Frullaniaceae	Not Threatened	UNITEC 13189
Frullania rostellata Mitt.	Frullaniaceae	Not Threatened	UNITEC 13163
Cheilolejeunea comitans (Hook.f. et Taylor). R.M.Schust.	Lejeuneaceae	Not Threatened	AK 291330
Cheilolejeunea mimosa (Hook.f. et Taylor). R.M.Schust.	Lejeuneaceae	Not Threatened	UNITEC 13159
Cheilolejeunea sp.	Lejeuneaceae	Not Assessed	UNITEC 13187
Cololejeunea laevigata (Mitt.) R.M.Schust.	Lejeuneaceae	Not Threatened	UNITEC 13178

Lejeunea colensoana (Steph.) M.A.M. Renner	Lejeuneaceae	Not Threatened	UNITEC 13171
Lejeunea flava (Sw.) Nees	Lejeuneaceae	Not Threatened	AK 291373
Lejeunea oracola M.A.M. Renner	Lejeuneaceae	Not Threatened	UNITEC 13183
Lopholejeunea (a) (AK 327822; New Zealand (*Lopholejeunea plicatiscypha* of Hamlin 1972)	Lejeuneaceae	Not Threatened	UNITEC 13186
Lopholejeunea colensoi Steph.	Lejeuneaceae	Not Threatened	CHR 620593
Thysananthus anguiformis (Hook.f. et Taylor) Taylor ex Gottsche, Lindenb. et Nees	Lejeuneaceae	Not Threatened	UNITEC 13182
Siphonolejeunea nudipes (Hook.f. et Taylor) Herzog var. *nudipes*	Lejeuneaceae	Not Threatened	UNITEC 13169
Spruceanthus olivaceus (Hook.f. et Taylor) X.Q.Shi, R.L.Zhu et Gradst.	Lejeuneaceae	Not Threatened	UNITEC 13190
Lepidolaena clavigera (Hook.) Trevis.	Lepidolaenaceae	Not Threatened	UNITEC 13158
Lepidolaena taylorii (Gottsche) Trevis.	Lepidolaenaceae	Not Threatened	UNITEC 13179
Chiloscyphus muricatus (Lehm.) J.J.Engel et R.M.Schust.	Lophocoleaceae	Not Threatened	UNITEC 13176
Dendromastigophora flagellifera (Hook.f.) R.M.Schust.	Mastigophoraceae	Not Threatened	UNITEC 11549
Metzgeria sp. (possibly *M. howeana* Steph.)	Metzgeriaceae	Not Threatened	UNITEC 13108
Plagiochila trispicata Colenso	Plagiochilaceae	Not Threatened	AK 316878
Plagiochila banksiana Gottsche	Plagiochilaceae	Not Threatened	UNITEC 13088
Porella amoena (Colenso) Martin	Porellaceae	Not Threatened	UNITEC 13105
Porella elegantula (Mont.) E.A.Hodgs.	Porellaceae	Not Threatened	UNITEC 11747

Radula allisonii Castle	Radulaceae	Not Threatened	UNITEC 13170
Radula demissa M.A.M.Renner	Radulaceae	Not Threatened	AK 315585
Radula grandis Steph.	Radulaceae	Not Threatened	AK 312086
Radula marginata Taylor ex Gottsche, Lindenb. et Nees	Radulaceae	At Risk – Declining	UNITEC 13177
Radula strangulata Hook.f. et Taylor	Radulaceae	Not Threatened	AK 360278
Leiomitra lanata (Hook.) R.M.Schust.	Trichocoleaceae	Not Threatened	UNITEC 13157
Mosses (25)			
Cratoneuropsis relaxa (Hook.f. et Wilson) M.Fleisch.	Amblystegiaceae	Not Threatened	UNITEC 13110
Braithwaitea sulcata (Hook.) A.Jaeger	Braithwaiteaceae	Not Threatened	UNITEC 11746
Rosulabryum subtomentosum (Hampe) J.R.Spence	Bryaceae	Not Threatened	UNITEC 13112
Cryphaea dilatatus (Hook.f. et Wilson) Paris et Schimp	Cryphaeaceae	Not Threatened	UNITEC 13090
Cryphaea tenella (Schwägr) Müll.Hal.	Cryphaeaceae	Not Threatened	UNITEC 13091
Holomitrium perichaetiale (Hook.) Brid.	Dicranaceae	Not Threatened	UNITEC 13185
Lopidium concinnum (Hook.) Hook.f. et Wilson	Hypopterygiaceae	Not Threatened	UNITEC 13122
Weymouthia mollis (Hedw.) Broth.	Lembophyllaceae	Not Threatened	UNITEC 13099
Weymouthia cochlearifolia (Schwägr.) Dixon	Lembophyllaceae	Not Threatened	UNITEC 13047
Leptostomum macrocarpon (Hedw.) Bach.Pyl.	Leptostomataceae	Not Threatened	UNITEC 13049

Papillaria crocea (Hampe) A.Jaeger	Meteoriaceae	Not Threatened	AK 315250
Papillaria flavolimbata (Müll.Hal. et Hampe) A. Jaeger	Meteoriaceae	Not Threatened	UNITEC 13095
Alleniella hymenodonta (Müll.Hal.) S.Olsson, Enroth et D.Quandt	Neckeraceae	Not Threatened	UNITEC 13093
Leptodon smithii (Hedw.) F.Weber et D.Mohr	Neckeraceae	Not Threatened	AK 289421
Macromitrium gracile (Hook.) Schwägr.	Orthotrichaceae	Not Threatened	CHR 461640
Macromitrium helmsii Paris	Orthotrichaceae	Not Threatened	CHR 104379
Macromitrium longipes (Hook.) Schwägr.	Orthotrichaceae	Not Threatened	UNITEC 13145
Orthorrhynchium elegans (Hook.f. et Wilson) Reichardt	Orthorrhynchiaceae	Not Threatened	UNITEC 11748
Sciadocladus menziesii (Hook.) Broth.	Pterobryellaceae	Not Threatened	UNITEC 13089
Cladomnion ericoides (Hook.) Hook. f. et Wilson	Ptychomniaceae	Not Threatened	UNITEC 13097
Ptychomnion aciculare (Brid.) Mitt.	Ptychomniaceae	Not Threatened	UNITEC 13098
Tetraphidopsis pusilla (Hook.f. et Dixon) Wilson	Ptychomniaceae	Not Threatened	AK 317733
Wijkia extenuata (Brid.) H.A.Crum var. *extenuata*	Sematophyllaceae	Not Threatened	UNITEC 13180
Wijkia extenuata var. *caudata* Fife	Sematophyllaceae	Not Threatened	UNITEC 13141
Trachyloma diversinerve Hampe	Trachylomataceae	Not Threatened	UNITEC 13096
Pteridophytes (6)			
Asplenium flaccidum G.Forst.	Aspleniaceae	Not Threatened	UNITEC 11705

Icarus filiformis (A.Cunn.) Gasper et Salino	Blechnaceae	Not Threatened	UNITEC 11569
Hymenophyllum sanguinolentum (G.Forst) Sw.	Hymenophyllaceae	Not Threatened	UNITEC 11732
Pyrrosia elaeagnifolia (Bory) Hovenkamp	Polypodiaceae	Not Threatened	UNITEC 11709
Zealandia pustulata (G.Forst.) Testo et A.R.Field subsp. *pustulata*	Polypodiaceae	Not Threatened	UNITEC 11708
Spermatophytes (16)			
Monocots I (3)			
Astelia hastata Colenso	Asteliaceae	Not Threatened	UNITEC 12648
Earina mucronata Lindl.	Orchidaceae	Not Threatened	UNITEC 11704
Ripogonum scandens J.R.Forst. et G.Forst.	Ripogonaceae	Not Threatened	UNITEC 13084
Monocot II – Commelinids (1)			
**Dactylis glomerata* L.	Poaceae	Naturalised	UNITEC 11710
Core Eudicots (12)			
**Sison amomum* L.	Apiaceae	Naturalised	UNITEC 11731
Parsonsia heterophylla A.Cunn.	Apocynaceae	Not Threatened	UNITEC 11706
Griselinia lucida (J.R.Forst et G.Forst.) G.Forst.	Griseliniaceae	Not Threatened	UNITEC 13168
Metrosideros diffusa (G.Forst.) Sm.	Myrtaceae	Nationally Vulnerable	UNITEC 11702

Metrosideros fulgens Sol. ex Gaertn	Myrtaceae	Nationally Vulnerable	UNITEC 11733
Fuchsia perscandens Cockayne et Allan	Onagraceae	Not Threatened	UNITEC 11568
Passiflora tetrandra Banks ex DC.	Passifloraceae	Not Threatened	UNITEC 11735
Pittosporum cornifolium A.Cunn.	Pittosporaceae	Not Threatened	CHR 33664
Muehlenbeckia complexa var. *grandifolia* Carse	Polygonaceae	Not Threatened	UNITEC 11707
Korthalsella clavata (Kirk) Cheeseman	Santalaceae	At Risk / Declining	CHR 33525
Korthalsella lindsayi (Oliv. ex Hook.f.) Engl.	Santalaceae	At Risk / Declining	CHR 33925
Urtica sykesii Grose-Veldman et Weigend	Urticaceae	Not Threatened	UNITEC 13083
Lichenised Mycobiota (96)			
Arthonia epiodes Nyl.	Arthoniaceae	Data deficient	UNITEC 13073
Arthonia indistincta C. Knight et Mitt.	Arthoniaceae	Data deficient	UNITEC 13087
Brigantiaea chrysosticta (Hook.f. et Taylor) Hafellner et Bellem.	Brigantiaeaceae	Not Threatened	UNITEC 13031
Brigantiaea phaeomma (Nyl.) Hafellner	Brigantiaeaceae	Not Threatened	UNITEC 13032
Cladonia darwinii S.Hammer	Cladoniaceae	Not Threatened	UNITEC 13059
Coccocarpia erythroxyli (Spreng.) Swinscow et Krog.	Coccocarpiaceae	Not Threatened	UNITEC 13021
Coccocarpia palmicola (Spreng.) Arv. et D.J. Galloway	Coccocarpiaceae	Not Threatened	UNITEC 12151
Coenogonium luteum (Dicks.) Kalb et Lücking	Coenogoniaceae	Not Threatened	UNITEC 13181

Collema leucocarpum Hook.f. et Taylor	Collemataceae	Not Threatened	UNITEC 13154
Collema subconveniens Nyl.	Collemataceae	Not Threatened	UNITEC 13147
Collema subflaccidum Degel.	Collemataceae	Naturally Uncommon	UNITEC 13149
Leptogium aucklandicum Zahlbr.	Collemataceae	Not Threatened	UNITEC 13220
Leptogium coralloideum (Meyen et Flot.) Vain.	Collemataceae	Naturally Uncommon	UNITEC 13103
Leptogium crispatellum Nyl.	Collemataceae	Not Threatened	UNITEC 12152
Leptogium cyanescens (Rabenh.) Körb.	Collemataceae	Not Threatened	UNITEC 13023
Leptogium oceanium Kitaura et Marcelli	Collemataceae	Not Threatened	UNITEC 13079
Fissurina Fée	Graphidaceae	Not Assessed	UNITEC 13121
Thelotrema lepadinum (Ach.) Ach.	Graphidaceaee	Not Threatened	UNITEC 13082
Haematomma hilare Zahlbr.	Haematommaceae	Not Threatened	CHR 626799
Lecidea fuscocincta Stirt.	Lecideaceae	Data Deficient	UNITEC 13025
Dictyonema C. Agardh ex Kunth	Lichenomphalloideae	Not Assessed	UNITEC 13080
Megalospora gompholoma (Müll.Arg.) C.W.Dodge subsp. *gompholoma*	Megalosporaceae	Not Threatened	UNITEC 13027
Ochrolechia pallescens (L.) A.Massal.	Ochrolechiaceae	Not Threatened	UNITEC 13028
Erioderma leylandii (Taylor) Müll. Arg.	Pannariaceae	Naturally Uncommon	UNITEC 13070
Fuscopannaria granulans P.M.Jørg.	Pannariaceae	Data Deficient	UNITEC 13360

Leioderma sorediatum D.J.Galloway et P.M. Jørg.	Pannariaceae	Not Threatened	UNITEC 13362
Pannaria araneosa (C. Babington) Hue	Pannariaceae	Not Threatened	UNITEC 11771
Pannaria delicata P.M. Jørg. et D.J.Galloway	Pannariaceae	Not Threatened	UNITEC 13358
Pannaria immixta Nyl.	Pannariaceae	Not Threatened	UNITEC 13359
Pannaria aff. *minutiphylla*	Pannariaceae	Not Assessed	UNITEC 11772
Parmeliella nigrocincta (Mont.) Müll.Arg.	Pannariaceae	Not Threatened	UNITEC 13357
Psoroma allorhizum (Nyl.) Hue	Pannariaceae	Not Threatened	UNITEC 13361
Parmotrema crinitum (Ach.) M.Choisy	Parmeliaceae	Not Threatened	UNITEC 13119
Parmotrema perlatum (Huds.) M.Choisy	Parmeliaceae	Not Threatened	UNITEC 13033
Parmotrema robustum (Degel.) Hale	Parmeliaceae	Naturally Uncommon	UNITEC 13078
Tuckermannopsis chlorophylla (Willd.) Hale	Parmeliaceae	Data Deficient	UNITEC 13072
Usnea angulata Ach.	Parmeliaceae	Not Threatened	UNITEC 13060
Usnea baileyi (Stirt.) Zahlbr.	Parmeliaceae	Data Deficient	UNITEC 13215
Usnea dasaea Stirt.	Parmeliaceae	Not Assessed	UNITEC 13076
Usnea rubicunda Stirt.	Parmeliaceae	Not Threatened	UNITEC 12149
Usnea aff. *baileyi*	Parmeliaceae	Not Assessed	UNITEC 13233
Crocodia aurata (Acharius) Link	Peltigeraceae	Not Threatened	UNITEC 12146

Crocodia poculifera (Müller Arg.) D.J. Galloway et Elix	Peltigeraceae	Naturally Uncommon	UNITEC 12150
Crocodia rubella (Hook.f. et Taylor) Trevis.	Peltigeraceae	Not Threatened	UNITEC 13153
Podostictina pickeringii (Tuck.) Moncada et Lücking	Peltigeraceae	Not Threatened	UNITEC 13036
Pseudocyphellaria billardierei (Delise) Räsänen	Peltigeraceae	Not Threatened	UNITEC 13151
Pseudocyphellaria carpoloma (Delise) Vain.	Peltigeraceae	Not Threatened	UNITEC 13164
Pseudocyphellaria coriacea (Hook.f. et Taylor) D.J. Galloway et P. James	Peltigeraceae	Not Threatened	UNITEC 13129
Pseudocyphellaria chloroleuca (Hook.f. et Taylor) Du Rietz	Peltigeraceae	Not Threatened	UNITEC 13063
Pseudocyphellaria crocata (L.) Vain.	Peltigeraceae	Not Threatened	UNITEC 7123
Pseudocyphellaria dissimilis (Nyl.) D.J.Galloway et P.James	Peltigeraceae	Not Threatened	UNITEC 13065
Pseudocyphellaria faveolata (Delise) Malme	Peltigeraceae	Not Threatened	UNITEC 13086
Pseudocyphellaria glabra (Hook.f. et Taylor) C.W. Dodge	Peltigeraceae	Not Threatened	UNITEC 13085
Pseudocyphellaria haywardiorum D.J. Galloway	Peltigeraceae	Naturally Uncommon	UNITEC 13077
Pseudocyphellaria intricata (Delise) Vain.	Peltigeraceae	Naturally Uncommon	UNITEC 13043
Pseudocyphellaria montagnei (C.Bab.) D.J. Galloway et P. James	Peltigeraceae	Not Threatened	UNITEC 13165
Pseudocyphellaria multifida (Laurer) D.J. Galloway et P. James	Peltigeraceae	Not Threatened	UNITEC 13101
Pseudocyphellaria rufovirescens (C.Bab.) D.J. Galloway	Peltigeraceae	Not Threatened	UNITEC 13104
Sticta fuliginosa (Dicks.) Ach.	Peltigeraceae	Not Threatened	UNITEC 9627

Sticta latifrons A. Rich.	Peltigeraceae	Not Threatened	UNITEC 12147
Sticta limbata (Sm.) Ach.	Peltigeraceae	Not Threatened	UNITEC 13155
Sticta martini D.J.Galloway	Peltigeraceae	Not Threatened	UNITEC 13044
Lepra erythrella (Müll.Arg.) I.Schmitt, B.G.Hodk. et Lumbsch	Pertusariaceae	Not Assessed	UNITEC 13356
Lepra psoromica (A.W.Archer et Elix) A.W.Archer et Elix	Pertusariaceae	Not Threatened	UNITEC 13022
Pertusaria alboatra Zahlbr.	Pertusariaceae	Naturally Uncommon	UNITEC 13120
Pertusaria puffina A.W.Archer et Elix	Pertusariaceae	Naturally Uncommon	UNITEC 13034
Pertusaria sorodes Stirt.	Pertusariaceae	Not Threatened	UNITEC 13062
Pertusaria thiospoda C.Knight	Pertusariaceae	Not Threatened	UNITEC 13045
Leucodermia leucomelos (L.) Kalb	Physciaceae	Not Threatened	UNITEC 13024
Physcia albata (F. Wilson) Hale	Physciaceae	Not Threatened	UNITEC 13235
Physcia jackii Moberg	Physciaceae	Not Threatened	UNITEC 13156
Polyblastidium casarettianum (A.Massal.) Kalb	Physicaceae	Naturally Uncommon	UNITEC 13066
Phlyctis uncinata Stirt.	Phlyctidaceae	Not Threatened	UNITEC 13061
Phlyctis subuncinata Stirt.	Phlyctidaceae	Not Threatened	UNITEC 13209
Bapalmuia buchananii (Stirt.) Kalb et Lücking	Pilocarpaceae	Not Threatened	UNITEC 13058
Calopadia subcoerulescens (Zahlbr.) V□zda	Pilocarpaceae	Not Threatened	UNITEC 13188

Porina exocha (Nyl.) P.M.McCarthy	Porinaceae	Not Threatened	UNITEC 13042
Porina "green sorediate"	Porinaceae	Not Assessed	UNITEC 13232
Pyrenula leucostoma Ach.	Pyrenulaceae	Not Assessed	UNITEC 13056
Pyrenula nitidula (Bres.) R.C.Harris	Pyrenulaceae	Not Threatened	UNITEC 13057
Bacidia laurocerasi (Delise ex Duby) Vain.	Ramalinaceae	Not Threatened	UNITEC 13029
Bacidia leucothalamia (Nyl.) Hellb.	Ramalinaceae	Data Deficient	UNITEC 13204
Bacidia minutissima C.Knight	Ramalinaceae	Data Deficient	UNITEC 13126
Bacidia superula (Nyl.) Hellb.	Ramalinaceae	Data Deficient	UNITEC 13207
Megalaria grossa (Pers. ex Nyl.) Hafellner	Ramalinaceae	Not Threatened	UNITEC 13206
Megalaria melanotropa (Nyl.) D.J.Galloway	Ramalinaceae	Not Threatened	UNITEC 13068
Megalaria aff. *orokonuiana* Fryday et A.Knight	Ramalinaceae	Not Assessed	UNITEC 13064
Phyllopsora furfuracea (Pers.) Zahlbr.	Ramalinaceae	Data Deficient	UNITEC 13035
Ramalina geniculata Hooker f. et Taylor	Ramalinaceae	At Risk / Declining	UNITEC 12148
Enterographa pallidiella (Nyl.) Redinger	Roccellaceae	Not Threatened	UNITEC 13074
Bunodophoron murrayi (Ohlsson ex Tibell) Wedin	Sphaerophoraceae	Not Threatened	AK 309531
Lepraria Ach.	Stereocaulaceae	Not Assessed	UNITEC 13038
Lepraria ulrikii Grewe, Barcenas-Peña, Diaz et Lumbsch	Stereocaulaceae	Not Assessed	UNITEC 13039

Arthopyrenia peltigerella Zahlbr.	Trypethellaceae	Data Deficient	UNITEC 13213
Arthopyrenia sp.	Trypethellaceae	Not Assessed	UNITEC 13115
Normandina pulchella (Borrer) Nyl.	Verrucariaceae	Not Threatened	UNITEC 11744

Lophomyrtus obcordata

Taxon	Family	Threat Status	Voucher
Cyanophyceae (1)			
Tolypothrix c.f. *pseudodoxia*	Microchaetaceae	Not Assessed	CHR PdL 14668
Chlorophyta (1)			
Trentepohlia Mart.	Trentepohliaceae	Not Assessed	UNITEC 11495
Bryophytes (29)			
Liverworts (17)			
Frullania fugax (Hook.f. et Taylor) Taylor	Frullaniaceae	Not Threatened	UNITEC 11461
Frullania pycnantha (Hook.f. et Taylor) Gottsche, Lindenb. et Nees	Frullaniaceae	Not Threatened	UNITEC 13214
Frullania rostellata Mitt.	Frullaniaceae	Not Threatened	AK357971
Frullania squarrosula (Hook.f. et Taylor) Taylor	Frullaniaceae	Not Threatened	UNITEC 11460
Acrolejeunea mollis (Hook.f. et Taylor) Schiffn.	Lejeuneaceae	Naturally Uncommon	UNITEC 11529
Lejeunea demissa M.A.M. Renner	Lejeuneaceae	Not Assessed	UNITEC 13226

Lejeunea gracilipes (Taylor) Spruce	Lejeuneaceae	Not Threatened	UNITEC 11531
Lejeunea hodgsoniana Grolle ex R.J.Lewington, P.Beveridge et M.A.M.Renner	Lejeuneaceae	Not Threatened	UNITEC 11438
Lejeunea oracola M.A.M.Renner	Lejeuneaceae	Not Threatened	UNITEC 11444
Myriocoleopsis minutissima (Sm.) R.L.Zhu, Y.Yu et Pócs	Lejeuneaceae	Not Threatened	UNITEC 11440
Siphonolejeunea hamata (Grolle) M.A.M.Renner	Lejeuneaceae	Not Threatened	UNITEC 11441
Siphonolejeunea nudipes var. *nudipes* (Hook.f. et Taylor) Herzog	Lejeuneaceae	Not Threatened	UNITEC 13192
Spruceanthus olivaceus (Hook.f. et Taylor) X.Q.Shi, R.L.Zhu et Gradst.	Lejeuneaceae	Not Threatened	UNITEC 11445
Metzgeria sp. (possibly *M. howeana* Steph.)	Metzgeriaceae	Not Threatened	UNITEC 11436
Metzgeria bartlettii Kuwah.	Metzgeriaceae	Not Threatened	UNITEC 13191
Porella elegantula (Mont.) E.A.Hodgs.	Porellaceae	Not Threatened	UNITEC 13223
Porella sp. (a)	Porellaceae	Not Assessed	UNITEC 13224
Mosses (12)			
Camptochaete arbuscula (Sm.) Reichardt	Lembophyllaceae	Not Threatened	CHR 512948
Weymouthia cochlearifolia (Schwägr.) Dixon	Lembophyllaceae	Not Threatened	UNITEC 13200
Weymouthia mollis (Hedw.) Broth.	Lembophyllaceae	Not Threatened	UNITEC 13201
Leptostomum macrocarpon (Hedw.) Bach.Pyl.	Leptostomataceae	Not Threatened	UNITEC 11530
Papillaria crocea (Hampe) A.Jaeger	Meteoriaceae	Not Threatened	UNITEC 13199

Alleniella hymenodonta (Müll.Hal.) S.Olsson, Enroth et D.Quandt	Neckeraceae	Not Threatened	UNITEC 13193
Neckera laevigata Hook.f. et Wils.	Neckeraceae	Not Threatened	CHR 438747
Macrocoma tenue (Hook. et Grev.) Vitt	Orthotrichaceae	Not Threatened	UNITEC 11527
Orthotrichium tasmanicum Hook.f. et Wilson	Orthotrichaceae	Not Threatened	UNITEC 13222
Syntrichia laevipila Brid.	Pottiaceae	Not Threatened	UNITEC 11526
Syntrichia papillosa (Wilson) Jur.	Pottiaceae	Not Threatened	UNITEC 11528
Rhaphidorrhynchium amoenum (Hedw.) M.Fleisch.	Sematophyllaceae	Not Threatened	UNITEC 11525
Pteridophytes (4)			
Arthropteris tenella (G.Forst.) J.Sm. ex Hook.f.	Tectariaceae	Not Threatened	UNITEC 11552
Asplenium flaccidum G.Forst.	Aspleniaceae	Not Threatened	UNITEC 11553
Pyrrosia eleagnifolia (Bory) Hovenkamp	Polypodiaceae	Not Threatened	UNITEC 11555
Zealandia pustulata (G.Forst.) Testo et A.R.Field	Polypodiaceae	Not Threatened	UNITEC 11554
Spermatophytes (2)			
Monocots I (1)			
Drymoanthus adversus (Hook.f.) Dockrill	Orchidaceae	Not Threatened	UNITEC 11556
Core Eudicots (1)			
Korthalsella lindsayi (Oliv. ex Hook.f.) Engl.	Santalaceae	Not Threatened	CHR 507984

Lichenised Mycobiota (44)			
Arthonia atra (Pers.) A.Schneid.	Arthoniaceae	Naturally Uncommon	UNITEC 11427
Arthonia radiata (Pers.) Ach.	Arthoniaceae	Not Threatened	UNITEC 11442
Bactrospora arthonioides Egea et Torrente	Arthoniales incertae sedis	Data Deficient	UNITEC 11374
Dirinaria applanata (Fée) D.D. Awasthi	Caliciaceae	Not Threatened	UNITEC 11512
Calicium Pers.	Caliciaceae	Not Assessed	UNITEC 11523
Coenogonium luteum (Dicks.) Kalb et Lücking	Coenogoniaceae	Not Threatened	UNITEC 11428
Collema laeve Hook.f. et Taylor	Collemataceae	Not Threatened	UNITEC 13234
Leptogium aucklandicum Zahlbr.	Collemataceae	Not Threatened	UNITEC 13198
Leptogium cyanescens (Ach.) Körb.	Collemataceae	Not Threatened	UNITEC 11456
Leptogium coralloideum (Meyen et Flot.) Vain.	Collemataceae	Naturally Uncommon	UNITEC 11457
Leptogium crispatellum Nyl.	Collemataceae	Not Threatened	UNITEC 13203
Leptogium oceanium Kitaura et Marcelli	Collemataceae	Not Threatened	UNITEC 13231
Halegrapha mucronata (Stirt.) Lücking	Graphidaceae	Not Threatened	UNITEC 11382
Thalloloma subvelata (Stirt.) D.J. Galloway	Graphidaceae	Not Threatened	UNITEC 11375
Lecanora flavopallida Stirt.	Lecanoraceae	Not Threatened	UNITEC 11492
Opegrapha agelaeoides Nyl.	Opegraphaceae	Not Threatened	UNITEC 11522

Parmotrema crinitum (Ach.) M.Choisy	Parmeliaceae	Not Threatened	UNITEC 11453
Parmotrema perlatum (Huds.) M.Choisy	Parmeliaceae	Not Threatened	UNITEC 11431
Parmotrema reticulatum (Taylor) M.Choisy	Parmeliaceae	Not Threatened	UNITEC 11430
Usnea dasaea Stirt.	Parmeliaceae	Not Assessed	UNITEC 11435
Usnea rubicunda Stirt.	Parmeliaceae	Not Threatened	UNITEC 11429
Punctelia borreri (Sm.) Krog	Parmeliaceae	Not Threatened	UNITEC 11448
Sticta fuliginosa (Hoffm.) Ach.	Peltigeraceae	Not Threatened	UNITEC 13194
Pseudocyphellaria aff. *crocata* (a) (UNITEC 7123; Wairarapa)	Peltigeraceae	Naturally Uncommon	UNITEC 13196
Pertusaria puffina A.W. Archer et Elix	Pertusariaceae	Naturally Uncommon	UNITEC 11377
Pertusaria sorodes Stirt.	Pertusariaceae	Not Threatened	UNITEC 13228
Pertusaria thiospoda C. Knight	Pertusariaceae	Not Threatened	UNITEC 11511
Heterodermia spathulifera Moberg et Purvis	Physciaceae	Data Deficient	UNITEC 11449
Physcia adscendens (Fr.) H. Olivier	Physciaceae	Not Threatened	UNITEC 11458
Physcia poncinsii Hue	Physciaceae	Not Threatened	UNITEC 11379
Physcia jackii Moberg	Physciaceae	Not Threatened	UNITEC 11380
Polyblastidium casarettianum (A.Massal.) Kalb	Physciaceae	Naturally Uncommon	UNITEC 13219
Pyrenula Ach.	Pyrenulaceae	Not Assessed	UNITEC 11433

Ramalina celastri (Spreng.) Krog & Swinscow	Ramalinaceae	Not Threatened	UNITEC 11434
Ramalina peruviana Ach.	Ramalinaceae	Not Threatened	UNITEC 11455
Bacidia laurocerasi (Del. ex Duby) Vain.	Ramalinaceae	Not Threatened	UNITEC 11493
Bacidia leucocarpa C. Knight	Ramalinaceae	Data Deficient	UNITEC 13227
Bacidia leucothalamia (Nyl.) Hellb.	Ramalinaceae	Data Deficient	UNITEC 13205
Bacidia wellingtonii (Stirt.) D.J.Galloway	Ramalinaceae	Not Threatened	UNITEC 11494
Teloschistes sieberianus (Laurer) Hillmann	Teloschistaceae	Naturally Uncommon	UNITEC 11381
Teloschistes chrysophthalmus (L.) Th.Fr.	Teloschistaceae	Not Threatened	UNITEC 11443
Xanthoria parietina (L.) Th.Fr.	Teloschistaceae	Not Threatened	UNITEC 11454
Arthopyrenia minutella (C. Knight) Müll. Arg.	Trypethellaceae	Not Threatened	UNITEC 11514
Normandina pulchella (Borrer) Nyl.	Verrucariaceae	Not Threatened	UNITEC 11452

Lophomyrtus xralphii

Taxon	Family	Threat Status	Voucher
Spermatophytes (1)			
Core Eudicots (1)			
Korthalsella lindsayi (Oliv. ex Hook.f.) Engl.	Santalaceae	Not Threatened	

Authors

Manisha Prasad is a graduate of the Bachelor of Applied Science programme at the School of Environmental and Animal Sciences, Unitec, Te Pūkenga. She has previously volunteered at the Auckland Museum Botany Department and has undertaken field work at Āwhitu Peninsula and Awaroa Scenic Reserve examining the microbiome of *Lophomyrtus*. Manisha is now a Laboratory Technician at AsureQuality. manisha.prasad@AsureQuality.com

Luzie Schmid has completed the Bachelor of Applied Science programme at the School of Environmental and Animal Sciences, Unitec, Te Pūkenga. With interests in botany, genetics and taxonomy, she has been working in the Unitec Herbarium for two years, curating specimens and helping with research on *Lagenophora*, *Leptospermum* and *Muehlenbeckia*. Luzie has published three papers and undertaken field work on Rēkohu / Chatham Islands. lschmid@unitec.ac.nz

Andrew J. Marshall is a graduate of the Bachelor of Applied Science programme and now a Research Associate at the School of Environmental and Animal Sciences, Unitec, Te Pūkenga. He is an author of eight papers, has broad interests in botany and especially crustose lichens, and is engaged in a study of the lichenised mycobiota of northern Aotearoa / New Zealand. Andrew is the director of an ecological consultancy specialising in surveying and mapping the indigenous native and naturalised flora of the Tāmaki Makaurau / Auckland region. eco@lgm.kiwi

Dan J. Blanchon is Head of the School of Environmental and Animal Sciences and an Associate Professor at Unitec, Te Pūkenga, and teaches botany, biosecurity, ecology and biodiversity courses in the Bachelor of Applied Science. Dan currently has active research projects on the ecology and management of invasive plants and the systematics, ecology and conservation of native plants and lichens. dblanchon@unitec.ac.nz

Matthew A.M. Renner worked as a Research Scientist at the National Herbarium of New South Wales for over a decade, maintaining during that time a strong interest in the Australasian liverwort flora. Matt moved back to Aotearoa / New Zealand in 2022 to start a position as a Senior Botanist and Ecologist with Wildlands Consultancy. Matt has published many papers on a range of subjects from liverwort and vascular plant taxonomy to orchidology. He is a Fellow of the Linnean Society (elected 2010) and the recipient of the 2019 Richard Spruce Award for contributions to bryology (International Association of Bryologists). matthewamrenner@icloud.com

Yumiko Baba is the Associate Curator of Botany at the Auckland Museum herbarium (AK), where she works with a team of botanists looking after and researching the plant collections. Her research interests include whakapapa (lineages), the discovery of new species and the diversity of plants of Aotearoa / New Zealand and the Pacific regions through to Asia. Ybaba@aucklandmuseum.com

Mahajabeen Padamsee is the Curator of the New Zealand Fungarium (PDD) Te Kohinga Hekaheka o Aotearoa at Manaaki Whenua Landcare Research. As a mycologist, Mahajabeen has published primarily on fungal taxonomy of the agarics and rust fungi. She currently leads the Endeavour-funded Beyond Myrtle Rust programme. padamseem@landcareresearch.co.nz

Peter J. de Lange is a Professor teaching at the School of Environmental and Animal Sciences, Unitec, Te Pūkenga. A biosystematist, Peter regularly publishes on plant taxonomy, conservation, threat listing, and the flora of South Pacific and outlying Aotearoa / New Zealand islands. A recipient of the New Zealand Botanical Society Allan Mere Award (2006) and Loder Cup (2017), Peter is a Fellow of the Linnean Society and a lifetime member of the New Zealand Plant Conservation Network. pdelange@unitec.ac.nz

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Foliage consumption of the Honshu white admiral *Limenitis glorifica* Fruhstorfer, 1909 (Lepidoptera: Nymphalidae) on Japanese honeysuckle *Lonicera japonica* Thunb. (Dipsacales: Caprifoliaceae) in Aotearoa / New Zealand

Adam Parkinson

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Contact:
epress@unitec.ac.nz
www.unitec.ac.nz/epress/
Unitec, Te Pūkenga
Private Bag 92025
Victoria Street West, Auckland 1010
Aotearoa / New Zealand

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Foliage consumption of the Honshu white admiral *Limenitis glorifica* Fruhstorfer, 1909 (Lepidoptera: Nymphalidae) on Japanese honeysuckle *Lonicera japonica* Thunb. (Dipsacales: Caprifoliaceae) in Aotearoa / New Zealand

Adam Parkinson

Abstract

Aotearoa / New Zealand harbours more naturalised non-native plant species than almost any other island group in the world, some of which are serious threats to indigenous biodiversity. Japanese honeysuckle (*Lonicera japonica*), a non-native climbing vine, is widespread across the country, and is considered a serious threat due to the nature of its growth habits and smothering effects upon indigenous flora. In 2014, the Honshu white admiral butterfly (*Limenitis glorifica*) was released in Aotearoa / New Zealand as a biological control agent, as this species has been shown to be narrowly oligophagous to Japanese honeysuckle. It is believed that the larva of this butterfly could cause substantial feeding damage; sufficient to reduce the plants' fitness. However, the amount of foliage that could be consumed by Honshu white admiral larvae is unknown. This study monitored 30 larvae from egg to pupation, and found that a single larva could consume 2.13g of Japanese honeysuckle foliage before pupating. This equates to approximately 5.6 leaves (based on the mean weight of a mature honeysuckle leaf). These findings give an insight into the defoliation potential this biocontrol agent could have upon Japanese honeysuckle, although further research is needed to determine the physiological response of the invasive plant based on this level of herbivory.

Keywords

Biocontrol, invasive plant, Aotearoa / New Zealand, biodiversity, Lepidoptera, Nymphalidae, Dipsacales, Caprifoliaceae, *Lonicera japonica*, *Limenitis glorifica*

Introduction

Aotearoa / New Zealand's ecosystems are being impacted by over 2800 species of naturalised plant, of which over 300 are considered to be actual or potential invasive weeds (Froude 2002; Ogle et al. 2020; Schönberger et al. 2021). This estimate of invasive plant species is but a subset of the more than 19,000 non-native freshwater and terrestrial species currently in Aotearoa / New Zealand, thousands of which have naturalised since the late 19th century (Froude 2002). The consequences that these introductions pose are severe, with many highly invasive weeds having the potential to transform natural landscapes, community composition and ecological dynamics (Effah et al. 2020). As it is, approximately 50% of all uncultivated vascular plant species present in Aotearoa / New Zealand are non-indigenous, resulting in many coastal habitats, lowland forests, shrublands, wetlands and tussock grasslands being invaded and subsequently dominated (Hulme 2020; Aikio et al. 2012). This includes hundreds of thousands of hectares of conservation land and critically endangered ecosystems, where plant invasions threaten up to one-third of all this country's nationally threatened plant species (Hulme 2020).

Most flora introduced into Aotearoa / New Zealand lack the natural enemies that are present in their native range, and without these coevolved controls to limit their vigour and density, their growth and spread can become excessive (Poland et al. 2021). Japanese honeysuckle (*Lonicera japonica* Thunb., Caprifoliaceae) is native to Japan, Korea and eastern China. It was first recorded as being naturalised in this country in 1926, and today is abundant throughout the North Island, upper regions of the South Island, and a growing number of offshore islands, including the Chatham Islands (Webb et al.

Figure 1. *Lonicera japonica* (Caprifoliaceae) in flower, Split Apple Bay (western Tasman Bay), Te Wai Pounamu / South Island, 26 November 2019. Photo: Peter J. de Lange.

Figure 2. Honshu white admiral *Limenitis glorifica* Fruhstorfer, 1909 (Lepidoptera: Nymphalidae) imago. Photo: Adam Parkinson.

1988). The Department of Conservation (DOC) has listed Japanese honeysuckle as one of the 18 "A-category" invasive weeds, prevalent in Protected Natural Areas in 70% of DOC conservancies (Williams & Timmins 1998).

Japanese honeysuckle is a perennial vine that spreads by rhizomes, above-ground runners, and occasionally by seed. In Aotearoa / New Zealand it can be seen in bloom (Figure 1) from September through to May, flowers are sweetly fragrant white-yellow, and the fruit is a many-seeded black berry that matures in the autumn months (Waipara et al. 2007). Leaves are ovate or oblong in shape (young leaves are often lobed), 4–8 cm long, sparsely pubescent, with a short petiole (Nuzzo 1997). The leaf phenology of Japanese honeysuckle varies depending on its locality, deciduous in the colder parts of its range in Aotearoa / New Zealand, to evergreen in warmer regions (Schierenbeck 2004).

Once introduced to a site, Japanese honeysuckle can quickly build up a mass of vegetation, using surrounding vegetation and its own stems for support to form dense, tangled curtains. It competes with native flora and restricts seedlings from establishing beneath its canopy, leading to a simplified vegetation structure with lower biodiversity (Williams & Timmins, 1998). Herbicides are most commonly used to control Japanese honeysuckle, which are either sprayed directly onto standing foliage, or applied directly onto cut stem stumps and regrowth (Standish 2002). Although effective, conventional control is regarded as impractical at most sites as herbicide application can cause significant collateral damage to the non-target species (Peterson et al. 2020), which Japanese honeysuckle is often found smothering. This approach is also costly. DOC has estimated $791,621 per year over a 10-year period to eradicate Japanese honeysuckle at Kopuatai Peat Dome (-37.41653, 175.55092) in the North Island of Aotearoa / New Zealand, an area of 2111 ha. DOC emphasises the considerable risk of failure this approach may have (Paynter et al. 2017).

In 2012, the Greater Wellington Regional Council, in collaboration with Manaaki Whenua Landcare Research, made an application to the Environmental Protection Authority (EPA) to introduce the Honshu white admiral butterfly (*Limenitis glorifica* Fruhstorfer, 1909) as a biological control agent for Japanese honeysuckle. Although this species has not been used as a biocontrol agent anywhere in the world before, permission was granted by the EPA in 2013 and the butterfly was released in spring of 2014 (Paynter et al. 2017). The purpose of introducing the Honshu white admiral butterfly was to establish self-sustaining populations that would contribute to the suppression of Japanese honeysuckle (Environmental Protection Authority 2019).

The Honshu white admiral is endemic to the island of Honshu, Japan, and is mainly found in open areas or light shrubland in dry warm-temperate habitats (Tanaka 1978). It is widely distributed from the western lowlands of Yamaguchi Prefecture to Shimokita Peninsula in the

Figure 3. Honshu white admiral, *Limenitis glorifica* Fruhstorfer, 1909 (Lepidoptera: Nymphalidae) larvae final instar. December 2021. Photo: Adam Parkinson.

north, and has an altitudinal limit of 1450 metres but is most abundant in lowland areas (Tanaka 1978). Honshu white admiral imago (Figure 2) are black with have a distinctive white band across the fore and hindwings, with reddish-brown, white and black markings underneath (wingspan 50–70 mm). Females will deposit 150–200 eggs individually on the upper and lower surfaces of Japanese honeysuckle leaves over a 2–4-week period. Fertile eggs take c.7 days to hatch in optimal conditions (Paynter et al. 2017). As the larvae (Figure 3) feed on Japanese honeysuckle foliage, they develop and grow through five instars. Initially hatching as a minute (4–5 mm) brown larva, when fully grown (25 mm) has a double row of branched reddish spines along its dark-green body. Development from egg to imago can take place within c.8 weeks if temperatures are warm and favourable. Within its natural range of Japan, this species will produce 1–4 generations annually; however, it is still uncertain how many generations will be produced in this country (Paynter et al. 2017).

The EPA reported that each larva could destroy several leaves during its development (Hill 2019). However, the quantity of Japanese honeysuckle leaves a single larva can consume has not been tested. Despite being a common butterfly in Japan, the Honshu white admiral is little studied, other than the species' distribution and host plant preferences. This study aims to collect preliminary data on the consumption quantities of Honshu white admiral larvae on Japanese honeysuckle under controlled conditions.

Methods

Japanese honeysuckle was sourced from naturalised plants growing on the Unitec, Te Pūkenga campus, Tāmaki Makaurau / Auckland. These were grown on from cuttings in the Unitec butterfly enclosure (36°52'47.5"S 174°42'21.0"E), under naturalistic conditions, in 13 m plots in organic potting mix (Living Earth). No additional fertilisers were used. Mature leaves were harvested for feeding trials six months after initial planting. Consumption tests were conducted between 27 November and 21 December 2021.

Fertile eggs of the Honshu white admiral were obtained from an established captive population, donated by Manaaki Whenua Landcare Research, Lincoln. To ensure that the larvae were in similar stages of development, those selected for consumption measurements had emerged from the egg within a 3-hour window of one another. Between consumption tests the larvae were kept in 33 cm x 33 cm x 61 cm mesh enclosures in the Unitec butterfly enclosure, with access to the host plant.

Undamaged mature leaves that had reached their full dimensions were cut from the main stem at the midpoint of the petiole. The weight (g) of each leaf was recorded using a Sartorius (type 1702) precision scale prior to each consumption test, and these amounts were combined to give a mean value. The ends of the petioles were then wrapped in moistened cotton to prevent desiccation (3 ml of water added to the cotton by pipette). Larvae were placed individually on each single leaf of weighed honeysuckle. Each leaf and larva were enclosed in a paper cup (10 cm height, 7 cm diameter), covered with monofilament polyethylene bio-mesh, securing the larvae, protecting them from predation and allowing ventilation (Figure 4). After 24 hours, the larvae, frass and silk were removed, and remaining leaf material was weighed. This trial was repeated every 4 days until the larvae pupated. Growth rates of the larvae were not monitored; however, observations on instar stages were noted throughout the experiment.

A single control leaf was monitored during each consumption test to calculate moisture loss caused by evaporation. These control leaves were exposed to the same conditions as the experimental group (petiole submerged in cotton wool with 3 ml of water added), and weighed before and after the 24-hour test period.

The larvae were managed as a cohort, and their consumption amounts were combined. Individual larva consumption quantities were not recorded. The mean

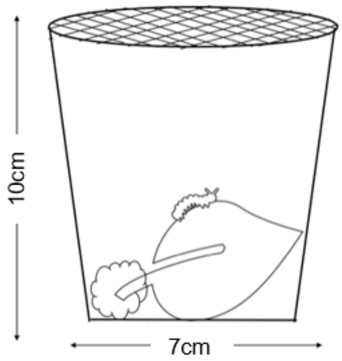

Figure 4. Honshu white admiral larva, and Japanese honeysuckle leaf with moistened cotton around petiole to prevent desiccation in containment over 24-hour test period. Secured with monofilament polyethylene bio-mesh.

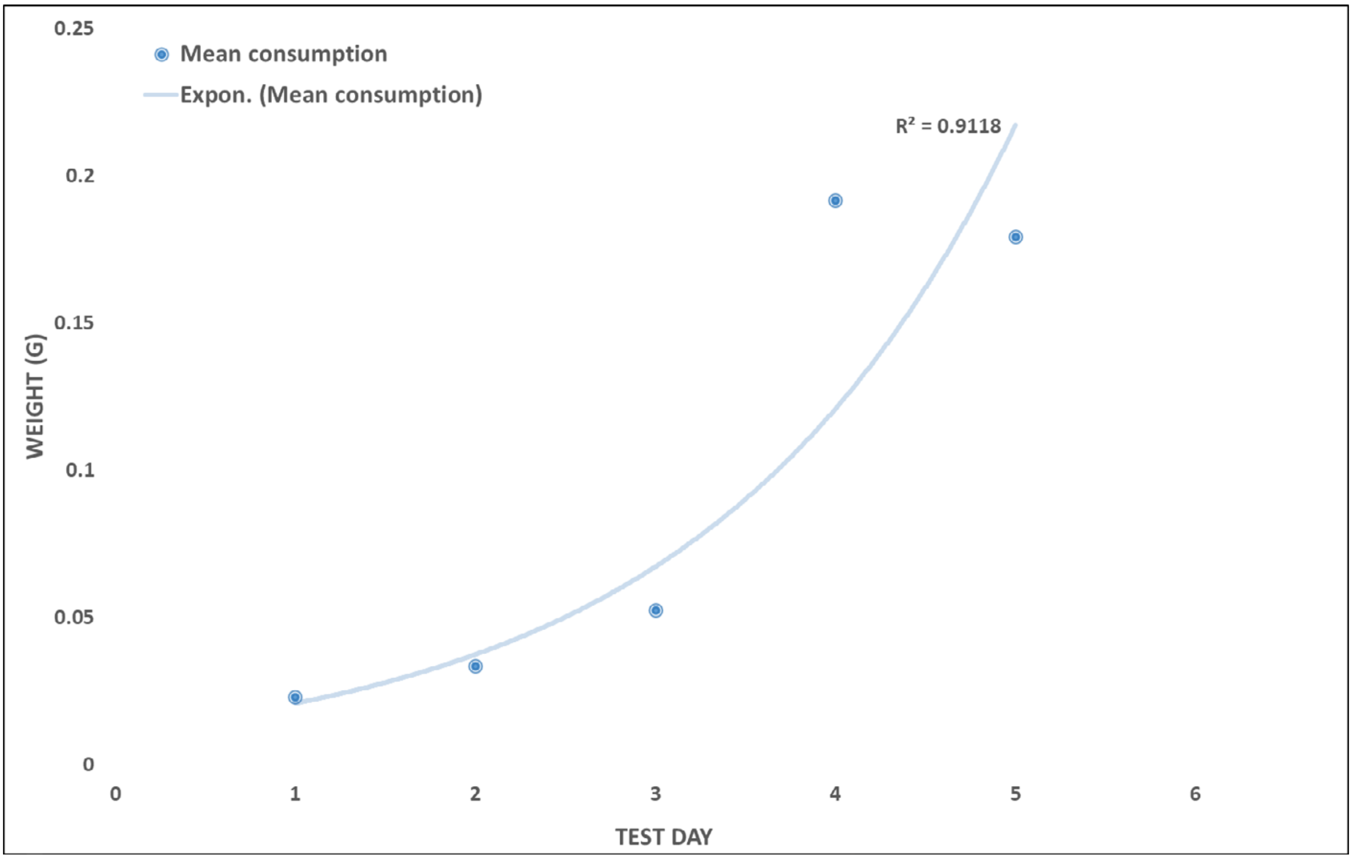

Figure 5. Exponential curve fitted to the collected data points (blue circles) of the combined mean consumption values (n = 30) for each test day, and predicted consumption weight.

Date	Test	Leaf consumption (g) after 24 hours (Mean)	Larval instar	Mean leaf weight (g)	Single control leaf moisture loss (g)	Temperature (°C)	Humidity (%)
27–28 Nov 21	1	0.02291	1	0.26567	0.0203	High 23.9 – Low 13.4	71.5
3–4 Dec 21	2	0.03336	2	0.483253	0.0060	High 24.5 – Low 18	59
9–10 Dec 21	3	0.05249	3	0.317543	0	High 26 – Low 18	64
15–16 Dec 21	4	0.19152	4	0.43985	0.1012	High 23.9 – Low 17	70
21–22 Dec 21	5	0.17930	5	0.407787	0.1012	High 23 – Low 17	52

Table 1. The combined mean larva consumption weight (n = 30) of each test day, and observed stage of larval development. Combined mean weight of honeysuckle leaf (n = 30) prior to consumption test, singular control leaf moisture-loss quantities, and ambient environment variables during test period.

consumption per larva was estimated by subtracting the weight of remaining leaf tissue post-consumption from the initial weight of leaf tissue. Thirty replicates (larvae) (*n* = 30) were used for each consumption, and were tested until feeding ceased in the pre-pupal stage or pupation. To determine the quantity of foliage consumed, a regression model was used and an exponential curve was fitted to the mean value of the data. The goodness of fit (r2) was calculated to determine how well the data fitted within the regression curve. The fitted curve was used to predict the mean consumption of the larvae between consumption tests, and to give an approximate quantity a single larva could consume. Leaf moisture-loss was not deducted from the combined mean consumption values.

Results

By using exponential model analysis (exponential regression curve; $y = 0.0189e^{0.0977x}$), Figure 5 presents predicted consumption weight between the plotted data points. This study shows mean consumption per larva was 2.13g of Japanese honeysuckle foliage, which equates to 5.6 leaves. While a gradual increase in consumption was observed through test dates 1–3, leaf consumption during the first three instars was very low, with a combined mean total of 0.10867 g (Table 1). There was significant increase in Test 4 (instar 4), with larvae consuming almost four times the amount of foliage to that of Test 3 (instar 3). A slight decrease in consumption was observed between Tests 4 and 5. The developmental time from hatch to pupal stage spanned 25–27 days (Table 1).

Discussion

This study presents preliminary data on the potential quantity of Japanese honeysuckle the Honshu white admiral larvae can consume, a mean of 2.13 g or 5.6 leaves per larva. These findings support Hill (2019), who states that each larva can destroy several leaves during its development, further maintaining confidence in the biocontrol. The consumption tests aligned with larval instar development, and the consumption increase over the course of development was gradual, with peak consumption quantities occurring on Tests 4 and 5 (instars 4 and 5). The exponential model was statistically significant (R^2 = 0.9118), indicating confidence in the overall consumption-quantity prediction. A slight decrease in consumption was observed between Tests 4 and 5, which can largely be accounted for by five of the larvae entering pupation during Test 5. These larvae did not consume any proportion of the honeysuckle leaf; as such the combined mean consumption amount for Test 5 incorporates the 25 remaining larvae. It is plausible that these five early-stage larvae consumed foliage at a faster rate, which accelerated development and earlier morphological change, which is not uncommon amongst Lepidoptera (Mukerji & Guppy 1970). As the larva consumption rates were not tracked individually, this assumption cannot be verified. Due to limited resources and processing constraints, moisture loss of the leaves used in this study were not deducted from the mean consumption values.

To estimate the overall defoliation success the Honshu white admiral would have on Japanese honeysuckle in the wild, other variables would need to be taken into consideration. The high availability of Japanese honeysuckle for the Honshu white admiral could increase the population densities across sites where the butterfly has successfully established, as previous studies have found a strong relationship between population density and the abundance of associated host plant, particularly species of butterfly that are dietary specialists (Curtis et al. 2015). However, the biology and ecology of the Honshu white admiral is little understood, and population densities maybe mediated by species traits to not exceed the carrying capacity of their host plants, further limiting the impact they could have on Japanese honeysuckle. There is sufficient evidence to suggest that tolerance to herbivory is common, and that plant tissues removed by herbivores might not in fact reduce plant fitness (Agrawal 2000). Schierenbeck (2004) found that under combined herbivory from mammals and insects, and a comparison of growth and biomass allocation patterns across three herbivory treatments, Japanese honeysuckle has a compensatory response to herbivory and greater biomass allocation to leaves than in non-herbivory treatments. Schierenbeck (2004) went on to conclude that this response to herbivory plays a key role in the spread and persistence of the species. This study may not be directly comparable, yet it does outline the significance of gaining a greater understanding of the relationship between the Honshu white admiral and Japanese honeysuckle.

Conclusion

While this study does demonstrate that Honshu white admiral larvae can indeed consume multiple leaves, it does not suggest that the quantity of leaves consumed would reduce the fitness of the plant, and therefore no conclusions can be drawn as to whether this level of herbivory would have any effect upon reducing Japanese honeysuckle in Aotearoa / New Zealand. Further investigation into the response of defoliation, and how this may disrupt the normal physiological processes, is needed to determine the effectiveness of the Honshu white admiral as a biocontrol agent.

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Author

Adam Parkinson is a Lecturer at the School of Environmental and Animal Sciences, Unitec, Te Pūkenga. His research interests span across conservation and taxonomy of Lepidoptera of the Aotearoa / New Zealand archipelago, and freshwater fish of the Amazon basin, Brazil. aparkinson@unitec.ac.nz

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