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Catchment Management and Restoration Plan

for Rarotonga Cloud Forest Ecosystems
Cook Islands

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CATCHMENT MANAGEMENT AND RESTORATION PLAN FOR RAROTONGA CLOUD FOREST ECOSYSTEMS, COOK ISLANDS

January 2016

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EXECUTIVE SUMMARY

This document provides a plan to protect and enhance the cloud forests of Rarotonga so that their indigenous ecosystems, habitats for endemic species, and water supply functions are preserved in perpetuity.

Montane habitats of the interior of Rarotonga, southern Cook Islands, are critical to the health and well-being of the island's people, and its indigenous biota. The steep mountain slopes, isolated and at least partly protected by their extreme terrain, support one of the best remaining examples of montane rainforest in the tropical Pacific, and are critical habitat for many of the island's endemic species. For these reasons, the montane and cloud forests of Rarotonga are internationally significant. Rainfall increases dramatically with altitude, and cloud forest on the mountain summits intercepts, filters, and releases water that supplies the island's streams, that are the sole water supply for the island. Cloud forest habitats, with their abundance of non-vascular plant species such as lichens, can also increase water yield relative to other vegetation types, as lichens can absorb water from moisture-laden air, in the absence of precipitation. The importance of the island's montane habitats must also be seen in the context of all terrestrial and marine ecosystems; a ridge to reef management approach will ensure that the inherent linkages between land management and marine resources are recognized and protected.

The rugged terrain of Rarotonga's montane forests, with over-steepened valley heads and razor-backed ridges, has led to the survival of a cloud forest ecosystem that is both relatively intact, and poorly studied. Compared to other Pacific nations, the cloud forests are untouched by roading, agriculture, and human settlement. However, poor access due to the steepness of the terrain and the presence of only rudimentary tracks means that until now, whole taxonomic groups have been almost overlooked. Vascular plants, whether indigenous or introduced, are relatively well known. Eighteen plant species are endemic to the island of Rarotonga, of which 12 occur in cloud forest habitats, and two are solely found in cloud forest (Te Manga Cyrtandra (Cyrtandra lilianae) and Radiogrammitis cheesemanii). Rarotonga's cloud forests are critical for the conservation of endemic flora, providing habitat for eight of the island's 10 endemic flora listed by the IUCN as "Critically Endangered", "Endangered", or "Vulnerable". In sharp contrast, little is known regarding the non-vascular flora of Rarotonga's montane habitats, and further study is likely to result in the addition of many new indigenous moss, lichen, and liverwort species, some of which are likely to be undescribed endemics. Cloud forest provides habitat for two lizard species, and at least nine bird species, including nesting sites for at least four species of seabird. Prior to human settlement, and the arrival of mammalian predators, the cloud forests of Rarotonga may have supported huge numbers of nesting seabirds, to the extent that it could have been a seabird-driven ecosystem. In contrast to vertebrate species, there have been no recent surveys of invertebrate fauna. The last extensive survey of landsnails was in the late 1800s, and it is unknown if many of these species are still present or extinct. The degree to which invasive invertebrates, including landsnails and ants, have colonised the interior was unknown prior to this survey.

To prepare this management plan, a field survey of cloud forest habitats was completed over three weeks in May 2015. The survey included multi-day trips to the three highest peaks, Maungatea (523m), Te Kou (588 m), and Te Manga (653 m), with an exploratory day trip to Maungaroa (509 m). Broad vegetation patterns within cloud forest habitats on each peak were described, and collections were made via manual searches for landsnails, introduced vascular flora, and lichens. Indigenous vascular flora was collected where the Auckland Museum herbarium lacked a specimen for that particular location. Pan traps were used to trap Hymenoptera, including ants, within cloud forest on Te Kou and Te Manga. The distributions and abundances of invasive plant species were noted on topographical maps. All collection locations were recorded using a hand-held GPS. On return to New Zealand, all specimens were identified and accessioned to the Auckland Museum. Specimens requiring identification by international experts will be loaned to overseas collections to enable identification to species level.

The 2015 survey identified 107 vascular plant species within cloud forest habitats, including several threatened endemics such as Te Manga Cyrtandra, Rarotonga Sclerotheca (Sclerotheca viridiflora), and Radiogrammitis cheesemanii. In contrast to the lowlands, most vegetation communities are dominated by indigenous species, and some of the worst invasive plants of lowland habitats, such as mile-a-minute (Mikania micrantha) are absent or uncommon over large areas. Invasive plants such as white-flowered ginger (Hedychium coronarium) and night-blooming cestrum (Cestrum nocturnum) may slowly be increasing in range and abundance in cloud forest habitats, and could dramatically increase in dominance following a disturbance event. Indigenous non-vascular flora, including lichens, mosses, and liverworts, are abundant in cloud forest habitats. Further study of the specimens collected in 2015 is likely to result in many new species records for the Cook Islands.

The 2015 survey found 12 species of landsnails in cloud forest habitats, of which four were indigenous and eight were introduced. One or more species of undescribed endemic Lamprocystis were found on Te Kou, along with the endemics Lamprocystis globosa and Lamprocystis venosa. Extensive searches failed to find four endemics presumed to be extinct, or the Te Kou landsnail (Tekoulina pricei) last seen in 2005. Further work is being undertaken to determine the identity of the undescribed Lamprocystis. Te Kou is an important site for landsnail conservation in the Cook Islands. Trapping of invertebrates on Te Kou and Te Manga confirmed for the first time the presence of invasive ants in the cloud forests of Rarotonga.

Whilst many knowledge gaps remain, a review of relevant literature and the results of the 2015 survey confirm that invasive species are the primary threat to the island's cloud forest ecosystems. Management is needed to reduce the impact and spread of the invasive species that are present, and to reduce the likelihood that additional unwanted species establish. Biosecurity is critical to managing these threats, both at the international border and within the island. Cleanliness of footwear, clothing, and equipment is critical to reducing the spread of invasive species. Track signage should be installed to inform track users of their biosecurity obligations. Ants and introduced mammal species, and in particular rodents, are likely to be having significant adverse effects on the flora, lizards, birds, and invertebrates of cloud forest habitats. Whilst control of rodents is challenging from a logistical perspective, control may be feasible, using bait stations, within localised areas where gentler terrain permits. Similarly, the control of invasive plants should be trialled at Te Kou and Te Manga. Control of invasive species may not just result in the retention of existing habitats, but the restoration of ecosystem components that have been all but lost, such as seabird breeding colonies.

The establishment of a vegetation and rodent monitoring programme is needed to measure baseline population densities, assess likely impacts, and document long term ecological change, to provide objective measures of success for any management that is implemented, and to inform future decision-making.

Legal protection of Rarotonga's inland habitats has considerable merit, as it would recognise the significance of the ecosystems present, and the critical role they play in security of water supply. If legal protection is considered, the boundaries of the reserve should include not only the cloud forest on the highest peaks, but also inland forests upstream of the water intakes.

CONTENTS

1. INTRODUCTION

The National Environment Service of the Cook Island Government commissioned Wildland Consultants Ltd to assist with the preparation of a catchment and biodiversity management plan for the cloud forests of Rarotonga. This report describes the ecological survey and assessment of cloud forest habitats on Te Manga, Te Kou, and Maungatea and provides a management plan for the protection of indigenous vegetation, flora, and fauna in the upper catchments.

This project is a collaborative effort between Wildland Consultants Ltd, the Cook Islands Government, and the Auckland Museum. The Auckland Museum holds thousands of biological specimens from the Cook Islands, including 999 specimens collected by Thomas Cheeseman in 1899 which represent the first floral survey of Rarotonga. As part of this project, the Auckland Museum will digitise the original Cheeseman collections and specimens collected during the most recent 2015 survey, and supply them to the Cook Island Government.

Invasion by weed species, with the potential replacement of indigenous vegetation with exotic vineland, has serious implications for Rarotonga's water supply catchments. Steep slopes covered in exotic vines and herbaceous growth are of lower conservation value and more prone to erosion and soil loss, especially during extreme rainfall events. Mueller-Dombois and Fosberg (1998, p. 394) in their account of the vegetation of the tropical Pacific, placed great importance on Rarotonga's cloud forest within the Pacific when they stated the following:

> *"It is appropriate here to stress the desirability of complete protection of this finest remaining example of original small-island montane rain and cloud forest vegetation. Hardly anything like this native forest remains in such good condition at comparable altitudes. It illustrates many aspects of native island ecosystems, serves as a habitat for many endemic species, and from a more practical viewpoint, will, as long as intact, preserve Rarotonga's indispensable supply of pure freshwater".*

The protection and restoration of cloud forest ecosystems is therefore critical for both effective catchment management, and the conservation of Rarotonga's endemic cloud forest species.

2. OBJECTIVE

The objective of this project is to protect and enhance the cloud forests of Rarotonga so that their indigenous ecosystems, habitats for endemic species, and water supply functions are preserved in perpetuity.

3. ECOLOGICAL CONTEXT

3.1 Geology

The southern Cook Islands lie near the centre of the Pacific Ocean about 1,000 km east of Niue, and 850 km south-west of Tahiti. These islands developed as basaltic volcanoes near the centre of the Pacific Plate (Mueller-Dombois and Fosberg 1999), and the soils are derived from basalt, or from limestone, which formed on fringing coral reefs.

Rarotonga is the summit of a Pliocene-Pleistocene volcanic complex that rises 5,000 m from the sea floor. The island is likely to have developed from a single eruptive phase, with cone building around at least two vents, and the development of parasitic cinder cones (Thompson *et al.* 1998). Prior to erosion, the volcano is likely to have had a summit *c.*900 m above sea level (Wood and Hay 1970), approximately 250 m taller than the present summit of Te Manga. Earlier accounts considered the island to have developed from volcanic eruptions over several distinct stages, followed by caldera collapse (e.g. Wood and Hay 1970). However, recent geological exploration by Thomson *et al.* (1998) found no evidence for caldera formation, and attributed the current topography of the inland of Rarotonga simply to erosion (Thompson *et al.* 1998).

Of the three main peaks on which montane forest occurs, Te Manga comprises "grey/to black basalts in ankaramites in flows, dikes, and pyroclastics" (Thompson *et al*. 1998 p. 42), and Te Kou and Maungatea comprise "roughly stratified breccia of angular and phonolitic rocks with beds of pale-grey phonolitic primary tuff and ash". Erosion has resulted in deep valleys, razor-backed ridges, and over-steepened stream headwaters (Thompson *et al.* 1998).

3.2 Biogeography

None of the Cook Islands have ever been connected to larger landmasses, and their associated biota is typical of long isolated oceanic islands. Species diversity generally decreases with increasing distance eastwards across the Pacific, but many islands, including Rarotonga, support endemic species. Botanically, the southern Cook Islands are considered part of Eastern Polynesia, as the flora shares more affinities with the Austral and Society Islands to the east, than with Tonga and Samoa to the west. The botany of the Cook Islands also has many affinities with New Zealand, which is located approximately 3,000 kilometres to the south-west.

3.3 Climate

Broadly speaking, the southern Cook Islands have a tropical rainforest climate, with a rainfall peak in November-December. The islands lie in the south-east trade wind belt, and orographic rain results in the higher islands having wet summits, and a reliable water supply (Mueller-Dombois and Fosberg 1998). Mean annual precipitation is approximately 2,000 mm on the coast, rising to 4,000 mm on the highest peaks. Most of the peaks above 400 m, which support cloud forest, receive at least 3,000 mm of precipitation per annum.

3.4 Cloud forest vegetation

At 64 km^2, Rarotonga is the largest island in the southern Cook Islands; it is also the highest, with Te Manga reaching 653 m (Mueller-Dombois and Fosberg 1998). Like many islands in the tropical

Pacific, the lowlands have been extensively modified by a long history of human occupation. The islands has been occupied by Polynesians for approximately 4,000 years (Fujiki *et al*. 2014), and as a consequence little, if any, unmodified lowland vegetation remains. In sharp contrast, the steep mountainous interior of Rarotonga supports some of the best and most extensive montane forest in all of Polynesia (Mueller-Dombois and Fosberg 1998). Disturbed lowland vegetation extends to 50-200 m above sea level and beyond this, montane forest extends to approximately 400 m asl. The highest peaks above 400-500 m are commonly shrouded in cloud, and support tropical montane cloud forest (TMCF) (Merlin and Juvik 1995). This ecosystem type can occur at such a low altitude on Rarotonga due to the steepness of the mountains, their proximity to the sea, and their location within a super-humid climate. Although cloud forest habitats cover only *c*.150 ha (1.5 km^2) of Rarotonga, these habitats support a disproportionate proportion of the island's endemic plant species; two species are entirely restricted to cloud forest habitats (Te Manga Cyrtandra, *Radiogrammitis cheesemanii*), and for others (e.g. Rarotonga Sclerotheca), cloud forest is a major stronghold for remaining populations.

Merlin (1985) completed the first quantitative study of the inland forests of Rarotonga. This study determined species frequency, tree height, and basal area along 19 transects, using the point centred quarter method. Cluster analysis identified three transects, at 260 m, 490 m, and 565 m altitude, as comprising cloud forest dominated by rata (*Metrosideros collina*) or Kaiatea Ko'u (*Ascarina diffusa*), with Kaiatea Ko'u being more abundant in the highest and wettest habitats. Other species noted as present in cloud forest included kiekie (*Freycinetia arborea*), neinei (*Fitchia speciosa*), karaka Rarotonga (*Elaeocarpus tonganus*), kaiatea (*Weinmannia samoensis*), and kavakava (*Pittosporum rarotongense*). Less common species present included two endemic shrubs, Rarotonga coprosma (*Coprosma laevigata*) and 'Ange (*Geniostoma rarotongensis*), as well as *Xylosoma gracile* and Polynesian blueberry (*Vaccinum cereum*). McCormack and Kunzle (1990) broadly supported this description in their account of Rarotonga cloud forest, noting that rata and neinei, a key component of ridgeline vegetation at lower altitudes, become the dominant tree species within cloud forest. They suggested that the presence of several indicator species can be used to demarcate cloud forest habitats: glossy tongue-fern (*Elaphoglossum savaiense*) is restricted to cloud forest, Kaiatea Ko'u is noted as only being common in cloud forest, and in cloud forest, Moumea Ko'u (Cloud Blechnum; *Blechnum societatum*) replaces tangle fern (Tuanu'e; *Dicranopteris linearis*) as the dominant fern. For this report, the presence of any of these three species has been used to identify cloud forest habitats.

3.5 Hydrological importance of cloud forest

The steep, mountainous nature of Rarotonga's interior, whilst increasing rainfall through cloud interception, also results in inherent water storage limitations. Once rainfall enters streams, it flows quickly down the catchments, and marked peaks in flow are typical. The cloud forests provide a protective cover for the steepest and wettest slopes, resulting in typically high water quality in headwater streams.

However, the importance of cloud forest for the island's water supply is further increased by the structure and composition of the cloud forest vegetation itself. Cloud forests, in addition to rainfall intercepted by steep mountain peaks, also receive "horizontal precipitation" as the vegetation intercepts moisture contained within clouds (Merlin and Juvik 1995). This interception is greatest at exposed, windward locations, and the ratio of moisture interception to rainfall increases during times of drought (Juvik and Nullet 1995).

Cloud forest is characterised by an abundance of non-vascular plant species (mosses, liverworts, and lichens), which occur both as epiphytes on woody vegetation and on the ground. This component of the vegetation can significantly increase the interception of moisture compared to that intercepted by a canopy comprised mostly of leaves. The biomass of lichens and bryophytes within tropical montane forest, whilst being highly variable on a global scale, can reach several tonnes per hectare, and hold many times its weight in water (Holscher *et al.* 2004). Lichens can also absorb water directly from clouds, without precipitation occurring (Smith 1995). In effect, cloud forest acts not only as a protective cover, but also as a giant sponge, trapping, holding, and slowly releasing both condensation and precipitation (Foster 2001). Thus the cloud forests of Rarotonga, and their abundance of non-vascular species, not only play a critical role in water quality, but also ensure the reliability of the water supply.

4. HISTORY OF BIOLOGICAL EXPLORATION

4.1 Vascular flora

Thomas Cheeseman, during a visit to Rarotonga in May-July 1899, was the first European to survey the island's flora (Cheeseman 1903). He catalogued 334 species of vascular plants, of which he regarded 235 as indigenous, 18 as endemic, and 99 as introduced. He regarded 19 species as pre-European introductions. Cheeseman (1903) noted the extremely high proportion of vascular plants that were ferns, this group accounting for close to one-third of all indigenous plant species on Rarotonga. Specimens collected by Cheeseman are held in the Auckland Museum Herbarium, and his observations provide a useful baseline for the assessment of vegetation change on Rarotonga over the past century. Cheeseman (1903, p. 266) described the interior of Rarotonga as seldom visited, with 'a total absence of tracks', and 'dense jungle-like forest that everywhere covers the surface'. Cheeseman found and described the endemics Rarotonga Sclerotheca, *Cyrtandra rarotongensis*, *Garnotia cheesemanii*, *Meryta pauciflora*, *Coprosma laevigata*, *Myrsine cheesemanii*, and *Pittosporum rarotongense*. Whilst several of the species Cheeseman described as endemic are now known to be more widespread (e.g. revision of *Weinmannia rarotongensis* to *W. samoensis*), the number of Rarotonga endemics remains at 18 due to the subsequent discovery of new species (e.g. *Balanophora wilderi*), or recognition of indigenous species as endemic (e.g. revision of *Cyathea milnei* to *Cyathea parksiae*) by Gerrit Wilder (1931). During his field surveys in 1925, 1927, and 1929, Wilder also discovered two endemics, Te Manga Cyrtandra, a shrub restricted to the cloud forests of Rarotonga, and *Acalypha wilderi*, a lowland species now regarded as extinct.

No further botanical surveys of any note were subsequently undertaken until the 1980s, by which time Te Manga Cyrtandra, then known only from the type specimen, was thought to be extinct, and the continued survival of both *C. rarotongensis* and *Sclerotheca viridiflora* was in doubt. Gerald McCormack rediscovered Te Manga Cyrtandra in cloud forest high up on Te Manga in 1988, and both *Sclerotheca viridiflora* and *C. rarotongensis* were found by McCormack and Bill Sykes in 1990 (Sykes 1990). Sykes (1990) also found an undescribed *Psychotria* in 1982, which was later recognized as the endemic *P. whistleri*.

The first detailed ecological study of the forests of Rarotonga was undertaken by Merlin in 1983 (Merlin 1985). This study aimed to identify and describe the woody plant associations that occurred in the uplands, measure dominance and frequency of species, and assess the extent of introduced species. Using cluster analysis, and a point-centred quarter method of sampling along transects, Merlin identified three main vegetation types in inland Rarotonga: *Homalium* montane-slope forest, *Fagraea-Fitchia* ridge forest, and *Metrosideros* cloud forest. Cloud forest occurred along three transects, at altitudes between 240-280 m and 440-490 m, and at 565 m. *Metrosideros collina* or Kaiatea Ko'u were the dominant species, forming a 3-5 m high canopy with *Fitchia speciosa*, *Elaeocarpus rarotongensis*, *Weimnannia samoensis*, and *Pittosporum rarotongense*. In general, Merlin found that cloud forest occurred above 350 m altitude, but could occur as low as 200 m on exposed windward ridges. At the time of Merlin's study, the cloud forest was very intact, with few exotic woody species. In disturbed areas, woody weed species included strawberry guava (*Psidium cattleianum*), African tulip tree (*Spathodea campanulata*), and *Cecropia palmata*, and herbaceous weed species included mile-a-minute, *Elephantopus mollis*, and *Paspalum conjugatum*.

Gerald McCormack, as Director of the Cook Islands Nature Heritage Trust, spent extensive time in the interior of Rarotonga from 1984 to 2000. As part of his work, he described the major plant communities of Rarotonga, which are described in the book "Rarotonga's Mountain Tracks and Plants: a field guide" (McCormack and Kunzle 1995). This book expands on parts of Merlin's 1985 work, describing the key vegetation communities that one passes through while ascending Rarotonga's high peaks. McCormack and Kunzle regarded 400 m as the typical elevation at which cloud forest began, and suggested that two plant species act as indicators of cloud forest: the glossy tongue-fern and Kaiatea Ko'u.

Rarotonga's most recently named endemic plant species is a fern of the cloud forest. Previously identified as the more widespread *Grammitis hookeri*, which occurs from Sri Lanka to the Society Islands, Parris (1993) recognized the Rarotonga plants as a distinct species, describing it as *Grammitis cheesemanii*. This small epiphytic fern is found above 450 m altitude, and only occurs on Rarotonga. *Grammitis* was recently revised and the species is now known as *Radiogrammitis cheesemanii*.

A field survey of Rarotonga endemic flora was undertaken by Tim Martin, Peter de Lange, and Gerald McCormack in July 2010 (Martin 2012). The focus of the survey was rare endemic species such as *Cyrtandra lillianae*, *Sclerotheca viridiflora*, *Radiogrammitis cheesemanii*, and *Garnotia cheesemanii* within cloud forest habitats, and *Balanophora wilderi*, *Cyrtandra rarotongensis*, and *Psychotria whistleri* at lower elevations. The extinct *Acalypha wilderi* and extirpated (locally extinct) *Pilea bisepala* were also searched for during the survey. IUCN Red List assessments were prepared for 18 species, and these were included in the updated Red List in June 2014. None of the Rarotonga endemic plant species are currently subject to conservation management and, subsequently, the long-term survival of several species is unlikely. The survey noted that several invasive weed species (e.g. mile-a-minute) are now establishing within cloud forest on the remote mountain peaks that had previously acted as almost weed-free refuges for endemic flora (e.g. *Sclerotheca viridiflora*).

4.2 Lichens

Until recently, the lichens of Rarotonga were very poorly understood. The first account of the lichens of Rarotonga was produced over 70 years ago (Sbarbaro 1939), and then little study occurred until an overview of Cook Island lichens was published by Elix and McCarthy (1998). Following this, accounts have now been published for four groups of lichens. Louwhoff and Elix (2000) published a preliminary list for Parmeliaceae (10 species), and McCarthy (2000) described four new pyrenocarpous lichens, including four endemics, and noted 28 additional taxa. During this study of pyrenocarpous lichens, it was noted that the lichens in the families Graphidaceae and Thelotremataceae were abundant and diverse on Rarotonga (McCarthy 2000), but to date, neither of these groups are known to have been studied (Robert Lucking, Field Museum, pers. comm. 2015). Archer and Elix (2015) published an account of the genus *Pertusaria*, based on specimens collected during the 1998 survey by Elix and McCarthy (1998). *Pertusaria*, a crustose lichen, is represented by eight species on Rarotonga, including five endemics. The most recent collections of note were those made during the 2010 survey, which resulted in three new records in the genus *Ramalina* (Blanchon and de Lange 2011).

The Auckland Museum holds specimens for only 22 species of lichens from Rarotonga, but published accounts and comparisons with other islands suggest the total diversity of the lichen flora may exceed a hundred species. The current lichen flora is approximately 78 species, with 67 species listed by Australian Biological Resources Study (2015), but this list omits the recent accounts for *Pertusaria* (8 species) and *Ramalina* (3 species). The Society Islands, to the east of the Cook Islands, are known to support at least 221 taxa (McCarthy 2000), and species richness of the Cook Islands could be similar. A fuller understanding of the lichen flora of Rarotonga, and in particular of cloud forest ecosystems, is much needed. Few of the previous surveys included higher altitude cloud forest habitats, with most of the specimens collected by Elix and McCarthy in 1998 being from coastal areas. Lichens play important roles in the function of forest ecosystems (Ellis 2013), and the lichen flora of Rarotonga is likely to include undescribed endemics, and species of conservation concern. Lichens are also known to be vulnerable to the impacts of climate change (Ellis 2013).

4.3 Bryophytes

Liverworts and mosses have been collected opportunistically during previous surveys of vascular plants, but no systematic collections have ever been made. Further field surveys, dedicated to documenting lower plants, are needed to fully understand the biodiversity and importance of bryophytes within Rarotonga's cloud forests.

4.4 Fauna

4.4.1 Landsnails

Prior to European settlement, Rarotonga had a rich landsnail fauna, with at least 43 species, including 17 coastal plain endemics and 26 species endemic to inland habitats (Brook 2010). There appears to be little overlap between the species of coastal and inland habitats, with most species being restricted to either coastal or inland parts of the island. Extensive modification and loss of coastal habitat has resulted in the extinction of at least 25 landsnail species, including all but two of the coastal endemics. In contrast, species of inland habitats have fared considerably better. Ten of the 14 landsnail species likely to be present in cloud forest habitats were regarded as extant following surveys in 2005-2007 (Table 1). However, even within remote, inland habitats, declines in landsnail abundance between surveys suggest ongoing threats. Brook (2010) suggests that the first wave of extinction, affecting lowland species, occurred following Polynesian settlement, with a second wave of decline and extinction following European settlement due to the introduction of species such as ship rat (*Rattus rattus*), Norway rat (*Rattus norvegicus*), house mouse (*Mus musculus*), and ants. A third decline may now be occurring, as introduced species, such as ants, that have until recently been restricted to the lowlands, colonise the higher peaks.

Table 1: Landsnails of cloud forest habitats, Rarotonga

Family	Species	Habitat	Location
Achatinellidae	*Tekoulina pricei*	Montane fernland and forest	Summit basin of Te Kou
Partulidae	*Partula assimilis*	Cloud forest,	Upper Tupapa and Takuvaine Valleys
Endodontidae	*Liberia tumuloides*	Mountain ravines	-
Endodontidae	*Minidonta unilamellata*	Mountain ravines	-
Charopidae	*Sinployea decorticata*	Mountain ravines	-
Charopidae	*Simployea harveyensis*	Montane fernland	Summit of Te Kou
Charopidae	*Simployea taipara*	Cloud forest	NNE flank of Te Manga, summit basin of Te Kou
Euconulidae	? *Diastole sp.*	Cloud forest	Te Kou, Te Manga
Euconulidae	*Lamprocystis* (*Avarua*) *globosa*	Cloud forest	Te Kou, Te Manga
Euconulidae	*Lamprocystis* (*Avarua*) *venosa*	Cloud forest	Widely distributed
Euconulidae	*Lamprocystis* (*Avarua*) sp. 1	Cloud forest, montane fernland	Widely distributed in south and east.
Euconulidae	*Lamprocystis* (*Avarua*) sp. 2	Cloud forest, montane fernland	Te Kou, Te Manga
Euconulidae	*Lamprocystis* (*Avarua*) sp. 3	Cloud forest	Te Kou, Te Manga
Euconulidae	*Lamprocystis* (*Avarua*) sp. 4	Cloud forest	Te Kou, Te Manga
Euconulidae	*Lamprocystis* (*Avarua*) sp. 5	Cloud forest	Northern slopes of Maungatea, upper Avatiu Valley

Cloud forest on the summit of Te Kou provides habitat for *Tekoulina pricei*. This species was placed in its own genus as it is the only landsnail in the world to hatch its eggs and feed its young internally (McCormack and Kunzle 1990). Based on the number of specimens collected by a survey in the 1960s, it was relatively common at the time, being found on the ground under vegetation and rotting leaves. Searches in 2005, 2006, and 2007 found no living specimens, but did locate fresh, empty shells.

4.4.2 Insects

Lepidoptera (butterflies and moths)

Among the indigenous insects of Rarotonga, the butterflies are best known with 14 species recorded (Patrick & Patrick 2012). There are no species endemic to Rarotonga, but the bright blue *Jamides walkeri* is only known elsewhere from Aitutaki of the Cook Island group and the Austral Islands of French Polynesia (Patrick & Patrick 2012). This species is distinctive in its genus in being without tailed hindwings, in contrast to its sister species found on Tonga, Samoa, and Fiji. Otherwise, the butterfly fauna is typical of other South Pacific islands, with widespread, mainly lowland species. It is possible that additional species, including local endemics, are found in the Rarotonga cloud forests, as no targeted survey work has been carried out there for butterflies, and other islands (i.e. Samoa and Fiji) have a small number of local endemics in less disturbed upland and inland areas. Rarotonga and Niue exclusively share a subspecies of crow butterfly *Euploea lewinii perryi*, a widespread butterfly of the South Pacific with six subspecies recognized.

Hymenoptera (sawflies, wasps, bees, and ants)

The Hymenoptera order of insects encompasses ants, bees, sawflies and wasps. With the exception of ants, there appear to be no published descriptions of the Hymenoptera fauna of Rarotonga. The ant fauna of lowland Rarotonga comprises 26 species, all of which are introduced (Brook 2010). The ant fauna of inland habitats is unknown.

4.4.3 Birds

Modern Day Avifauna

Five species of indigenous land birds are known to occur within the forested inland of Rarotonga. Rarotonga fruit dove (*Ptilinopus rarotongensis*), Rarotonga flycatcher (*Pomarea dimidiata*), and Rarotonga starling (*Aplonis cinerascens*) are endemic, and the Pacific pigeon (*Ducula pacifica*) and long-tailed cuckoo (*Eudynamis taitensis*) are native, also being found elsewhere in the Pacific (Holyoake 1980). The cloud forests of Rarotonga also provide nesting habitat for seabirds, including brown noddy (*Anous stolidus*) which nests in trees (Holyoake 1980) or on cliff ledges (Rinke *et al.* 1992), and herald petrel (*Pterodroma heraldica*) which has colonies on several of the peaks (McCormack and Kunzle 1990). Herald petrel breed on steep rocky faces and after feeding at sea, can be seen as they return to nest sites in the mid to late afternoon (Department of the Environment 2015). Small numbers of red-tailed tropicbird (*Phaethon rubricauda*) and several hundred pairs of white-tailed tropic bird (*Phaethon lepturus*) nest on cliffs (Holyoake 1980).

Cloud forest on the summit of Te Kou provides habitat for *Tekoulina pricei*. This species was placed in its own genus as it is the only landsnail in the world to hatch its eggs and feed its young internally (McCormack and Kunzle 1990). Based on the number of specimens collected by a survey in the 1960s, it was relatively common at the time, being found on the ground under vegetation and rotting leaves. Searches in 2005, 2006, and 2007 found no living specimens, but did locate fresh, empty shells.

Historical Loss and Decline

Prior to human settlement, Rarotonga is likely to have supported bird species that are either now extinct, or restricted to outlying islands (Carter and Carter 2000). Steadman (1995) estimated that each of Oceania's 800 major islands have lost, conservatively, an average of ten species of birds. Rarotonga was likely to have had one to four rail species, and genera now represented by one species are likely to have been formerly two to three species. No fossil deposits on Rarotonga have been studied. However, for Mangaia, a smaller island to the east of Rarotonga, fossil bones indicate the extinction of four rail, two pigeon, and two parrot species (Steadman 1995), and the extirpation (local extinction) of two seabirds, the burrow-nesting black- winged petrel (*Pterodroma nigripennis*) and the Polynesian storm petrel (white- throated storm petrel; *Nesofregetta fuliginosa*) (Steadman and Kirch 1990). As Mangaia is smaller in area than Rarotonga (52 km^2 compared to 67 km^2), a similar or greater loss of avifauna on Rarotonga is likely to have occurred. The number and extent of seabird colonies within the cloud forest is also likely to be significantly reduced compared to pre-human extent (Steadman 2006). Huahine Island, in the Society Island group, at 72 km^2, is only slightly larger than Rarotonga.

Missionaries visiting this island in 1809 reported "vast numbers of aquatic birds, of various kinds" nesting on the side of a mountain (Medway 2009, p. 54), but, despite further accounts of explorations in subsequent decades, this spectacle was not recorded again. Bird bones from an archaeological site indicated that 15 species of seabirds formerly nested on Huahine Island, including six species of shearwaters (*Puffinus* spp.) and petrels (*Pseudobulweria* and *Pterodroma* spp.). Of these 15 species, only three species, white-tailed tropic bird, brown noddy, and white tern (*Gygis alba*) nest on Huahine today (Medway 2009). These three species also persist on Rarotonga, suggesting that the current seabird fauna is much diminished, and largely comprises those nesting in remote habitats, or those that are less vulnerable to the effects of predation or harvest (Carter and Carter 2000).

Flow-On Effects of Avifauna Decline

Seabird guano is the main pathway for the transport of nutrients from marine to terrestrial environments (Havik *et al*. 2014). Prior to invasion by rodents, seabirds are likely to have been a critical driver of cloud forest ecosystems, importing nutrients and energy from the marine environment, and causing vegetation and soil disturbance through trampling and burrowing. The decline or loss of seabird colonies on Rarotonga may have had, and will continue to have, significant flow-down effects such as changes in soil nutrients, soil pH, rates of plant growth, and composition of plant communities. Extinction or extirpation, particularly of species that fed on nectar or fruit, is also likely to have permanently altered pollination and seed dispersal in the cloud forests of Rarotonga.

4.4.4 Freshwater fish

A survey of Rarotonga's freshwater fauna was undertaken in 2010. Seventeen sites were surveyed using an electric fishing machine, hand netting, and by snorkelling. The sites included some stream reaches above 200 m altitude (Keith *et al.* 2010), but no assessment was done of streams within cloud forest habitats. Eighteen fish species and 10 crustacean species were found. Three fish species were introduced: tilapia (*Oreochromis mossambicus*), guppy (*Poecilia reticulata*), and molly (*Poecilia sphenops*). Most species are restricted to the lowland reaches of the catchments, with only two species found at altitudes over 200 m, a prawn (*Macrobrachium latimanus*) and an eel (*Anguilla megastoma*). It is unknown if these two species occur at altitudes over 400 m.

4.4.5 Terrestrial reptiles

The terrestrial reptile fauna of Rarotonga comprises at least seven gecko and four skink species. The Rarotonga tree skink (dandy skink; *Emoia tuitarere*) (Plate 1) has recently been recognized as the island's only endemic reptile species, being distinct from the more widespread *Emoia samoensis* (Zug *et al.* 2011). This species is primarily arboreal and is found in forest habitats throughout the island. The Oceanic gecko (*Gehyra oceanica*) and Pacific slender-toed gecko (*Nactus pelagicus*) are regarded as indigenous, with the Oceanic gecko most often associated with old trees in lowland areas, and the Pacific slender-toed gecko being found in forests up to 800 m altitude (Crombie and Steadman 1986). The remaining gecko species, stump-tailed gecko (*Gehrya mutilata*), common house gecko (*Hemidactylus frenatus*), Indo- Pacific gecko (*Hemidactylus garnotii*), and mourning gecko (*Lepidodactylus lugubris*) are regarded as introductions, either during Polynesian or European settlement. These introduced geckoes are most commonly found in coastal areas close to human habitation. Three other skink species, the copper-tailed skink (*Emoia cyanura*), inland blue-tailed skink (*Emoia impar*), and moth skink

(*Lipinia noctua*) are also regarded as introductions, although their widespread distribution in the tropical Pacific means it is difficult to accurately determine whether they are indigenous or introduced. Introduced skink species are not known to occur in cloud forest habitats.

Plate 1: Adult Rarotonga tree skink found sun-basking on the high ridge between Te Manga and Te Atuakura. 19 May 2015. Talie Foliga.

5. METHODS

5.1 Study sites

The field survey targeted montane habitats above 400 m altitude on Maungatea, Maungaroa, Te Kou, and Te Manga (Figure 1). Five smaller peaks that had summits between 400 and 500 m altitude were not surveyed. These were regarded as being unlikely to support cloud forest, based on either local knowledge, or previous accounts of the vegetation (e.g. McCormack and Kunzle 1990).

5.1.2 Maungatea

Maungatea was surveyed over a two day, one night trip on 6-7 May 2015. The survey team was unable to reach the summit of Maungatea due to dense vegetation, dwindling water supplies, and further ascent on the selected route being blocked by cliffs. The study site from where specimens were collected was located at the lower altitudinal limit of cloud forest at 480 m. If a second attempt is to be made to reach the summit, access should be via ridges that lead up from the upper Takuvaine Valley to avoid difficult terrain (Colin Rattle, pers. comm. May 2015).

5.1.3 Te Kou

Te Kou was surveyed over a three day, two night trip on 11-13 May 2015. The summit was reached via a track on the northern slopes that ascends from the Takuvaine Valley. A base camp was set up on the northern rim of the summit basin. Specimens were collected from throughout the summit area, including the northern and southern rim of the summit valley, and down the stream valley to the point where the stream drops steeply over a waterfall.

5.1.4 Te Manga

Te Manga was surveyed over a three day, two night trip from 18-20 May 2015. The peak was climbed via a track from the end of Tupapa Road. Basecamp was set up on the western summit and from there surveys were carried out along the Te Manga- Te Atukura ridgeline, and down the ridges that radiate out from the western summit.

5.1.5 Maungaroa

Maungaroa was surveyed during a day trip on 15 May 2015. This peak was climbed via a ridgeline to the north-west of the summit. Whilst the summit of Maungaroa reaches 509 m altitude, no cloud forest was present, as indicated by the absence of glossy tongue-fern and Kaiatea Ko'u. However this peak has had little biological exploration in recent years. The last known botanical specimens from this area, held by Auckland Museum, date to the 1970s, and there are no known collections of landsnails from Maungaroa. As such, the survey collected lichens, vascular plants, and landsnails at altitudes from 400 to 509 m, along the ridgeline that leads in a westerly direction from Maungaroa towards Raemaru.

5.2 Field survey preparation

The following methods are derived from the vegetation and flora chapter of "Guidelines for undertaking rapid biodiversity assessments in terrestrial and marine environments in the Pacific" (Wildland Consultants 2013):

- Aerial photography and topographical maps for the cloud forest of Rarotonga were obtained.
- Relevant literature regarding geology, climate, vegetation and flora for the cloud forest ecosystems of Rarotonga was obtained, including species lists, papers, reports, and herbarium records. Known locations of the threatened or rare flora of Rarotonga were primarily obtained from Gerald McCormack (CINHT) or from the 2010 survey (Wildland Consultants 2010). Gerald also provided sketch maps of where subpopulations of endemic species had previously been located. These were used to both relocate subpopulations, and to note subpopulations that had been lost since the previous survey.
- Photographs of herbarium specimens were printed and laminated as identification guides for the field survey team.
- Major bioclimatic environments were identified, based on the following variables:
    - Drainage/soils;
    - Aspect;
    - Climate/altitude.
- Where possible, any unusual features that may support historically rare or uncommon ecosystem types were identified and mapped prior to the field survey, so that the survey of these areas could be prioritised. Elsewhere in the Pacific, historically rare ecosystem types are those that have always been very limited in extent, even prior to human settlement, and are often characterised by the presence of rare or endemic species (Williams *et al.* 2007). Possible examples present on Rarotonga include rock outcrops and seabird colonies.

5.3 Description of ecological units

Natural areas within a survey area were described as ecological units that reflected their environmental, structural, and floral characteristics. If there was a common or local name for a species that is of widespread usage, this was used preferentially over its botanical name, to increase non-specialist understanding and engagement. All common or local names used are listed in a flora checklist alongside their botanical names (Appendix 1). Species mentioned within the names of ecological units were restricted to those that are most common within that unit (c.f. Paijmans 1976, Atkinson 1985).

5.3.1 Vegetation structure

Within each natural area, vegetation was classified according to the major landform on which it occurred (e.g. ridge, summit, gully, or plateau) and the dominant structural form (e.g. trees, shrubs, grasses, vines, or herbs). These are physiognomic- environmental vegetation types and can be regarded as comprising a vegetation classification at a landscape level. The following list of vegetation structural types is derived from Atkinson (1985), with minor modifications for applicability to cloud forest ecosystems (Table 2).

Table 2: Structural classes for mapping and classification of vegetation types.

Structural Class	Definition
Forest (including cloud forest)	Woody vegetation in which the cover of trees in the canopy is >80% and in which tree cover exceeds that of shrubs. Trees are woody plants ≥10 cm diameter at breast height (dbh). Tree ferns ≥10cm dbh are treated as trees.
Treeland	Vegetation in which the cover of trees in the canopy is 20-80% with tree cover exceeding any other growth form, and in which the lower canopy is non-woody vegetation.
Vineland	Vegetation in which the cover of unsupported woody vines in the canopy is 20-100% and in which the cover of these vines exceeds any other growth form. Vegetation containing woody vines supported by trees or shrubs is classified as forest, scrub, or shrubland.
Scrub	Woody vegetation with the cover of shrubs and trees in the canopy is >80% and in which shrub cover exceeds trees. Shrubs are defined as woody plants ≤10 cm dbh.
Shrubland	Vegetation in which the cover of shrubs in the canopy is 20-80% and in which the cover of shrubs exceeds any other growth form or bare ground.
Fernland	Vegetation in which the cover of ferns in the canopy is 20-100% and in which the cover of ferns exceeds any other growth form or bare ground. Tree ferns≥10 cm dbh are excluded as trees.
Grassland	Vegetation in which the cover of grasses or grass-like plants in the canopy is 20-100% and the cover of grasses exceeds any other growth form or bare ground.
Herbfield	Vegetation in which the cover of herbs in the canopy is 20-100% and the cover of herbs exceeds any other growth form, bare ground, or open water. Herbs include all herbaceous and semi-woody plants not separated as ferns, grasses, reeds, mosses, or lichens.

5.3.2 Canopy composition

For each vegetation structural type, the floristic characters were described to complete the description of an ecological unit. It is at the floristic level of classification that vegetation types, often called associations, have limited geographical ranges (Mueller-Dombois and Fosberg 1998). For each ecological unit, each species in the canopy, or uppermost vegetation layer, is assigned to one of the following four categories: greater than 50% cover, defined as "abundant"; 20-49% cover, defined as "common"; 5-19% cover, defined as "frequent"; and less than 5% cover, defined as "occasional".

Compositional names were derived from the names of the most common canopy species as follows:

- If one canopy species is ≥50% cover by percentage cover or basal area, this species is assigned to the structural class and major environment to complete the name of the ecological unit.
- If no single canopy species exceeds 50% cover by percentage cover or basal area, any species ≥20% cover is assigned to the name (Atkinson 1985).
- If no species reach the 20% level, the two most abundant species from 1-20% cover by percentage cover or basal area are assigned to the name (Atkinson 1985).

5.3.3 Additional description of ecological units

Ecological units with complex vertical stratification, such as some forest habitats, are unlikely to be described adequately by the canopy species alone. Other vegetation layers or tiers that may also be present include canopy emergents, subcanopy, shrub layer, and ground tier (Clapham 1973). Epiphytes and lianas are also common in cloud forest and may not be present in the uppermost vegetation layer. Wherever possible, all multi-layered vegetation types were further investigated and described. Walk-through surveys were undertaken at multiple sites within each ecological unit, and the species composition of each of the layers described, using the abundance categories described above. Any localised variations that do not warrant classification as a separate ecological unit, for example canopy gaps created by tree falls or landslides, were noted and briefly described.

5.3.4 Location of ecological units

Rapid biodiversity surveys usually rely on the availability of high resolution aerial photography to determine the identity and extent of each vegetation type (Atherton and Jefferies 2012). However, mapping was not possible due to the poor resolution of the available aerial photography, and in many places, also due to obscuring of the land surface by clouds. Ecological units were therefore described for point locations which are shown in Figures 2-4.

5.4 Flora survey

5.4.1 Checklists

Checklists were compiled for all higher plant species and lichens encountered during the field survey, and annotated with general comments on the distribution and abundance of each species (e.g. "common in forest on western slopes of Te Kou").

5.4.2 Voucher specimens

Whenever possible, species in the checklist were accompanied by a voucher specimen, unless the species was collected from that location by the author in 2010, or if collection of a specimen would endanger the population of an indigenous species (e.g. only one seedling of a species was observed). In this situation, photographs were taken to document the find. If present, voucher specimens included flowers and/or fruit.

All specimens were photographed in the field, and the photograph number was included with the collection data, including location, date, habitat notes, abundance, and collector. Specimens were then placed in a plant press between sheets of newspaper with corrugated cardboard separators. Specimens were dried in a warm, dry location, with the newspapers changed as needed to prevent build-up of moisture. Once dried, specimens were collated and wrapped in newspaper prior to transportation to Auckland Museum.

5.5 Fauna survey

5.5.1 Hymenoptera

Hymenoptera (sawflies, bees, wasps, and ants) were sampled within cloud forest at one sample site each on Te Manga and Te Kou, and from a lowland site near Muri Lagoon. To maximise the number of species collected, attempts were made to coincide the sampling period with fine weather. Within each sample site, yellow pan traps were placed at regular intervals along a transect (Plate 2). Within the cloud forest on Te Kou, 32 pan traps were set as there was a natural water source near the summit. On the summit of Te Manga, only four pan traps were set as the water needed to be carried in. At the lowland site, 30 pan traps were set. The pans were placed on flat ground and ¾ filled with clean water. A few drops of surfactant were added to each pan, which were then left in place for the duration of the trapping. All traps were set for 24 hours. After discarding any fallen plant material (e.g. leaves and twigs), each set of pans was then emptied into a fine-meshed aquarium net to make one combined sample for a site. The sample was washed in the net, and then emptied into a twirl bag. Ethanol at 95% concentration was added to each bag to preserve the sample. The bag was then labelled with location, habitat, and collection date. Samples were shipped to John Early (Hymenoptera specialist, Auckland Museum) for identification.

Plate 2: Yellow pan trap set for sampling Hymenoptera, western summit of Te Manga. 20 May 2015.

5.5.2 Landsnails

Landsnails were collected at one site each on Maungatea and Te Kou, and from five sites on Te Manga, following the sampling protocol described by Brook (2007). At each sampling site, 30 minutes were spent searching for snails within a circular area 20 m in diameter. Searching included looking for snails and snail shells under litter, fallen wood, and ground-tier vegetation, and on the lower trunks, branches, and leaves of woody plants. A series of spot samples of litter and soil, with a combined volume of 4L, was then collected from within the circular sample area and sorted later in a laboratory using a binocular microscope.

All specimens were placed in plastic vials labelled with location, date, habitat description, and collector. If a sample included live snails they were preserved in ethanol. All specimens were accessioned to Auckland Museum for identification by Wilma Blom (Curator for Invertebrates).

Tekoulina pricei, previously found on Te Kou, is suspected to be threatened if not extinct. Therefore if any individuals of this species were discovered, they would be photographed and released.

5.5.3 Freshwater fish

Where streams were close to the camp site, and away from safety hazards such as cliffs, night-spotting using a torch light was undertaken to determine if fish were present.

5.5.4 Terrestrial reptiles

Opportunistic searches were made for reptiles throughout the survey period in or under likely refugia, e.g. hollow trees, peeling bark, and fallen logs. If flowering or fruiting trees were located in or close to camp sites, and away from safety hazards such as cliffs, they were slowly scanned at night with head torches. Records (species, habitat, location, date, and time) were made for all species seen during the survey.

5.5.5 Birds

All bird species seen or heard in the cloud forest were recorded along with the habitat, location, date, and time of the observation. Searches were undertaken for seabird burrows in likely habitats (e.g. steep faces of highest peaks with loose soil and disturbance of the understorey).

5.6 Monitoring

Ten photopoints were established within representative habitat types, with five on Te Kou and five on Te Manga. Wherever possible, the photopoint was marked by placing a numbered aluminium tag on an adjacent tree trunk. One photograph was taken at each point. For each photopoint the following was recorded:

- Site name;
- Date;
- Time;
- Observer;
- Recorder;
- GPS reference (latitude, longitude);
- Compass bearing;
- Photograph number;
- Tree tag number (if relevant);
- Description of vegetation features (e.g. species, height, health);
- Sketch map to aid in finding photopoint.

Full details for each photopoint are provided in Appendix 2.

6. VEGETATION AND HABITATS

6.1 Overview

Vegetation patterns of the inland of Rarotonga have been broadly described by McCormack and Kunzle (1990), with quantitative descriptions of cloud forest habitats provided by Merlin (1985). Thus the species expected to be present in each altitudinal zone are well understood, but more subtle variations in composition and structure between the high peaks have not been thoroughly explored.

The peaks vary markedly in their topography. Cloud forest on Te Kou encompasses the headwaters of a basin-like valley, with areas of gentler slopes and riparian habitats, whilst all of the cloud forest on Te Manga occurs on steep upper slopes and ridgelines. Thus the cloud forest of Te Kou includes areas with minimal wind exposure and poorly drained soils, whereas all cloud forest on Te Manga is exposed to wind, with steep slopes ensuring good drainage.

The history of human use of cloud forest habitats on Rarotonga is also likely to have played a role in determining current vegetation patterns. Localised areas on Te Kou have been modified by the construction of a radio transmitter station, and trenches and tunnels, dug as fortifications during World War, are still present along the rim of the summit valley. Higher levels of historical use may explain the relatively high abundance of introduced plant species on Te Kou relative to other cloud forest habitats on Rarotonga.

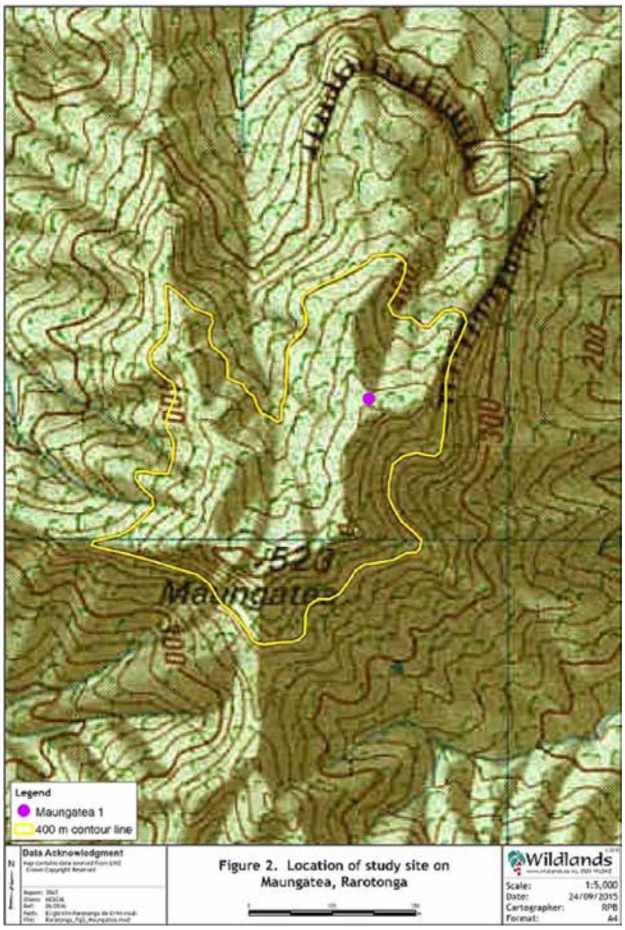
There are also indications that altitudinal zonation occurs within cloud forest habitats, creating differences in the vegetation between Te Manga, the highest peak, and lower peaks, such as Te Kou and Maungatea. At altitudes over 550 m on Te Manga, mosses appear to gain dominance over lichens in epiphytic niches. Kaiatea Ko'u, previously found on Te Kou which has a maximum altitude of 588 m, is now possibly restricted to the cloud forest on Te Manga, at altitudes over 600 m.

6.2 Cloud forest vegetation of Maungatea

A study site was established on a ridge on the northern face of Maungatea at 480 m altitude (Plate 3) (Figure 2, Maungatea 1). The vegetation of this site is best described as neinei-pua-rata treeland. The canopy is dominated by neinei, pua (*Fagraea berteroana*), and rata, with occasional kaiatea, karaka Rarotonga, and mato (*Homalium acuminatum*).These trees form a sparse canopy 3-4 m tall over a dense ground tier dominated by prickle fern (*Arachnoides aristata*), tangle fern, and kiekie, with occasional glossy tongue-fern, Nutupa (giant orchid; *Phaius tankervilleae*) and Malaxis orchid (*Malaxis resupinata*). Epiphytes, including the ferns *Belvisia mucronata*, *Humata banksii*, and *Ctenopterella blechnoides*, and lichens, especially *Pseudocyphellaria homalosticta* and *Sticta caperata*, are abundant on the trunks and branches of trees. The presence of both mato, that characterises slope forest habitats, and glossy tongue-fern, indicative of cloud forest, suggests that this site is transitional between slope forest and true cloud forest vegetation. This site, at 480 m altitude, is approximately 40 m below the summit of Maungatea (523 m), and it is possible that a complete transition to cloud forest vegetation occurs before the summit is reached.

Plate 3: Ridgeline vegetation at Maungatea study site (480 m). The study site was located on the knoll visible at the top right of the photograph. 7 May 2015. Tim Martin.

Figure 2: Location of study site on Maungatea, Rarotonga



6.3 Cloud forest vegetation of Te Kou

The gentler topography of the summit valley of Te Kou, combined with a multi-day survey, allowed the vegetation to be described at multiple locations on Te Kou.

Upper North-Facing Slopes

The final ascent to the northern rim of the summit valley is achieved by a series of steep rope climbs. The vegetation here, at 460-540 m altitude, is tangle fern fernland, with scattered trees of kaiatea, pua, and rata to 4 m tall (Figure 3, Te Kou 1). Epiphytes are abundant, including glossy tongue-fern, and foliose lichens such as *Sticta caperata*. On steeper faces, both to the east and west of the track, neinei becomes dominant, forming dense scrub.

Rim of Summit Valley

Along the rim of the summit valley, the vegetation is kaiatea-neinei treeland (Figure 3, Te Kou 2). Kaiatea and neinei are common, forming a broken canopy up to 4 m tall, with occasional rata, Homalanthus (*Homalanthus nutans*), pua, and Panga Ko'u (*Cyathea affinis*). Epiphytes include cloud grass-fern (*Radiogrammitis cheesemanii*), which is endemic to the cloud forests of Rarotonga, *Belvisia mucronata*, *Huperzia carinata*, and abundant lichens, particularly *Sticta caperata* and *Pseudocyphellaria homalosticta*. A wide range of species are locally dominant in the ground tier, including kiekie, the ferns Moumea Ko'u, prickle fern, tangle fern, and *Histiopteris incisa*, and Polynesian Isachne-grass (*Isachne distichophylla*). Along the north-eastern ridge that leads towards Te Manga, trees are more widely spaced and the ground-tier includes Polynesian blueberry, extensive swards of mosses, and patches of glossy tongue-fern, remu maunga (*Lycopodium cernuum*), and prickle fern (Figure 3, Te Kou 3) (Plate 4). To the east of the Te Kou track, there is an area of cherry guava scrub (Figure 3, Te Kou 4). Cherry guava is abundant, forming a canopy 3-4 m tall over a sparse ground tier of Moumea Ko'u, tangle fern, and smooth bird's nest fern (*Asplenium nidus*). Introduced species which have been planted in low numbers, with no evidence of spread, include gardenia (*Gardenia jasminoides*), kaute 'enua (hibiscus; *Hibiscus rosa-sinensis*), coconut (*Cocos nucifera*), and pineapple (*Ananas comosus*).

At the transmitter station (Figure 3, Te Kou 5), there is a small area of herbfield dominated by introduced plant species (Plate Te Kou 55). Sour paspalum (T-grass; *Paspalum conjugatum*) and elephant's foot (*Elephantopus mollis*) are common, with occasional oriental hawksbeard (*Youngia japonica*), *Crassocephalum crepioides*, comb hyptis (*Hyptis pectinata*), primrose willow (*Ludwigia octovalvis*), and mile-a- minute. The indigenous grass *Paspalum orbiculare* is occasional. Indigenous ferns have colonised the vertical clay bank at the rear of the transmitter building, including wedge blechnum (*Blechnum volcanicum*), *Hymenophyllum* species, and *Christella dentata*.

Figure 3: Location for vegetation descriptions and photographs, Te Kou, Rarotonga

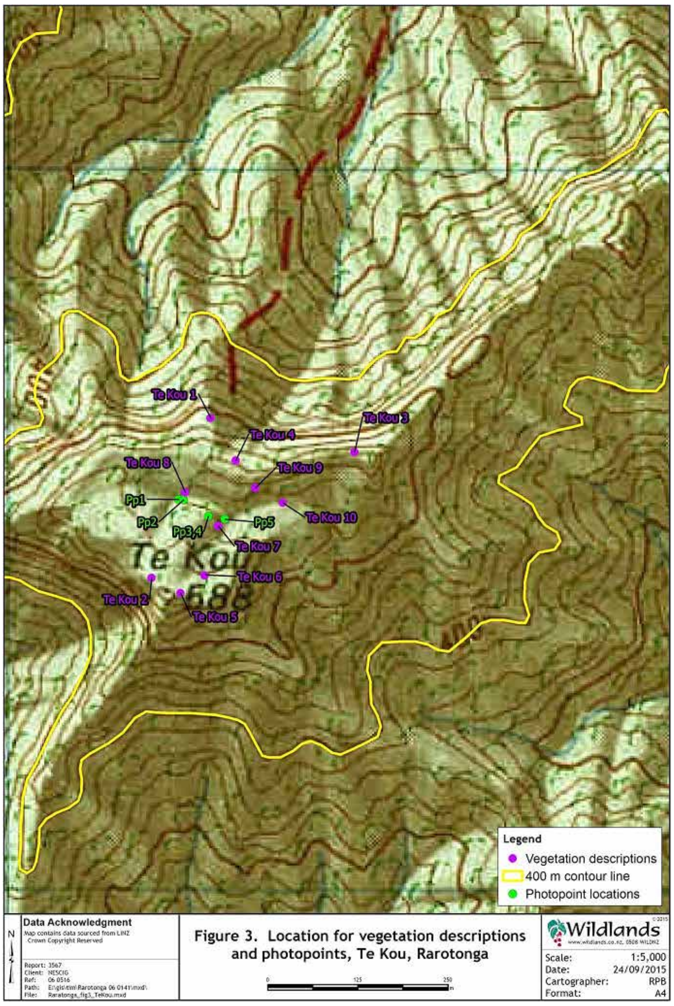


Plate 4: Vegetation on northern ridge of Te Kou dominated by glossy tongue-fern and mosses. 13 May 2015. Tim Martin.

North-Facing Slopes of Summit Valley

The upper north-facing slopes of the summit valley are primarily covered in shrubland, dominated by either Moumea Ko'u and neinei, or Moumea Ko'u and kaiatea, with frequent kiekie (Plate 5) (Figure 3, Te Kou 6). Other species present include pua, Panga Ko'u, rata, and 'Ua Motukutuku (*Melastoma denticulatum*). Invasive plant species present include white-flowered ginger (*Hedychium coronarium*), *Paspalum conjugatum*, African tulip tree (*Spathodea campanulata*), and mile-a-minute. On the lower north-facing slopes (Figure 3, Te Kou 7), Moumea K'o'u becomes the sole dominant over large areas, with frequent to occasional rata, kaiatea, kiekie and neinei, and occasional white-flowered ginger and cherry guava (*Psidium cattleianum*). At the headwaters of the stream, white-flowered ginger is dominant, with areas of *Paspalum conjugatum* grassland on the stream banks (Figure 3, Te Kou 8).

South-Facing Slopes of Summit Valley

The south-facing slopes of the summit valley are much steeper than the north-facing slopes, particularly to the east of the Te Kou track. Kiekie is dominant on the steepest faces, forming kiekie vineland with occasional neinei, kaiatea, and Panga Ko'u (Figure 3, Te Kou 9). Where this vegetation type descends to the stream, Moumea Ko'u and white-flowered ginger are locally abundant.

Stream Banks

To the east of the Te Kou track, the stream becomes steeply incised, and the riparian vegetation is dominated by kiekie, neinei, and the thin-trunked Panga Tua-more (*Cyathea decurrrens*) (Plate 6) (Figure 3, Te Kou 10). Ana'e (king fern; *Angiopteris evecta*), Moumea Ko'u, kiekie, *Pteris tripartita*, and smooth bird's nest fern are present in the ground tier. Night-blooming cestrum is common within a few metres of the stream, and in places forms dense thickets. White-flowered ginger is occasional, and one mature cecropia (*Cecropia palmata*) was found on the south bank of the stream. This tree was the only cecropia found in the summit valley of Te Kou and was felled using a machete.

Plate 5: North-facing slopes of summit valley on Te Kou. 11 May 2015. Tim Martin.

Plate 6: Riparian vegetation dominated by Panga Tua-more and white-flowered ginger on Te Kou. 13 May 2015. Tim Martin.

6.4 Cloud forest vegetation of Te Manga

Te Manga-Ikurangi Ridge

The ridgeline between Te Manga and Ikurangi, at 400-500 m altitude, is dominated by a series of steep-sided pinnacles (Plate 7), (Figure 4, Te Manga 1). These pinnacles are at the lower altitudinal limit of cloud forest. The vegetation is rata-neinei-kiekie shrubland, and canopy trees are very windshorn and *c*.3 m tall. Rata and neinei are common, with frequent kaiatea. Kiekie is the dominant species in the ground tier, and prickle fern, glossy tongue-fern, and mosses are also locally abundant. The epiphytes are primarily mosses and lichens, with the ferns *Humata banksia*, *Belvisia mucronata*, and *Hymenophyllum sanguinolentum*.

Upper East-Facing Hillslopes

The final ascent to the lower western summit of Te Manga is up a very steep ridge (Figure 4, Te Manga 2). The vegetation is similar to that on the Te Manga-Ikurangi ridgeline, but neinei increases in dominance to form neinei-kiekie-rata shrubland. Sour paspalum, an introduced grass, is locally abundant along the margins of the track.

Western Summit of Te Manga

The vegetation of the western summit of Te Manga is kiekie-neinei shrubland (Figure 4, Te Manga 3) (Plate 8). Kiekie is abundant in the ground tier, with frequent *Microsorum commutatum* and Moumea Ko'u, and occasional Wedge Blechnum. Neinei is frequent, forming shrubs and small trees to 3 m tall. The small area of flat land at the summit is largely bare, with scattered plants of sour paspalum and elephant's foot.

Plate 7: Steep-sided pinnacle on Te Manga - Ikurangi ridgeline. 21 May 2015. Tim Martin.

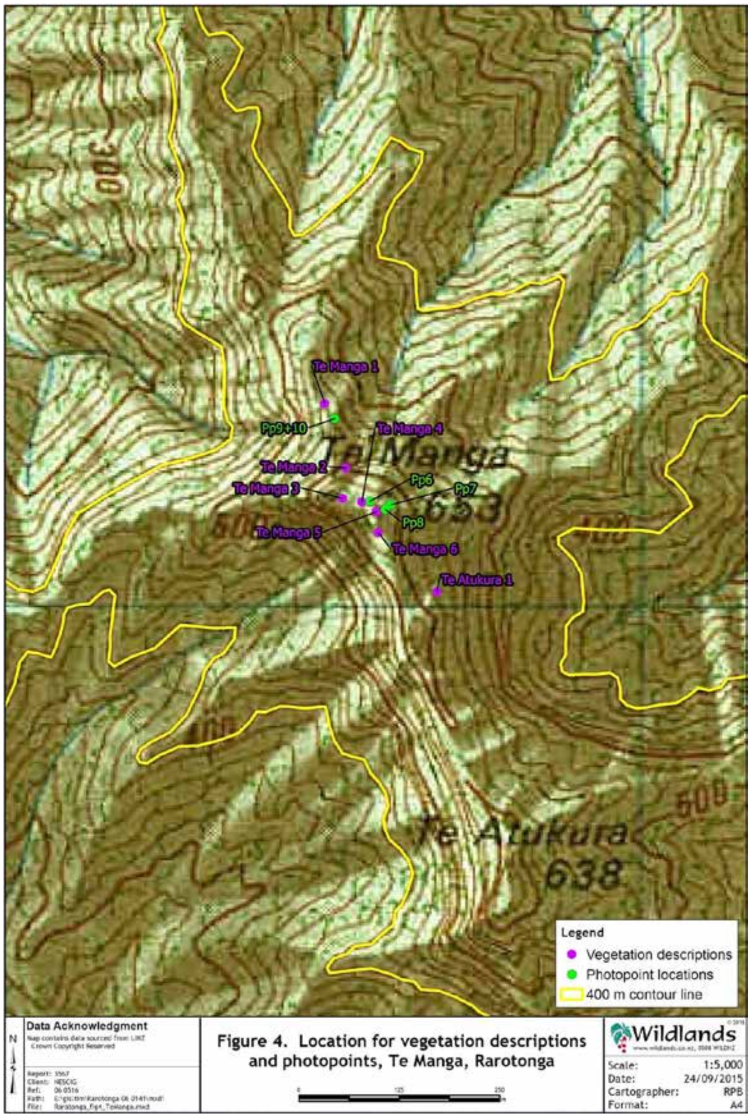


Figure 4: Location for vegetation descriptions and photopoints, Te Manga, Rarotonga

Plate 8: Western summit of Te Manga (photograph top right). 19 May 2015. Tim Martin.

Saddle Between the Eastern and Western Summits of Te Manga

The steep sided saddle between the two summits supports kaiatea-neinei-rata forest (Figure 4, Te Manga 4). Kaiatea, neinei, and rata are common, forming a low forest 3-4 m tall, with occasional Kaiatea Ko'u and rough-leaved shrub (*Cypholophus macrocephalus*). Panga Tua-more is locally common on the more gently sloping eastern side of the saddle, whereas the very steep western side is dominated by neinei and *Blechnum* species. The ground-tier is dominated by ferns including smooth bird's nest fern, Moumea Ko'u, Bolbitis Fern (*Bolbitis lonchophora*), and *Christella dentata,* and Malaxis orchid and Nutupa (giant orchid) are locally abundant. The epiphytic flora is dominated by mosses, with frequent lichens, and ferns, including *Belvisia mucronata*, cloud grass-fern, *Hymenophyllum sanguinolentum*, and glossy tongue-fern. Epiphytic orchid species included Oberonia orchid (*Oberonia equitans*), leafless orchid (*Taeniophyllum fasciola*), and native ladder-orchid (*Dendrobium involutum*).

Eastern Summit of Te Manga

The taller eastern summit of Te Manga is covered in rata-kaiatea-Moumea Ko'u shrubland (Figure 4, Te Manga 5). On the east-facing side of the summit, Moumea Ko'u is abundant, forming a dense low ground tier to *c*.0.5 m tall, with frequent kiekie. Mosses, liverworts, and glossy tongue-fern form a dense ground cover on the edges of the track. On the western crest of the summit, rata and kaiatea form a low wind-shorn canopy.

Te Manga-Te Atukura Ridgeline

The ridgeline between Te Manga and Te Atukura descends steeply, with a steep hillslope to the east and a cliff to the west. The vegetation here is low Moumea Ko'u- kiekie fernland (Plate 9) (Figure 4, Te Manga 6). Moumea Ko'u and kiekie are common, with rata as an occasional emergent shrub to 2 m tall. On the steepest parts of the ridge, the vegetation is reduced to a low sward of mosses, liverworts, and ferns, including prickle fern, Moumea Ko'u, glossy tongue-fern and remu maunga. Polynesian blueberry is also present.

Plate 9: Te Manga-Te Atukura ridgeline viewed from eastern summit of Te Manga. 20 May 2015. Tim Martin.

East Facing Gully Head Below Te Atukura

Ana'e fernland occurs in a steep east-facing gully head below Te Atukura (Figure 4, Te Atukura 1). Ana'e forms a canopy 2-4 m tall over a shrub tier of Te Manga Cyrtandra (Plate 10), night-blooming cestrum, and Kava Maori (*Piper methysticum*). One plant of Rarotonga Sclerotheca (*Sclerotheca viridiflora*), a Critically Endangered endemic, was found at this location.

Plate 10: Te Manga Cyrtandra growing with Ana'e on the upper eastern slopes of Te Atukura 20 May 2015. Tim Martin.

7.FLORA

7.1 Vascular flora

One hundred and eight vascular plant species were recorded at the study sites, and a checklist for each site is provided in Appendix 1.

Eighteen endemic plant species are included on the IUCN Red List (Table 3). Full assessment details are available for all of these species on the IUCN website (IUCN 2015).

Table 3: IUCN Red List Threat Assessments for Rarotonga flora.

Species	Family	Distribution	Threat Classification	Present in Cloud Forest
Acalypha wilderi	Euphorbiaceae	Rarotonga	Extinct	
Asplenium schizotrichum	Aspleniaceae	Rarotonga	Critically Endangered	
Balanophora wilderi	Balanophoraceae	Rarotonga	Data Deficient	
Coprosma laevigata	Rubiaceae	Rarotonga	Critically Endangered	Yes
Cyath ea parksiae	Cyatheaceae	Rarotonga	Least Concern	Yes
Cyrtandra lilianae	Gesneriaceae	Rarotonga	Critically Endangered	Yes
Cyrtandra rarotongensis	Gesneriaceae	Rarotonga	Critically Endangered	
Fitchia speciosa	Asteraceae	Rarotonga	Least Concern	Yes
Garnot ia cheesemanii	Poaceae	Rarotonga	Critically Endangered	Yes
Geniostoma rarotongensis	Loganiaceae	Rarotonga	Data Deficient	Yes
Haloragis stokesii	Haloragaceae	Rarotonga	Critically Endangered	Yes
Homalium acuminatum	Salicaceae	Rarotonga	Least Concern	
Mer yta pauciflora	Araliaceae	Rarotonga	Vulnerable	Yes
Myrsine cheesemanii	Primulaceae	Rarotonga, Ma'uke, Miti'aro, Mangaia	Data Deficient	Yes
Pittosporum rarotongense	Pittosporaceae	Rarotonga, Ma'uke, Miti'aro, Mangaia	Least Concern	
Psychotria whistleri	R ubiaceae	Rarotonga	Critically Endangered	Yes
Radiogrammitis cheesemanii	Grammitidaceae	Rarotonga	Endangered	Yes
Sclerotheca viridiflora	Campanulaceae	Rarotonga	Critically Endangered	Yes

One species was assessed as "Extinct", eight species as "Critically Endangered", one species as "Endangered", one species as "Vulnerable", three species as "Data Deficient", and four species as "Least Concern". Of the 10 endemic flora listed as "Critically Endangered", "Endangered", or "Vulnerable", eight occur in cloud forest habitats (*Coprosma laevigata*, *Garnotia cheesemanii*, *Haloragis stokesii*, *Myrsine cheesemanii*, *Meryta pauciflora*, *Radiogrammitis cheesemanii*, *Sclerotheca viridiflora*, and *Psychotria whistleri*) and two are found solely in cloud forest habitats (*Cyrtandra lilianae* and *Radiogrammitis cheesemanii*). None of the Rarotonga endemic species are currently subject to active conservation management, and with a lack of management the long-term survival of several species is unlikely. Many of the key habitats for endemic flora are chronically threatened by weed invasion, and several invasive weed species (e.g. mile-a-minute) are now establishing in cloud forest on the remote mountain peaks that have, until recently, acted as refuges for "Critically Endangered" endemics (e.g. *Cyrtandra lilianae* and *Sclerotheca viridiflora*).

7.2 Non-vascular flora

This report will be revised to include non-vascular plant species (lichens, liverworts, and mosses) when identification work has been completed. A preliminary list of the taxa collected in 2015 is provided in Appendix 3. Initial identification work has indicated that the number of indigenous lichen species known to occur on Rarotonga will substantially increase. These lichens include additional species within genera previously recorded on Rarotonga (e.g. *Sticta fuliginosa*), and genera not previously recorded from anywhere in the Cook Islands, including three *Cladonia* species (Plate 11), three *Heterodermia* species (*H. hypocaesia*, *H. japonica*, *H. reagens*), and two *Parmeliella* (*P. brisbanensis*, *P. mariana*).

Plate 11: Collection of a lichen in the genus Cladonia from Te Manga (grey finger like growths with red fruiting bodies). This genus is a new record for the Cook Islands.

8. FAUNA

8.1 Invertebrates

8.1.1 Landsnails

Indigenous landsnails confirmed as still present in cloud forest habitats include the endemics *Lamprocystis globosa* and *Lamprocystis venosa*, one or more undescribed species of endemic *Lamprocystis*, and a species of *Nesopupa* (Table 4). The undescribed endemic *Lamprocystis* species were found on Te Kou, Maungaroa, and Maungatea. The presence of these undescribed *Lamprocystis* on Te Kou, along with *Lamprocystis globosa* and *Lamprocystis venosa* at the same site, highlights the importance of cloud forest on Te Kou for landsnail conservation on Rarotonga. However, until all *Lamprocystis* specimens collected in 2015 are identified to species level, it cannot be ruled out that Te Kou, Maungaroa, and or Maungatea, could support new endemic species not found on other peaks.

Extensive searching failed to find live or dead specimens of any of the four cloud forest species presumed to be extinct (*Liberia tumuloides, Minodonta unilamellata, Sinployea decorticata*, and *Sinployea taipara*). The results of the 2015 survey provides further evidence that these species are likely to be extinct. In addition, no specimens were found of the endemics *Tekoulina pricei* or *Sinployea harveyensis* at their previous known location, despite many hours of searching. These two species are likely to be on the verge of extinction, or already extinct.

Eight introduced landsnails were confirmed as present in cloud forest habitats (Table 5). All of these species were found during the surveys of 2005-2007 by Brook (2010). Six introduced species were found in slope forest habitats on Maungaroa, which was surveyed for the first time during this survey.

Table 4: Indigenous landsnails of inland habitats, Rarotonga

Family	Species	Status	Habitat	Location (2005-2007 Surveys)	Confirmed Locations in 2015
Achatinellidae	*Tekoulina pricei*	Threatened endemic	Montane fernland and forest	Summit basin of Te Kou	Not found
Partulidae	*Partula assimilis*	Threatened endemic	Cloud forest	Upper Tupapa and Takuvaine Valleys	Te Kou slope forest (MA120846)
Endodontidae	*Liberia tumuloides*	Endemic, presumed extinct	Mountain ravines	-	Not found
Endodontidae	*Minidonta unilamellata*	Endemic, presumed extinct	Mountain ravines	-	Not found
Charopidae	*Sinployea decorticata*	Endemic, presumed extinct	Mountain ravines	-	Not found
Charopidae	*Sinployea harveyensis*	Threatened endemic	Montane fernland	Summit of Te Kou	Not found
Charopidae	*Sinployea taipara*	Endemic, presumed extinct	Cloud forest	NNE flank of Te Manga, summit basin of Te Kou	Not found
Assimineidae	*Omphalotropis variabilis*	Endemic to Southern Cook Islands	Slope forest	Common in inland habitats, nearly extirpated from coastal plain	Maungaroa slope forest (MA120857)
Euconulidae	*Lamprocystis* (Avarua) *globosa*	Endemic	Slope forest, cloud forest	Locally common in slope and cloud forest on Te Manga and Te Kou	Te Manga cloud forest (MA38416, MA120869) Te Kou cloud forest (MA38408, MA38410, MA120841)
Euconulidae	*Lamprocystis* (Avarua) *venosa*	Common endemic	Cloud forest	Widely distributed	Te Kou cloud forest (MA120841, MA38402,MA 120879)
Euconulidae	*Lamprocystis* (Avarua) sp. 1	Locally common endemic	Cloud forest, montane fernland	Widely distributed in south and east.	Not found
Euconulidae	*Lamprocystis* (Avarua) sp. 2	Endemic	Cloud forest, montane fernland	Te Manga, Te Kou	Not found
Euconulidae	*Lamprocystis* (Avarua) sp. 3	Endemic	Cloud forest	Te Manga, Te Kou	Not found
Euconulidae	*Lamprocystis* (Avarua) sp. 4	Endemic	Cloud forest	Te Manga, Te Kou	Not found
Euconulidae	*Lamprocystis* (Avarua) sp. 5	Endemic	Cloud forest	Northern slopes of Maungatea, upper Avatiu Valley	Not found
Vertiginidae	*Nesopupa* sp.				Maungatea cloud forest (L40516)

Table 5: Introduced landsnails of inland habitats, Rarotonga.

Family	Species	Status	Habitat	Location (2005-07 Surveys)	Confirmed Locations in 2015
Bradybaenidae	*Bradybaena similaris*	Introduced from Asia	Slope forest, cloud forest	Slope forest, cloud forest	Te Manga slope forest (MA38399, MA120883), Te Manga cloud forest (MA120874, MA120866) Maungaroa slope forest (MA120855, MA120863) Maungatea cloud forest (MA120832) Te Kou slope forest (MA120848)
Subulinidae	*Allopeas clavulinum*	Probably native to Asia	Cloud forest	Widespread in inland habitats	Te Manga slope forest (MA120881) Te Manga cloud forest (MA120878) Te Kou cloud forest (MA120847) Maungatea cloud forest (MA120836) Maungaroa slope forest (MA120856)
Subulinidae	*Paropeas achatinaceum*	Probably introduced from south-east Asia	Slope forest, cloud forest	Common in inland habitats	Te Manga slope forest (MA120881, MA120873) Te Manga cloud forest (MA120878,MA120868) Te Kou slope forest (MA120852, MA38409, MA120842) Te Kou cloud forest (MA120847) Maungaroa slope forest (MA120860, MA120862)
Euconulidae	*Kororia palaensis*	Introduced, first recorded in 1994	Coastal plain, slope forest, cloud forest	Scarce on coastal plain, common in slope forest and cloud forest	Te Manga cloud forest (MA120869, MA 120866) Te Kou cloud forest (MA120844, MA120849) Maungatea slope forest (MA120833, MA120840)
Assimineidae	*Assiminea nitida*	May be the same as A .lucida			Te Manga cloud forest (MA120870)
Subulinidae	*Subulina octona*	Introduced from American tropics	Coastal plain, slope forest, cloud forest	Locally common in inland habitats	Te Manga slope forest (MA120881) Maungaroa slope forest (MA120859)
Euconulidae	? *Diastole* sp.	Probably introduced	Slope forest, cloud forest	Uncommon in slope forest and cloud forest of Te Manga and Te Kou	Te Manga cloud forest (MA120876) Te Manga slope forest (MA120822) Te Kou cloud forest (MA120850) Te Kou slope forest (MA120843) Maungatea cloud forest (MA120834) Maungaroa slope forest (MA120864)
Euconulidae	*Diastole conula*	Introduced from French Polynesia	Coastal forest, slope forest, cloud forest	Sparse on coastal plain, locally abundant in slope forest and cloud forest	Te Manga slope forest (MA120872, MA120882) Te Kou slope forest (MA120853, MA120843) Maungaroa slope forest (MA120859, MA120864)
Achatinellidae	*Elasmias* sp.				Maungatea cloud forest (MA120838)

8.1.2 Ants

Twenty-four species belonging to this order were recorded, comprising nine ant, one bee, and 14 wasp species. With the exception of two species, all were only recorded at the lowland site. One specimen collected at Muri has tentatively been identified as *Monomorium liliuokalanii*, a species not currently recorded from Rarotonga. Many of the ant species recorded at Muri are described as "tramp" species; that is, species that have a wide distribution and are easily transported through human activities. The Rarotonga ant fauna includes several species that are detrimental to human health and livelihoods including the tropical fire ant (*Solenopsis germinata*) and the crazy ant (*Paratrechina longicornins*). Within cloud forest, the domestic honey bee (*Apis mellifera*) was recorded at Te Manga, and the introduced ant, *Pheidole fervens*, was found on Te Kou.

8.2 Herpetofauna

Two lizard species were seen in cloud forest habitats during the 2015 survey. An adult Rarotonga tree skink was seen sun-basking on 19 May 2015 approximately 20 m to the east of the eastern Te Manga summit. This was the only sighting of this species in cloud forest during the survey. Its location, at approximately 640 m altitude and *c*.10 m below the highest peak on the island, indicates that the altitudinal range of this species encompasses all cloud forest habitats.

Oceanic gecko were seen at two locations on Te Kou. Several adults were seen in the interior of a small derelict shed, to the west of the transmitter station, on 12 May 2015. One adult Oceanic gecko (Plate 12) was found in the canopy foliage of a rata, close to the northern rim of the summit basin.

Plate 12: Oceanic gecko on rata, Te Kou, 12 May 2015. Tim Martin.

A third species, inland blue-tailed skink (*Emoia impar*), was frequently seen sun- basking in the upper slope forest along the Te Manga track. This species is also likely to be present within the cloud forest.

Table 6: Hymenoptera of inland habitats, Rarotonga.

Sub-Family (Ants Only)	Species	Common Name/ General Description	Recorded Prior to 2010 (Brook 2010, ants only)	Recorded in 2015	Location 2015	Comment
n/a	*Apis mellifera*	Honey bee	n/a	Yes	CR216	
n/a	*Proconura*? Sp.	Chalcid wasp	n/a	Yes	CR54	
n/a	*Pison* sp.	Fairy wasp	n/a	Yes	CR54	
n/a	*Pison westwoodi*	Parasitic wasp	n/a	Yes	CR54	
n/a	Species	Parasitic wasp	n/a	Yes	CR54	
n/a	Species 1	Parasitic wasp	n/a	Yes	CR54	
n/a	Species 2	Parasitic wasp	n/a	Yes	CR54	
n/a	Species 3	Parasitic wasp	n/a	Yes	CR54	
Myrmicinae	*Cardiocondyla emeryi*	Ant	Yes	Yes	CR54	
Myrmicinae	*Cardiocondyla nuda*	Ant	Yes	No	n/a	
Myrmicinae	*Monomorium destructor*	Singapore ant	Yes	No	n/a	
Myrmicinae	*Monomorium floricola*	Ant	Yes	Yes	CR54	
Myrmicinae	*Monomorium liliuokalanii?*	Ant	No	Yes	CR54	Possible new record for the Cook Islands
Myrmicinae	*Pheidole fervens*	Ant	Yes	Yes	CR54, CR224	
Myrmicinae	*Pheidole megacephala*	Ant	Yes	No	n/a	
Myrmicinae	*Pheidole oceanica*	Ant	Yes	No	n/a	
Myrmicinae	*Pheidole umbonata*	Ant	Yes	No	n/a	
Myrmicinae	*Rogeria stigmatica*	Ant	Yes	No	n/a	
Myrmicinae	*Solenopsis geminata*	Tropical fire ant	Yes	Yes	CR54	
Myrmicinae	*Solenopsis papuana*	Ant	Yes	No	n/a	
Myrmicinae	*Strumigenys godeffroyi*	Ant	Yes	No	n/a	
Myrmicinae	*Tetramorium nr simillimum*	Ant	Unsure	Yes	CR54	
Myrmicinae	*Tetramorium pacificum*	Ant	Yes	No	n/a	
Myrmicinae	*Tetramorium simillimum*	Ant	Yes	No	n/a	
Myrmicinae	*Tetramorium tonganum*	Ant	Yes	No	n/a	
Dolichoderinae	*Tapinoma melanocephalum*	Ant	Yes	No	n/a	
Dolichoderinae	*Technomyrmex albipes*	Ant	Yes	No	n/a	
Formicinae	*Anoplolepis gracilipes*	Yellow crazy ant	Yes	No	n/a	
Formicinae	*Paratrechina bourbonica*	Robust crazy ant/flesh eating crazy ant	Yes	Yes	CR54	
Formicinae	*Paratrechina longicornis*	Longhorn crazy ant	Yes	Yes	CR54	
Formicinae	*Paratrechina vaga*	Ant	Yes	No	n/a	
Ponerinae	*Anochaetus graeffei*	Ant	Yes	No	n/a	
Ponerinae	*Hyponera confinis*	Ant	Yes	Unsure	Unsure	
Ponerinae	*Hypoponera* sp.	Ant	Yes	Yes	CR54	
Ponerinae	*Hypoponera eduardi*	Ant	Yes	Unsure	Unsure	
Ponerinae	*Hypoponera opaciceps*	Ant	Yes	Unsure	Unsure	
Ponerinae	*Hypoponera punctatissima*	Ant	Yes	Unsure	Unsure	
n/a	Species	Fairy wasp	n/a	Yes	CR54	
n/a	*Aphanomerus* sp.	Parasitic wasp	n/a	Yes	CR54	
n/a	*Scelioninae* species	Parasitic wasp	n/a	Yes	CR54	
n/a	*Telenomus* sp.	Parasitic wasp	n/a	Yes	CR54	
n/a	Species	Parasitic wasp	n/a	Yes	CR54	
n/a	*Spalangia* sp.	Parasitic wasp	n/a	Yes	CR54	
n/a	*Polistes olivaceus*	Common paper wasp	n/a	Yes	CR54, CR179	

8.3 Birds

Four indigenous species were seen or heard within cloud forest habitats; ioi, Pacific pigeon, white-tailed tropicbird, and Herald or Trindade petrel. Ioi and Pacific pigeon were occasionally heard calling on the upper north-facing slopes of Te Kou and the upper east-facing slopes of Te Manga. These species are likely to be present throughout slope forest and cloud forest habitats. White-tailed tropic bird was frequently seen wherever there were cliffs or rock outcrops; groups of birds were seen in flight between Te Kou and Maungatea, and beside rock outcrops to the east of Te Manga. Whilst commonly seen from vantage points within cloud forest, white- tailed tropic bird may not breed within cloud forest habitats as most rock faces tend to occur on the over-steepened faces of the upper valleys, within the altitudinal range of slope forest Herald petrel were seen in flight in the late afternoon above the steep ridge that leads from Te Manga to Te Kou (Plate 13). To confirm whether this ridgeline is a breeding site, specialist equipment (e.g. abseiling gear) is likely to be needed.

Plate 13: Herald petrel in flight over ridgeline between Te Manga and Te Kou. 20 May 2015. Tim Martin.

8.4 Freshwater fish

The summit basin of Te Kou is the only catchment within cloud forest habitats that has permanent flowing water (Plate 14). The stream was surveyed using a kick-net and no fish were found. A further survey, undertaken at night using spot-lighting, found a mature tuna kavi (Pacific longfin eel; *Anguilla melastoma*) in the pool immediately below where the Te Kou track crosses the stream.

Plate 14: Permanent stream within the summit basin of Te Kou. 13 May 2015. Tim Martin.

9. ECOLOGICAL SIGNIFICANCE

Cloud forest habitats of Rarotonga are internationally significant based on an assessment of biodiversity values using recognized international criteria. Sites can be regarded as key biodiversity areas (KBAs) on a global scale if they meet one or more of the following criteria described by Eken *et al.* (2004):

Criterion 1: Globally Threatened Species. Sites in which a globally threatened species regularly occurs in significant numbers.

Criterion 2: Restricted-range species. Sites that hold a significant proportion of the global population of one or more restricted range species on a regular basis.

Criterion 3: Congregatory species. Sites that hold a significant proportion of the global population of a congregatory species on a global basis.

Criterion 4: Biome-restricted assemblages. Sites that hold a significant proportion of the group of species whose distributions are restricted to a biome or a subdivision of it.

The cloud forests of Rarotonga meet three of the four criteria for recognition as a Key Biological Area (Table 7).

Table 7: Assessment of Rarotonga cloud forests against the KBA criteria.

Criterion	Assessment	Justification
1. Globally threatened species	Yes ✓	Key site for eight vascular plant species that are globally threatened.
2. Restricted range species	Yes ✓	Supports all of the global population for several landsnail species and two vascular plant species.
3. Congregatory species	No ✗	No congregatory species are present in large numbers.
4. Biome-restricted assemblages	Yes ✓	One of the largest remaining areas of small-island low-altitude cloud forest. Retains almost the full suite of plant species and genera restricted to cloud forest habitats of the tropical Pacific.

10. THREATS

10.1 Overview

On a global scale, key threats to cloud forest habitats include climate change (Loope and Giambelluca 1998, Foster 2001), introduced feral ungulates (Meyer 2010), invasion by alien plants or pathogens (Whistler 1995), loss of fauna due to predation by introduced species (Watling and Gillison 1995), clearance for agriculture and housing (Raynor 1995), road construction (Raynor 1995, Meyer 2010), hydro- electricity development (Meyer 2010), hunting (Raynor 1995), and damage caused by tourism activities (Raynor 1995).

The cloud forests of Rarotonga are subject to a much narrower range of threats, primarily due to their extreme topography, and resulting inaccessibility. Habitat loss due to clearance for houses, roads, or agriculture is not occurring due to the steep and remote nature of the mountain peaks, and similarly, the steep terrain also limits use and damage by tourists. Feral ungulates, such as goats (*Capra hircus*), pigs (Sus *scrofa*), and cattle (*Bos taurus*), which have caused the severe modification of other cloud forests in the tropical Pacific (Mueller-Dombois and Fosberg 1998), are absent or have never been abundant in the montane areas of Rarotonga. The effects of introduced rodents are less known; ship rat, Pacific rat (*Rattus exulans*), Norway rat and house mouse, are all known to be present on Rarotonga, and are also likely to be present in cloud forest habitats (c.f. Townsend *et al.* 2009).

Invasive plant species, particularly those that are widely dispersed by birds or wind, are a significant threat to the cloud forests of Rarotonga, and management is needed to both limit the spread of species currently present, and to reduce the risk that further species become established. Monitoring, with prompt remedial action as required, is also needed ensure that any new threats that may arise are addressed.

10.2 Climate change

Cloud forest ecosystems of the tropical Pacific are particularly vulnerable to the potential effects of climate change (Loope and Giambelluca 1998). The biota of cloud forests typically has very specific environmental requirements (e.g. high humidity, cloud cover), and habitats with these characteristics can occur over very restricted areas. Additionally, island biotas are highly vulnerable to invasion by introduced species. Climate-change, such as increased cyclone frequency, could facilitate the invasion of cloud forest ecosystems by non-native species (e.g. Bellingham *et al.* 2005).

The potential effects of climate change are likely to be greatest for cloud forests that, like those in Rarotonga, occupy habitats on mountain summits. Increasing temperatures are likely to result in the upward migration of lower altitude ecosystems and the permanent loss of cloud forests and their associated biota (Foster 2001). However, climate change is likely to cause significant changes in ecosystem function well before altitudinal shifts and the potential loss of cloud forest occur. As discussed in Section 4.5 above, epiphytes, and in particular lichens and bryophytes, play a critical role in the hydrological cycle. Epiphytes often occupy micro-niches, and can be the first component of an ecosystem to respond to the effects of climate change, such as lower humidity, increasing variability of precipitation, and drought (Foster 2001, Ellis 2013). The modification or loss of epiphytes, as well as alterations to the hydrological cycle, may lead to further flow-on effects for biodiversity.

10.3 Invasive species

10.3.1 Invasive plant species

Meyer (2004) provided a preliminary list of the invasive plant species of Rarotonga, and categorised them as dominant invaders, moderate invaders, and potential invaders, with each of these divided geographically, where possible, into lowland versus inland habitats. The invasive plant species of Rarotonga cloud forests, derived from Meyer (2004) with modifications following the 2015 survey, are provided in Table 8. Five species not listed as present in the inland of Rarotonga were confirmed as present in cloud forests in 2015 (i.e. shoebutton ardisia, night-blooming cestrum, mile-a-minute, African tulip tree, sour paspalum). The preliminary list was derived from a literature review and consultation with local experts, and it is unknown if these species are relatively new arrivals in cloud forest habitats or if these species were present in 2000 but overlooked.

Table 8: Key invasive plant species of Rarotonga cloud forest (derived from Meyer 2000).

Scientific Name	Common Name	Threat	Distribution in Cloud Forests in 2015
Ardisia elliptica	Shoebutton ardisia	Dominant invader	Occasional
Cardiospermum grandiflorum	Balloon vine	Dominant invader	Occasional
Cecropia sp.	Cecropia, trumpet tree	Dominant invader	Occasional
Cestrum nocturnum	Night-blooming cestrum	Dominant invader	Locally abundant on Te Kou and Te Manga
Hedychium coronarium	White ginger	Dominant invader	Occasional, locally abundant on Te Kou
Mikania micrantha	Mile a minute	Dominant invader	Occasional
Psidium cattleianum	Strawberry guava	Dominant invader	Occasional. Locally abundant on Te Kou
Spathodea campanulata	African tulip tree	Dominant invader	Occasional
Paspalum conjugatum	T-grass, sour paspalum	Moderate invader	Locally abundant, generally restricted to disturbed areas and tracks
Syzygium jambos	Rose apple	Moderate invader	Occasional

10.3.2 Invasive animal species

Effects of Rodents on Flora and Vegetation

The vegetation of Rarotonga cloud forests is likely to be adversely affected by rodent species, especially ship rat, and if present, Norway rat. Rats can cause high rates of seed predation, particularly of large-seeded species. Ship rat have been shown to be the cause of regeneration gaps for two endemic palm species of cloud forest habitats on Lord Howe Island (Auld *et al*. 2010). During the 2015 survey, ship rat were frequently seen in the canopy of cloud forest trees. Inspection of canopy trees with fruit found that most of the unripe fruit on *Homalanthus nutans*, an uncommon tree species restricted to cloud forest, had been rat-gnawed, with most of the seed consumed. No seedlings or saplings of this species were seen anywhere in cloud forest habitats during either the 2010 or 2015 surveys, and it is probable that rats pose a significant threat to the long-term survival of *Homalanthus nutans* on Rarotonga. Ship rats are also known to damage plants within cloud forest habitats by twig cutting; a recent study in the Ogasawara Island group of Japan found twig cutting by ship rat on 42.6% of woody species, including a high probability of cutting for two genera also found in Rarotonga cloud forest (*Psychotria*, *Pisonia*) (Abe and Umeno 2011). Experimental studies would be needed to fully ascertain the effects of introduced rodents on the vegetation of Rarotonga cloud forests. As per the study undertaken on Lord Howe Island, regeneration of indigenous species could be compared between areas with and without rodent control, and survival of *Homalanthus* fruit could be compared between branches with and without rat-exclusion cages.

Effects of Rodents on Fauna

Rodents are also likely to be significant predators of the fauna of cloud forest habitats, including lizards, insects, landsnails, and birds. The introduction of rodents has resulted in the loss or decline of seabird colonies throughout the tropical Pacific, with species being most vulnerable if they are strictly ground-nesting or of small size (Carter and Carter 2000). Ship rats and Norway rats are likely to be reducing breeding success on Rarotonga for Herald petrel, a medium-sized petrel which is ground- nesting, and brown noddy, which nests in trees or on the ground (Holyoak 1980). It is likely that other species such as Polynesian storm petrel (*Nesofregata fuliginosa*) formerly bred on Rarotonga, but were lost following the introduction of rodents (Carter and Carter 2000). Rats are also known predators of forest bird species such as kakerori (Rarotonga flycatcher), and within cloud forest habitats will prey on the eggs and nestlings of Rarotonga fruit dove, Pacific pigeon, and ioi (Rarotonga starling). The effect of rodents on the birds of Rarotonga has been clearly demonstrated by the plight of kakerori, which was nearly extinct in the 1980s, being reduced to only 29 birds. The control of rats in the Takitimu Conservation Area has increased nesting success and numbers are now increasing (with a population of 292 birds by 2003 (Carter and Carter 2000, Robertson and Saul 2005). Rats are likely to be a key factor in the relative scarcity of all bird species in cloud forest habitats.

All of the rodent species present will also prey on lizards (e.g. McCallum 1986) and invertebrates, including indigenous land snails (Brook 2010). Declines and extinctions of landsnails of inland habitats have been attributed to predation by introduced rodents (including house mouse, ship rat, Norway rat and Pacific rat) and invertebrates, including 26 exotic ant species, and a predatory slug (*Deroceras laeve*) (Brook 2010). Twelve inland landsnail species are now regarded as extinct, and others are either very rare or extinct (Brook 2010). The effects of invasive animal species are likely to be ongoing, as more recent colonists, such as the ants, spread to reach their full extent on the island.

10.3.3 Introduced pathogens

Exotic plant pathogens such as *Phytophthora* are recognized as a serious threat to indigenous plant species and vegetation (Barrett *et al*. 2007, Worboys and Gadek 2004). *Phytophthora* is readily spread by the movement of contaminated soil on footwear, clothing, and equipment, and can cause widespread forest dieback. *P. cinnamomi* can infect a very wide range of plant species, and has caused widespread tree death around the globe. The introduction of *Phytophthora cinnamomi* into Australian ecosystems has caused forest dieback (Worboy and Gadek 2004), and increased the risk of extinction for endemic plant species, particularly those with very restricted distributions (Barrett *et al.* 2007). In New Zealand, *Phytophthora* has been identified as the pathogen causing dieback in kauri (*Agathis australis*) forest, and the death of puka (*Meryta sinclairii*), a genus of trees that is represented in the inland forests of Rarotonga by the endemic *Meryta pauciflora*. *Phytophthora* could pose a substantial threat to species such as *Meryta pauciflora* if it becomes established in inland forests.

10.4 Recreational use

Recreational use of Rarotonga's cloud forests by tourists is currently limited to climbing Te Kou and Te Manga, via rudimentary trails that lead from the road ends to the mountain summits. These two tracks are marked on tourist brochures and, based on a log book on the summit of Te Manga, the highest peak is likely to be visited at least several times per month. Trails on the lower slopes, within the lower altitudinal limits of cloud forest, may be visited more frequently, as some tourists turn back at the start of the final steep ascents to the summits. After passing through areas of cultivation in the valleys, both tracks follow steep ridges. Similar to other mountain tracks in the tropical Pacific (e.g. Pohnpei in Micronesia), they can be described as "little more than unconstructed paths-of-least resistance evolved over many years of use and sustained without resource damage by "light" overall use" (Raynor 1995 p. 279). The tracks are marked at intervals with tags on trees adjacent to the track, and the ascent of steeper sections is assisted by rope sections. The ridges are typically narrow, and are often no wider than the track itself. This, in combination with the free-draining soils, largely prevents foot traffic from eroding and widening the track.

The greatest threat likely to be posed by recreational use is the introduction or spread of invasive species, via propagules carried on footwear, clothing, or camping equipment. International travellers are known vectors for insects, plant diseases, and seeds of invasive species (McNeill *et al.* 2008), with contaminated footwear (McNeill *et al*. 2008, Webber and Rose 2007, Worboys and Gadek 2004) and camping equipment (McNeill *et al*. 2008) posing significant biosecurity risks. A study of passengers arriving at international airports in New Zealand found that for 157 pairs of soiled footwear, 50% carried seeds, and 73% of seeds were viable. Unintentional transport of biological material by tourists has, in addition to seeds, included fungi, fresh foliage, nematodes, rust spores, and feathers (McNeill *et al*. 2008). Tourists can also facilitate the spread of invasive organisms that are currently present in a region into sensitive natural areas (McNeill *et al*. 2008, Webber and Rose 2007, Worboy and Gadek 2004).

The high rainfall of cloud forest habitats on Rarotonga reduces, but does not eliminate the risk posed by accidental fires. Fires do occur within cloud forest ecosystems, and an increase in fire frequency can significantly alter vegetation communities (Asbjornsen and Wickel 2009). Accidental fires, originating from camp cooking fires, could potentially occur and cause widespread damage, particularly if they coincided with a period of reduced rainfall. If fires occur, these are likely to alter the composition of the vegetation by favouring species that are fire resistant, or can regrow from damaged stems, or can rapidly germinate and establish within areas cleared by fire. Fire, like other disturbances, may also favour the regeneration of invasive species over indigenous species (Bellingham *et al.* 2005).

10.5 Disturbance events

The cloud forests of Rarotonga cover an area of only 150 hectares, and of this area, most of the cloud forest area is on the upper ridges leading to one peak, Te Manga. The cloud forest, and all species that are restricted to cloud forest habitats, are therefore inherently vulnerable to disturbance events, even if these are of natural origin. This is a common theme that has been noted for cloud forests across the tropical Pacific; most cloud forests on small islands are extremely limited in extent, with inherent vulnerability (Merlin and Juvik 1995). Within Rarotonga cloud forest, disturbances could include events such as such as fire, felling of vegetation by severe winds, or landslides. Where disturbance events act on a large area of habitat, or on a species with a large population, risk of loss is low, as it is likely that at least one area, or part of the population, will survive. In contrast, where events impact a small area of habitat or population, the chances of permanent loss or extinction are much higher. The risk posed by disturbance events needs to be assessed on a case by case basis, considering the nature of the event, and its likely extent or impact.

10.5. 1 Natural fire events

The role of fire in tropical montane cloud forests is relatively poorly understood. Few studies of the effects of fire have been undertaken, due to fires being historically rare in habitats characterised by high precipitation. However there is a growing body of evidence that fires do occur within cloud forest, and can play a significant role in the disturbance regime, successional trajectories, and in some cases, in facilitating forest loss (Absjornsen and Wickel 2009). Historical evidence from tropical montane forests in other regions suggests that during relatively wet periods, natural fires do not occur due to high rainfall, humidity and high soil moisture. Conversely, during drier periods, natural fires can occur from ignition by lightning, and fires lit by humans are likely to be more frequent and more severe (Absjornsen and Wickel 2009). Fires, whether ignited by lightning or people, have the potential to burn over tens or hundreds of hectares, particularly if they coincide with dry conditions (Whelan 1995). The risk posed by fire to the cloud forest of Rarotonga can be summarised as of low probability (due to prevailing wet conditions), but of high consequence (due to the small total extent of cloud forest, with most of the habitat confined to one location). Probability will significantly increase during periods of low rainfall when recreational use provides a potential fire source in addition to lightning.

10.5.2 Landslides and wind-throw

Landslides and wind-throw of trees during storm events are an important part of the natural disturbance regime of cloud forests (Brokaw and Walker 1991). The scale of these disturbances within Rarotonga cloud forests is unlikely to directly affect all of the cloud forest habitats within any one event. The severity of wind-throw damage is strongly influenced by factors such as soil depth, variation in the structure and age of the vegetation, and topography, and any one severe wind event is only likely to affect a portion of the habitat present. Similarly, the location and size of landslides is influenced by steepness of slope, soils, and time since last disturbance. Landslides are likely to occur on steeper hillslopes as opposed to ridges, and are likely to be more frequent where landslides have previously occurred.

The greatest risk posed by landslides and wind-throw is the creation of habitats favourable for the establishment of invasive plant species. Sites where severe disturbance has occurred could become beachhead locations for species such as mile- a-minute or balloon vine (*Cardiospermum grandiflorum*), with subsequent spread into adjacent undisturbed habitats. An increase in the abundance and frequency of invasive plant species in upland habitats of Rarotonga has been noted following large-scale disturbance by cyclones, and anecdotally, has been attributed to the facilitated spread of propagules from adjacent lowland areas into upland areas during severe wind events (Peter de Lange pers. comm. 2010). The role of cyclones in facilitating the spread of invasive plant species in montane forests has been demonstrated in other regions, such as the Caribbean (Bellingham 2005). The risk of increased invasion by exotic plant species can be regarded as high, as cloud forest habitats are known to be affected periodically by storm events, and invasive plant species are a recognized threat to the cloud forest, and the endemic plant species dependant on it. A secondary risk posed by wind-throw and landslides is the possibility the an event will damage or remove an endemic plant population of very restricted distribution e.g. the only known population of Te Manga Cyrtandra at the head of a former landslide on the eastern face of Te Manga.

11. RESTORATION AND MANAGEMENT

11.1 Overview

Management of Rarotonga cloud forest cannot be undertaken in isolation from the surrounding lowland areas. Threats that may pose a serious risk to the mountain summits, such as invasive species and fire, may first occur or establish within adjacent lowland areas, and subsequently spread to montane habitats further inland. The following management will therefore be most effective if it is applied not only to cloud forest habitats, but also to all of the inland forests of the island.

11.2 Legal protection of water catchments and inland habitats

Rarotonga's reliance on streams for its water supply places great importance on the protection of the inland habitats through which these streams flow. At present, activities such as farming, hiking, and swimming occur upstream of most of the water uptakes (Nath *et al*. 2006), and pose significant risks regarding the quality of water supply. Future population growth could also lead to further vegetation clearance in the water catchments, and even possibly the construction of dwellings in the inland valleys.

Legal protection of cloud forest habitats on the three highest peaks was proposed in 1969. The proposed Te Manga Nature Reserve, mapped by the Department of Survey, included land above 400 m altitude on Te Manga, Te Atukura, and Te Kou. This proposed reserve encompassed 118 hectares, which is approximately 80% of cloud forest habitats on Rarotonga. Legal protection of Rarotonga's inland habitats has considerable merit, as it would recognise the significance of the ecosystems present, and the critical role they play in security of water supply. If legal protection is considered, the boundaries of the reserve should include not only the cloud forest on the highest peaks, but also inland forests upstream of the water intakes. This would protect all of the water catchments, and complete ecological sequences from lowland to montane habitats. The boundaries for a proposed reserve are provided in Figure 7. This reserve would protect the four main water supply catchments for Rarotonga (Papua Stream, Avana Stream, Tupapa Stream, and Takuvaine Stream), and encompass all of the known cloud forest habitats. The reserve also includes montane habitats on Maungatea and Maungaroa above 300 m altitude, as these peaks support intact representative examples of montane vegetation, and provide habitat for undescribed endemic landsnails. The inclusion of the remaining eight minor water catchments should be considered on a case by case basis, with greater importance placed on those catchments that support indigenous forests, and that are contiguous with the reserve boundaries proposed here.

11.3 Conservation of threatened endemic flora

Rarotonga's endemic cloud forest species have a high risk of extinction in the short to medium term if they have very restricted distributions and small population sizes. At present, no endemic plant species of cloud forest habitats are known to be present in cultivation, and ex-situ conservation is urgently needed to ensure their survival. Based on their rarity, growth form and ecological niches, cultivation trials should be attempted for the following species:

- Rarotonga Garnotia-Grass (*Garnotia cheesemanii*);
- Rarotonga Psychotria (*Psychotria whistleri*);
- Rarotonga Sclerotheca (*Sclerotheca viridifolia*);
- Te Manga Cyrtandra (*Cyrtandra lilianae*).

These species should be brought into cultivation by the collection of a small amount of seed from as many plants as possible. If no viable seed can be found for Rarotonga Sclerotheca or Te Manga Cyrtandra, cuttings could be trialled for these species, with only a small cutting taken off any one plant. Under no circumstances should whole plants be removed from the wild.

11.4 Invasive species

11.4.1 Overview

Management of invasive species should have a two-pronged approach that includes regular monitoring to ensure the early detection of newly invading species, and control of existing invasive species, where this is feasible and likely to have significant conservation benefits. The frequency of monitoring required will vary according to the species being targeted, with more regular monitoring required for species capable of rapid spread and high potential impacts. Conversely, monitoring can be less frequent for species with slow growth rates, limited dispersal abilities, and/or lower potential impacts.

11.4.2 Pest animals

Feral Ungulates

The absence of introduced ungulates, including goats, pigs, cattle, has been a major factor in the cloud forest persisting in its relatively unmodified state. However all of these species are present as domesticated animals on Rarotonga, posing a threat that escapees could lead to the establishment of feral populations. Cattle, and to a lesser extent pigs, are likely to be limited by the extreme terrain of the inland areas, but the steep and rocky terrain of inland Rarotonga is ideal habitat for feral goats. All environment staff on the island should be familiar with feral goat sign (droppings, hoof prints, and browse damage) and immediately report any sightings of animals or sign to NES. If any ungulates are confirmed as present, immediate control is of the highest priority.

Rodents

A study should be conducted to assess the feasibility of rodent control within cloud forest habitats that support particularly vulnerable species or ecosystems. The findings of the 2015 survey suggest that rodent control should be considered for two sites; the summit valley of Te Kou, and the upper slopes of Te Manga. The summit valley of Te Kou encompasses *c*.6 ha of cloud forest (300 m east-west by 200 m north-south) which, because of gentler slopes, can be traversed on foot. Rats are known to be present on Te Kou, and are possibly causing recruitment failure for *Homalanthus*, a large-seeded tree species restricted to cloud forest habitats. The site is also the only known location for *Tekoulina pricei*, an endemic landsnail, which is either very rare or extinct. Bait should be deployed in bait stations, with a "no-control' buffer within 20 m of the stream. Bait stations placed on a 50 × 50 m grid could achieve a high level of control of rats (Figure 5). If the outer-most bait stations are placed along the outer rim of the valley, control is likely to result in a 'core' area at the centre of the valley that is largely free of rats, and a 'halo' of habitat on the steep slopes leading up to the valley within which rodent numbers are reduced. Any rodent control at this site should be accompanied by monitoring of rat abundance, and of *Homalanthus* seed production and regeneration, to determine the effects of control. The feasibility study should encompass the following:

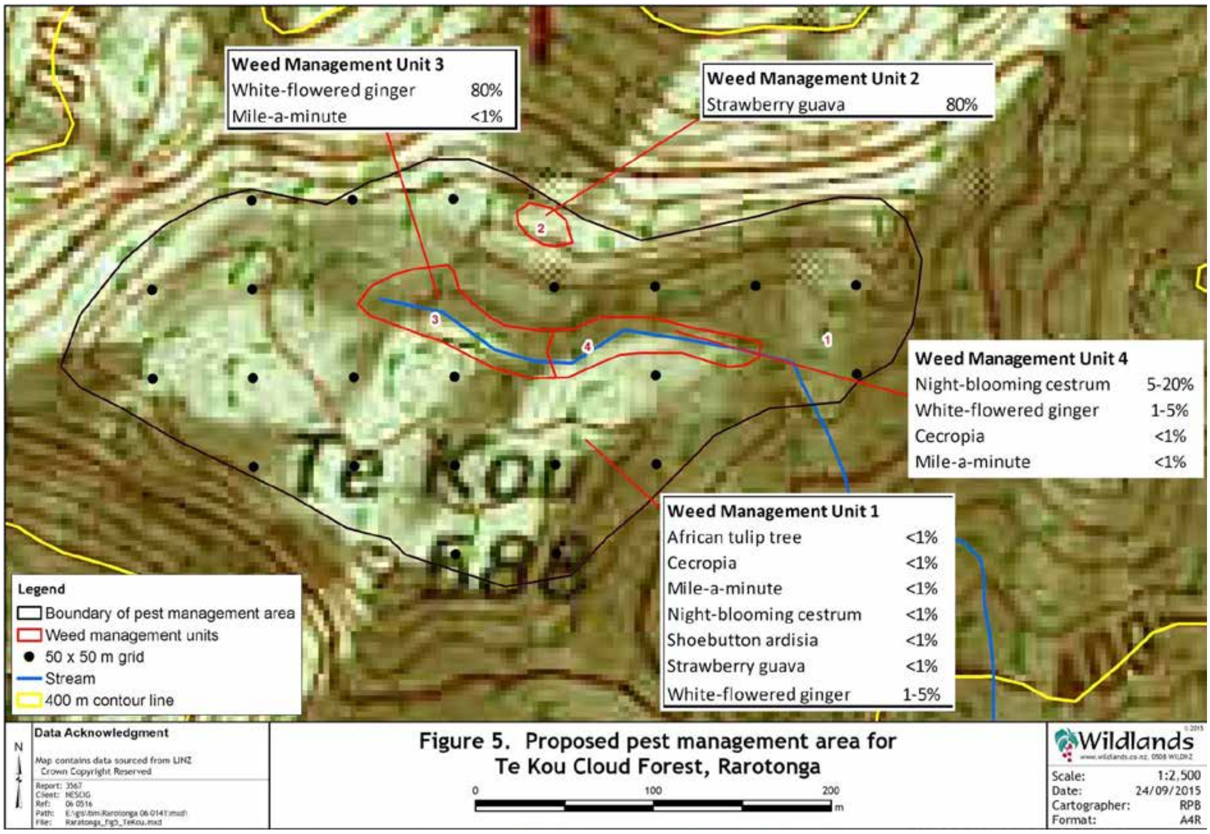
- Baseline monitoring of rodent abundance and *Homalanthus* seed predation;
- Any barriers to the use of toxins in the catchment;
- Logistics for the transport of bait stations and bait to the summit;
- Availability of staff or volunteers to set up the project and replenish the bait stations with bait.

The upper slopes of Te Manga are probably a breeding site for Herald petrel, a ground-nesting seabird. Rodents prey on the eggs and chicks of Herald petrel, resulting in clutch failure and limiting colony size. If Herald petrel is confirmed as present, intensive rodent control in the breeding colony could lead to expansion of the colony. This would not only make the population less vulnerable to loss, but have flow-on effects that benefit the cloud forest ecosystem as a whole. As for Te Kou, bait stations should be established at 50 m intervals along accessible ridges, with these intervals measured along the ground surface[1] (Figure 6). Bait stations can only be located along ridgelines, as the adjacent slopes are too steep to traverse. In these areas, broadcasting of bait by hand will achieve greater coverage, and achieve a higher level of rodent control. This is likely to be needed, and important, as many seabirds nest on steep slopes or cliffs. The feasibility study should have the same components as described for Te Kou. In addition, a survey would be needed, assisted with specialist climbing gear, to determine the location and extent of the colony, and accessibility.

11.4.1 Pest plants

Weed management programmes in New Zealand, and more recently in Australia, can generally be regarded as either weed-led or site-led. A weed-led programme has as its key objective the eradication or containment of newly established weeds, and is targeted at specific species. The success of a "weed-led" programme is heavily reliant on early detection, when eradication is still achievable. In contrast, a "site-led" programme has as its core objective the management of weed species to protect a specific area (Downey and Sheppard 2006). The selection of areas for site-led programmes can be assessed using a ranking system that considers flora and fauna values, and the nature and urgency of the threats posed. Neither "site-led" nor "weed- led" programmes target all naturalized plant species; effort is focused on those species that pose, or are likely to pose, a significant threat to natural areas.

Figure 5: Proposed pet management area for Te Kou Cloud Forest, Rarotonga



[1] On very steep slopes, placement of traps 50 m apart based on a "birds eye" view would result in traps being placed at much greater intervals apart along the ground surface.

Figure 6: Proposed pet management area for Te Kou Cloud Forest, Rarotonga

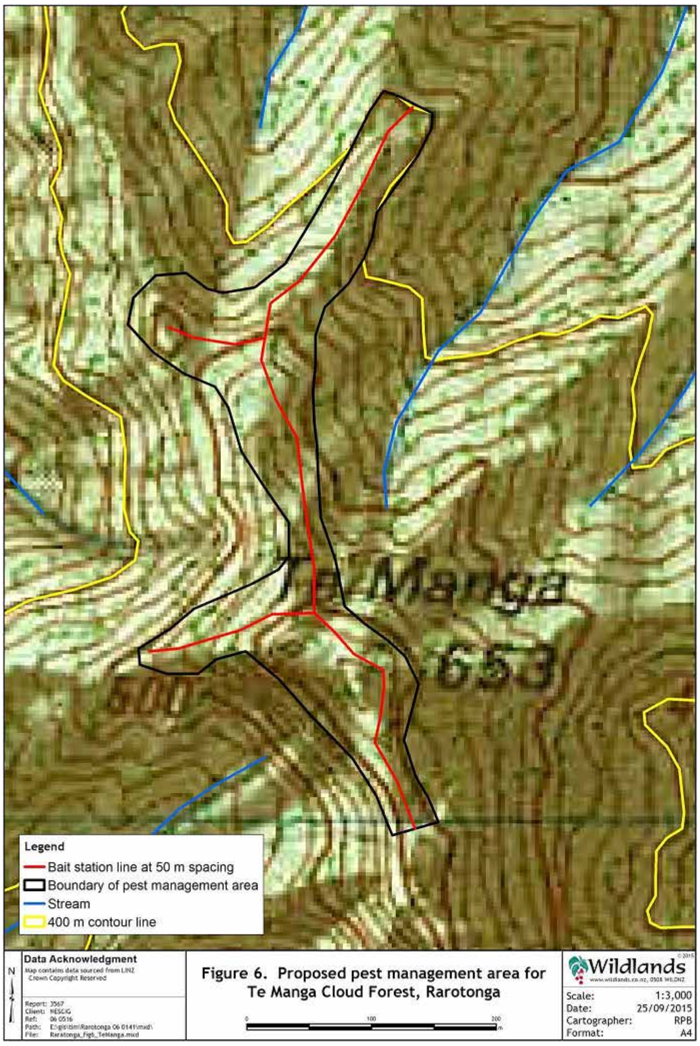
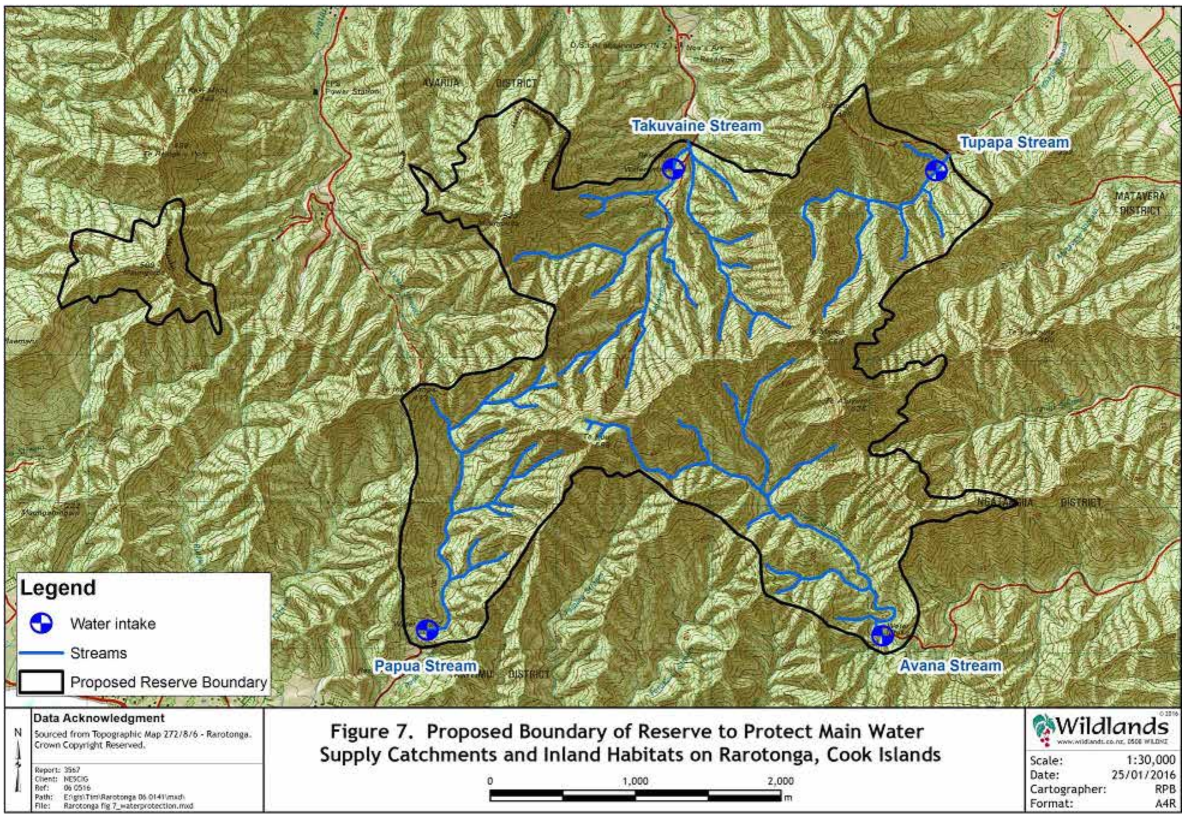


Figure 7: Proposed Boundary of Reserve to Portect Main Water Supply Catchments and Inland Habitats on Rarotonga, Cook Islands



Within the cloud forest habitats of Rarotonga, a site-led approach is eminently more suitable than a weed-led approach. The access issues associated with extreme terrain, coupled with the established nature of many weed species, means that eradication is not achievable. Any weed-led programmes in the cloud forest are highly likely to fail. In contrast, whilst difficult terrain is still a significant issue for site-led programmes, areas of high ecological value can be identified within which control of key weed species is feasible, and is likely to result in significant ecological benefits. However, any areas selected for site-led weed management programmes should met all five of the criteria listed in Table 9.

Table 9: Criteria for selection of areas for site-led weed management.

Criteria	Explanation
1. Accessibility	Site accessible on foot whilst carrying personal supplies (e.g. food, water, shelter) and required weed control equipment.
2. Terrain	Terrain suitable for traversing on foot, without high risk of injury or unacceptable damage to indigenous vegetation and habitats.
3. Water	Availability of water on-site, or the presence of weed species that can be controlled using methods that don't require large volumes of water e.g. treating cut stumps with herbicide gel, or manual control.
4. Ecological values, threatened endemics	Presence of indigenous vegetation and/or habitats of high ecological value, or threatened endemic species.
5. Threat	No weed control (the status quo) is likely to result in the decline or loss of ecological values or populations of threatened endemic species.

The following areas were selected for site-led management programmes (Table 10).

Table 10: Sites selected for site-led weed management programmes.

Site	Explanation of Criteria Met
Te Kou (summit rim and valley only)	1. Accessible via Te Kou track 2. Gentle terrain in summit valley 3. Water available from stream on-site 4. Presence of threatened endemics 5. Continued spread of mile-a-minute, white-flowered ginger, night-blooming cestrum, strawberry guava, African tulip tree, cecropia, and shoebutton ardisia will replace indigenous vegetation, and alter habitats for indigenous flora and fauna
Te Manga (ridges only)	1. Accessible via Te Manga track 2. Ridges leading up to Te Manga, and from Te Manga to Te Atukura, accessible on foot 3. Weed species present can be controlled by manual methods 4. Presence of threatened endemics 5. Continued spread of mile-a-minute, strawberry guava, cecropia, night-blooming cestrum, African tulip tree, and white-flowered ginger will modify and or replace indigenous vegetation, and alter habitats for indigenous flora and fauna

Pest plant control should be undertaken at both of these sites. Te Kou is a larger site, with greater abundance of pest plants, but is logistically easier to access, while Te Manga has a lower abundance of pest plants, but is logistically more challenging to access. Recommended weed management strategies for these two sites are presented below:

Te Kou Site-Led Weed Management Strategy

The weed species in the Te Kou pest management area (Figure 5) can be divided into two categories; species that are well established and locally abundant (strawberry guava, white-flowered ginger, and night-blooming cestrum), and species which are occasional, suggesting either a slow rate of spread (African tulip tree and shoebutton ardisia), or recent arrival in the summit valley (mile-a-minute).

The first phase of weed management, which is likely to require work over 1-2 years, will protect indigenous vegetation and habitats by:

- Controlling outlier populations of strawberry guava, white-flowered ginger, andnight-blooming cestrum within Weed Management Unit 1 (Figure 5). An outlier population can be defined as a cluster of less than 10 plants. **Objective: No mature (flowering or fruiting) plants of target species present within outlier populations;**

- Controlling all mature (e.g. individuals of fruiting size) plants of African tulip tree, shoebutton ardisia, and mile-a-minute within all Weed Management Units (Figure 5). **Objective: No mature (flowering or fruiting) plants of target species present within any Weed Management Unit.**

The second phase of weed management should only be started when the objectives of the first phase have been achieved. The second phase, which is likely to require 2-5 years, will restore and enhance indigenous vegetation and habitat by:

- Controlling core populations of strawberry guava (Weed Management Unit 2), white-flowered ginger (Weed Management Unit 3), and night-blooming cestrum (Weed Management Unit 4). Where populations are dense and form more than 50% cover over areas of >200m^2, control should be staged, with control starting at the edge of the population furthest uphill or upstream. **Objective: No mature (flowering or fruiting) plants of target species present within Management Units 2, 3 or 4, excluding those infestations being controlled in a staged manner;**

- Controlling all individuals of African tulip tree, cecropia, shoebutton ardisia, and mile-a-minute so that plants are removed before they reach maturity (i.e. fruiting size) (all Weed Management Units). **Objective: No mature (flowering or fruiting) plants of target species present within any Weed Management Unit.**

The third and final phase of management should only be started when the objectives of the second phase have been met. This stage will protect and enhance vegetation and habitat by:

- Controlling all key weed species within allWeed Management Units. **Objective: No fruiting plants present in all management units**.

This phase will need to be ongoing due to reinvasion from nearby habitats that are not subject to weed control. This maintenance phase can probably be achieved by completing a round of control every 2-3 years. The frequency required will be determined by the growth rates of the targeted species; it is critical that individuals that establish are controlled before they can spread further by fruiting.

Recommended weed control methods for each of the targeted weed species are provided in Appendix 4.

Te Manga Site-Led Weed Management Strategy

The weed species in the Te Manga pest management area are all at low densities, and the site can be managed as one Weed Management Unit (Figure 6).

The first phase of weed management, which is likely to require work over 2-3 years, will protect indigenous vegetation and habitats within the Weed Management Unit by:

- Controlling all mature individuals of strawberry guava, white-flowered ginger, mile-a-minute, cecropia, African tulip tree, and night-blooming cestrum. **Objective: No mature (flowering or fruiting) plants of target species present within the Weed Management Unit.**

The second and final phase of management should only be started when the objectives of the first phase have been met. At this stage, all targeted weed species within accessible areas will be occasional, and not of fruiting size. The objective of the maintenance phase is as follows:

- Protect indigenous vegetation and habitats by controlling all key weed species before they reach fruiting size. **Objective: No mature (flowering or fruiting) plants of target species present within the Weed Management Unit.**

This phase will need to be ongoing due to reinvasion from nearby habitats that are not subject to weed control. This maintenance phase can probably be achieved by completing a round of control annually. The frequency required will be determined by the growth rates of the targeted species; it is critical that individuals that establish are controlled before they can spread further by fruiting. Some species could therefore be targeted for control on a less frequent basis. However the site should still be visited on an annual basis to monitor the weed infestations and control undertaken as required.

Recommended weed control methods for each of the targeted weed species are provided in Appendix 4.

Recording of Weed Distribution

The distribution of controlled weed species, particularly outliers, should be recorded by hand held GPS unit. The species, size, and age class of the controlled weed should also be recorded. This will allow effective follow-up of all known weed infestations, and allow assessment of previous control methodologies to be made. GPS data can be used to accurately map the distribution of weed species across the control areas.

Recording GPS coordinates for those species which are low in number or at low densities (new incursions) can be especially effective in ensuring control is undertaken before new or recently arrived weed species can establish on site.

Use of Agrichemicals

Manual control methods should be employed wherever possible to minimise the use of agrichemicals within the water catchment area. Unfortunately manual control methods alone will not be very effective on the existing weed populations, but can be effective on new infestations and new plants (seedlings) of those weed species already present, including those that are likely to grow from the existing seed bank in the soil once control has commenced. Suitable manual control methods are presented in Appendix 4.

Recommended control methods using agrichemicals are presented in Appendix 4. The preferred methods are generally those that are 'direct application' methods, rather than spraying methods. Direct applications methods can include:

- Cut and stump treat: Cutting the stems and treating the cut stems with a herbicide stump mix solution. This method is useful for small to medium sized plants, including white-flowered ginger, which can easily be cut.

- Frill and treat: Frilling (ring barking) around the whole stem and applying a stump mix solution to the cut. This method is useful for small to medium sized trees with soft bark, which can be left *in situ* to die.

- Drill and inject: Drilling holes into the cambium layer on a downward 45 degree angle at a maximum of 100 mm apart around the trunk, and filling with herbicide stump mix. This method is recommended for medium to large trees, where it can be useful to leave the tree standing *in situ* to die.

All agrichemical use, mixing and storage should be undertaken in line with the Agrichemical Users' Code of Practice, NZS 8409 2004: The Management of Agrichemicals. All persons handling and applying agrichemicals should be suitable trained and certified with current Growsafe certification, or equivalent.

All agrichemical application should be recorded on spray diaries as per the Agrichemical Users' Code of Practice, NZS 8409 2004: The Management of Agrichemicals. This also allows the volume of agrichemical applied to be monitored over time. It can also be used as a measure of success of a weed control project: controlling the same area effectively over time, but using less agrichemical, indicates a reduction in the weed infestations present.

11.5 Biosecurity

Biosecurity measures need to be implemented to reduce the spread of invasive species. All track users should ensure that clothing, footwear, and equipment is free of mud, soil, and plant material when arriving at track ends. The best place to do this is before departing for the track end, as thorough cleaning may require the use of running water and a scrubbing brush. If the planned route will cross more than one peak, people should also remove excess dirt from clothing and equipment between areas (Worboys and Gadek 2004).

If any existing infrastructure on the mountain summits requires replacing or repair, all building materials, including wood, roofing material, gravel, sand, and cement should be inspected by a quarantine officer. This check should be undertaken prior to the material being transported to the site, to ensure it is free of soil and all biological material (e.g. plant material, eggs, and seeds). No planting of cultivated material should be permitted due to transfer risk of invasive organisms including plants, pathogens, landsnails, and ants.

The biosecurity risks posed by track construction and maintenance can be minimized by ensuring construction is timed for periods with dry soil conditions. This reduces soil compaction and the movement of soil between sites. Any muddy areas on tracks should be crossed via raised walkways to prevent footwear becoming caked with soil.

11.6 Fire

Whilst fire may seem unlikely within cloud forests on Rarotonga, the impacts could be significant if one was to occur. The steep terrain, coupled with a lack of equipment on the island for fighting large scale or remote fires (e.g. helicopters with monsoon buckets), means that any fire is likely to burn uncontrolled. Increased diligence is needed, particularly during times of low rainfall when conditions are more suitable for ignition and spread. Overnight camping should be discouraged, and open fires should be prohibited. During periods of extreme dryness, no camping fires of any type should be permitted. If a fire does occur within cloud forest habitats, post-fire monitoring should be undertaken to determine any particular management needs that may arise (e.g. if vegetation recovery is dominated by invasive plant species).

11.7 Communication and education

Many of the threats described above can be minimised through effective communication and education, particularly if this involves stakeholder groups such as ecotourism operators, National Environment Service staff, schools, and interested locals.

11.7.1 Track signage

At present, signage at the public entry points to the inland forest areas is minimal. Where track ends lie within water catchment areas, there is signage stating that swimming is not permitted upstream of water intakes. Additional signage at every public access point, including the Cross Island Walk, is a high priority, and should convey the importance of the inland habitats for water supply and conservation, the potential threats posed by recreational use, and guidelines for minimising impacts. Signage should also include details as to the grade of track and expected terrain, recommended equipment and fitness level, and walking hours for the return trip. The mountain tracks on Rarotonga are of similar difficulty to advanced tramping tracks in New Zealand, for which the Department of Conservation provides users with the following advice:

Duration: Challenging day or multi-day tramping/hiking

Suitable for: People with moderate to high level backcountry (remote areas) skills and experience, navigation and survival skills required.

Standard: Track is mostly unformed, may be rough and steep. Track has markers, poles or rock cairns. Expect unbridged stream and river crossings.

Footwear required: Tramping/hiking boots

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The track standard should also include reference to rope climbs where this is relevant. Additional information is needed to both minimise risks to recreational users and the environment, as failure to return by dark may lead to further impacts, such as camp fires, accidental departure from track routes, and damage to vegetation.

Potential wording for signage could include the following, using the Te Manga track as an example:

<u>Te Manga Track</u> Summit
- 8 hours return

You are entering an ecologically sensitive area that is home to plants and animals found nowhere else on Earth. With your help, we can protect this area for future generations.

Please make sure you are not carrying any mud, soil, or living material (e.g. leaves, seeds, eggs, and ants) into the area on your footwear, clothing, or equipment.

For your safety, and to minimise damage to the forest, please stay on the marked track.

Do not light any fires.

Do not damage or remove any plants or animals.

The Te Manga Track is a challenging day tramp for people wit backcountry skills and a moderate to high level of fitness. The track is mostly unformed, steep, and includes rope climbs. Expect unbridged stream crossings. Wear footwear with good grip (walking shoes or hiking boots) and take adequate food and water, a raincoat, and spare clothing. Please make sure someone knows of your intended route and return time.

11.7.2 Communication with stakeholders

All key stakeholders should be identified. The management proposed by this plan can then be discussed with stakeholders, to ensure local buy in, and to check the actions proposed are achievable. Key stakeholders will include the managers of the Takatimu Conservation Area (155 hectares) and Takuvaine Water Catchment (229 hectares), Pa's Treks, the Cook Island Natural Heritage Trust, and all NGOs and government departments involved with biosecurity and or conservation in the Cook Islands.

11.7.3 Community awareness and education

The cloud forests of Rarotonga are an ecosystem of critical importance, both as a water supply and as habitat for endemic flora and fauna. Raising public awareness of the importance of the island's cloud forests is an important step in ensuring that they are valued and protected by the local communities that depend on them. The uniqueness of cloud forest habitats on the island, with their rich biodiversity, lends itself easily to coverage by media, and incorporation into educational syllabuses. Developing media and communication strategies for greater exposure and awareness of invasive species is an action listed in the Cook Islands 4th National Report to the Convention on Biological Diversity (National Environment Service 2011), and this could be broadened in scope to include knowledge of endemic species, and all threats to indigenous biodiversity.

11.8 Climate change

Climate change poses a significant long term threat to the cloud forests of Rarotonga. Their mountain summit location means that retreat to higher altitudes is not possible, should cloud height lift or become more variable. Climate change is a global issue that requires a global response, and little can be done at a national scale to address this threat. However the threat posed to cloud forest by climate change, and the linkages between cloud forest and essential ecosystem services such as water supply, should be recognized in government policy.

11.9 Monitoring

Whilst providing useful "snap-shots' in time, infrequent, one-off surveys of Rarotonga's cloud forest are limited in their ability to determine long-term trends, the impact of threats, and the effectiveness of any prescribed management. The establishment of a monitoring programme is needed to address all three of these aspects.

11.9.1 Vegetation

Traditional vegetation monitoring techniques, such as quantitative assessments of permanent plots, are all but impossible to employ in the steep upper slopes of the cloud forest. Photopoint monitoring is cost-effective and repeatable, and can visually track changes in vegetation communities, including the abundance of invasive plant species. The ten photopoints established in 2015 should be assessed every three to five years, and the coverage of sites expanded to include habitats on Maungatea, and the lower cloud forest of Te Kou, at 400-450 m altitude. Prior to the implementation of the site-led weed plans, photopoints should be established that will document the fate of targeted weed species where these form dense infestations.

11.9.2 Rodents

Ship rats are known to be widespread in the cloud forest, but their abundance, and the presence or absence of other rodent species, is unknown. Trapping using snap-traps should be undertaken to determine which rodent species are present. Both small and large snap traps would be used to allow rats, and mice if present, to be caught. Traps should be carefully set and covered to reduce the risk to birds or other non-target species. The establishment of permanent tracking tunnel lines, with at least 10 tunnels per monitoring location, should be established to determine relative densities prior to any control operations. A minimum of 10 tracking tunnel lines/site is recommended to provide sufficient data to effectively monitor changes in rodent abundance. Tracking tunnel monitoring should be repeated following rodent control to allow the effectiveness of the control program to be quantified.

11.10 Summary of proposed actions

Recommended management actions are summarised in Table 11. These actions also outline the information gaps which need to be addressed in order to plan and prioritise future management approaches.

Table 11: Summary of proposed actions for restoration, management, and monitoring of Rarotonga cloud forest ecosystems.

Issue/knowledge gap	Proposed action/s
1. Risk of extinction for threatened endemic flora	Establish populations of threatened endemics in cultivation.
2. Establishment of additional invasive species/spread of existing invasive species	Install track signage regarding footwear/clothing/equipment hygiene. Develop biosecurity protocols for track and infrastructure users. Train staff in pest mammal sign and control.
3. Risk of fire/inadvertent damage	Install track signage regarding fire restrictions, track standards and return times, and guidelines for minimising impacts of use.
4. Unknown densities/impacts of introduced mammals, particularly rodents	Undertake baseline monitoring to determine species present and relative abundance. Assess baseline levels of seed predation for *Homalanthus nutans.* Determine location of seabird breeding colonies. Consider feasibility of pest mammal control at key sites.
5. Continued spread of invasive plants at key sites for threatened endemic fauna	Implement control of invasive plant species at Te Kou and Te Manga.
6. Long term trends in vegetation composition and health unknown	Continue assessment of photopoints established in 2015 at three to five year intervals. Expand coverage to include Maungatea, lower altitudes on Te Kou, and control sites of invasive plant species.
7. Climate change leading to modification or loss of cloud forest habitats	Ensure risk posed to cloud forests by climate change acknowledged in government policy.
8. Low public profile of cloud forest ecosystem and species due to inaccessibility	Community education and advocacy.

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APPENDIX 1

VASCULAR FLORA CHECKLIST

	Genus	Species	Family	Local Name	Te Manga	Te Kou	Maungatea	Maungaroa
Dicot	Ageratum	conyzoides	ASTERACEAE			AK360115		
Dicot	Ardisia	elliptica	MYRSINACEAE	Venevene Tinito		AK360028		X
Dicot	Ascarina	diffusa	CHLORANTHACEAE	Kaiatea Ko'u	X			
Dicot	Bidens	pillosa	ASTERACEAE	Cobbler's peg		AK360105		
Dicot	Cecropia	peltata	MORACEAE	Cecropia	X	X		AK360065
Dicot	Celtis	pacifica	ULMACEAE	Polynesian Celtis		AK319849		
Dicot	Cestrum	nocturnum	SOLANACEAE	Night-blooming Cestrum	X	X		
Dicot	Coprosma	laevigata	RUBIACEAE	Rarotonga Coprosma	X	AK319853		
Dicot	Crassocephalum	crepidioides	ASTERACEAE	Nodding-head daisy				AK360099
Dicot	Cyclophyllum	barbatum	RUBIACEAE	Matira		AK46036		AK360087
Dicot	Cypholophus	macrocephalus	URTICACEAE	Rough-leaved shrub	X, AK319982			
Dicot	Cyrtandra	lillianae	GESNERIACEAE	Te Manga Cyrtandra	X, AK319978			
Dicot	Decaisnina	forsteriana	LORANTHACEAE					AK360066
Dicot	Elaeocarpus	rarotongensis	ELAEOCARPACEAE	Karaka Rarotonga		X	X	X
Dicot	Elephantopus	mollis	ASTERACEAE	Elephant's Foot	X	AK360106		X
Dicot	Emilia	sonchifolia	ASTERACEAE			AK360057		
Dicot	Eugenia	jambos	MYRTACEAE	Rose apple		X		
Dicot	Fagraea	berteroana	LOGANIACEAE	Pua		X	X	X
Dicot	Fitchia	speciosa	ASTERACEAE	Neinei	X	X	X	AK360082
Dicot	Gardenia	augusta	RUBIACEAE	Gardenia	X	X, AK319835		X
Dicot	Geniostoma	rarotongense	GENIOSTOMACEAE	Ange	X		AK360026	AK360111
Dicot	Glochidion	concolor	PHYLLANTHACEAE	Glochidion, Ma'ame	X			
Dicot	Hibiscus	rosa-sinensis	MALVACEAE	Kaute 'Enua		X		
Dicot	Homalanthus	nutans	EUPHORBIACEAE	Homalanthus	X	AK360034		
Dicot	Homalium	acuminatum	SALICACEAE	Mato	X	X	X	X
Dicot	Hyptis	pectinata	LAMIACEAE	Comb Hyptis	X	X		X
Dicot	Jasminum	didymum	OLEACEAE	Native Jasmine, 'Aketa				AK360064
Dicot	Lantana	camara	VERBENACEAE	Lantana, Tataramoa Papa'a				X
Dicot	Leucosyke	corymbulosa	URTICACEAE	Rau Ta'uri	X, AK319947			
Dicot	Ludwigia	octavalvis	ONAGRACEAE	Willow-primrose	X	AK360092		
Dicot	Melastoma	denticulatum	MELASTOMACEAE	Ua Motukutuku	X	AK360114	X	X
Dicot	Metrosideros	collina	MYRTACEAE	Rata	X, AK319962	AK360103	X	AK360067
Dicot	Mikania	micrantha	ASTERACEAE	Mile a minute	X	AK360027		X
Dicot	Morinda	myrtifolia	RUBIACEAE					AK360063
Dicot	Osteomeles	anthyllidifolia	ROSACEAE	Osteomeles				X
Dicot	Peperomia	wilderi	PIPERACEAE	Cook Islands Peperomia		AK360095		X
Dicot	Pisonia	umbellifera	NYCTAGINACEAE	Mountain pisonia		AK360035, AK360036		
Dicot	Procris	pedunculata	URTICACEAE	Manga Rupe	X			
Dicot	Psidium	cattleianum	MYRTACEAE	Cherry guava	X	AK360023		X
Dicot	Psidium	guajava	MYRTACEAE	Common guava				X
Dicot	Psychotria	whistleri	RUBIACEAE	Rarotonga Psychotria	AK360075	AK 319850		
Dicot	Sclerotheca	viridiflora	CAMPANULACEAE	Rarotonga Sclerotheca	X, AK319975			
Dicot	Sida	rhombifolia	MALVACEAE	Broomweed				AK360102
Dicot	Spathodea	campanulata	BIGNONIACEAE	African tulip tree		X		

	Genus	Species	Family	Local Name	Te Manga	Te Kou	Maungatea	Maungaroa
Dicot	Vaccinium	cereum	ERICACEAE	Polynesian Blueberry	AK360021	X		AK360062
Dicot	Weinmannia	samoensis	CUNONIACEAE	Kaiatea	X	X, AK319843	X	AK360089
Dicot	Wikstroemia	foetida	THYMELAEACEAE	Wikstroemia				AK360112
Dicot	Xylosma	gracile	FLACOURTIACEAE	Xylosma				AK360088
Monocot	Ananas	comosus	BROMELIACEAE	Pineapple		X		
Monocot	Bulbophyllum	longiflorum	ORCHIDACEAE	Bulbophyllum Orchid		X		AK360084
Monocot	Cocos	nucifera	ARECACEAE	Coconut, Nu		X		
Monocot	Colocasia	esculenta	ARACEAE	Taro		X		
Monocot	Commelina	diffusa	COMMELINACEAE	Commelina		X		
Monocot	Dendrobium	involutum	ORCHIDACEAE	Native Ladder-Orchid	X			
Monocot	Dianella	adenanthera	LILIACEAE	Pu'i	X			X
Monocot	Freycinetia	arborea	PANDANACEAE	Kiekie	X	X, AK319838	X	X
Monocot	Hedychium	coronatum	ZINGIBERACEAE	White-flowered ginger	X	X		
Monocot	Isachne	disticophylla	POACEAE	Polynesian Isachne-Grass	X, AK99060	AK360060		
Monocot	Malaxis	resupinata	ORCHIDACEAE	Malaxis Orchid	X	X	X	
Monocot	Mariscus	cyperinus	CYPERACEAE	Long-headed sedge	AK360081	X, AK319847		
Monocot	Miscanthus	floridus	POACEAE	Kaka'o				X
Monocot	Oberonia	equitans	ORCHIDACEAE	Oberonia Orchid	X	AK360072	X	AK360083
Monocot	Oplismenus	compositus	POACEAE	Large Oplismenus-Grass	X	X		
Monocot	Paspalum	conjugatum	POACEAE	T-Grass	X	AK360056, AK360091		X
Monocot	Paspalum	orbiculare	POACEAE	Rice Grass	X, AK281603	AK360059		
Monocot	Phaius	tankervilleae	ORCHIDACEAE	Giant Orchid, Nutupa	X	X	X	
Monocot	Taeniophyllum	fasciola	ORCHIDACEAE	Leafless Orchid	X		AK360051	X
Monocot	Trachoma	papuanum	ORCHIDACEAE	Trachoma Orchid	X, AK319971			
Monocot	Zingiber	zerumbet	ZINGIBERACEAE	Shampoo ginger, Kopi 'Enua				X
Pteridophyte		Indet. fern				AK360101		
Pteridophyte		Indet. fern				AK360113		
Pteridophyte	Acrophorus	raiateensis	DRYOPTERIDACEAE	Rarotonga Acrophorus	X, AK319946	X, AK319855		X
Pteridophyte	Angiopteris	evecta	MARATTIACEAE	Ana'e	X	X		X
Pteridophyte	Arachniodes	aristata	DRYOPTERIDACEAE	Prickle fern	X	AK360015	X	
Pteridophyte	Asplenium	horridum	ASPLENIACEAE	Iwa, 'alae	X	AK360061		AK360116
Pteridophyte	Asplenium	nidus	ASPLENIACEAE	Smooth bird's nest fern	AK360016	X		X
Pteridophyte	Asplenium	caudatum	ASPLENIACEAE					AK360068
Pteridophyte	Asplenium	gibberosum	ASPLENIACEAE			AK360093		
Pteridophyte	Belvisia	mucronata	POLYPODIACEAE	Tailed Fern	X	AK360070, AK360079	AK360053	X
Pteridophyte	Blechnum	orientale	BLECHNACEAE	Moumea		AK360069		X
Pteridophyte	Blechnum	societatum	BLECHNACEAE	Moumea Ko'u	X	AK360049, AK360055		
Pteridophyte	Blechnum	vulcanicum	BLECHNACEAE	Wedge Blechnum	AK360090	AK360014		X, AK113795
Pteridophyte	Bolbitis	lonchophora	DRYOPTERIDACEAE	Bolbitis Fern	X	X		
Pteridophyte	Christella	dentata	THELYPTERIDACEAE	Downy Wood-fern	X	AK360076		X
Pteridophyte	Ctenopterella	blechnoides	POLYPODIACEAE	Comb Fern		X, AK353643	X	
Pteridophyte	Cyathea	affinis	CYATHEACEAE	Panga Ko'u	X	X, AK322106		

	Genus	Species	Family	Local Name	Te Manga	Te Kou	Maungatea	Maungaroa
Pteridophyte	Cyathea	decurrens	CYATHEACEAE	Panga Tua-more	X	X		
Pteridophyte	Cyathea	parksiae	CYATHEACEAE	Panga Tua-taratara		X, AK327476		
Pteridophyte	Dicranopteris	linearis	GLEICHENIACEAE	Tuanu'e	X	AK360073	X	X
Pteridophyte	Elaphoglossum	savaiense	DRYOPTERIDACEAE	Glossy Tongue-fern	X	AK360024	X	
Pteridophyte	Haplopteris	elongata	VITTARIACEAE	Tape Fern	AK352987			
Pteridophyte	Histiopteris	incisa	DENNSTAEDTIACEAE	Are-Rupe	X	AK360048		
Pteridophyte	Humata	banksii	DAVALLIACEAE	Polynesian Humata Fern	X	X	X	X
Pteridophyte	Huperzia	carinata	LYCOPODIACEAE	Keeled Clubmoss		X, AK352206		
Pteridophyte	Huperzia	phlegmaria	LYCOPODIACEAE	Coarse Clubmoss		X		
Pteridophyte	Hymenophyllum	polyanthos	HYMENOPHYLLACEAE	Cloud Filmy-fern		X, AK111463		X
Pteridophyte	Hymenophyllum	sanguinolentum	HYMENOPHYLLACEAE	Filmy Fern	X, AK320150			
Pteridophyte	Hymenophyllum		HYMENOPHYLLACEAE				AK360052	
Pteridophyte	Hymenophyllum		HYMENOPHYLLACEAE					AK360094
Pteridophyte	Hypolepis	dicksonioides	DENNSTAEDTIACEAE	Cloud Ground-fern	AK320153	X, AK319854		
Pteridophyte	Lastreopsis	pacifica	DRYOPTERIDACEAE					AK360098
Pteridophyte	Lindsaea	propinqua	DENNSTAEDTIACEAE	Necklace Fern		X, AK352860		
Pteridophyte	Lindsaea	repens	DENNSTAEDTIACEAE	Creeping Necklace Fern		X, AK352861		
Pteridophyte	Lindsea		DENNSTAEDTIACEAE			AK360107		
Pteridophyte	Lycopodiella	cernua	LYCOPODIACEAE	Remu Maunga	X	X		AK360109
Pteridophyte	Macrothelypteris	polypodioides	THELYPTERIDACEAE					
Pteridophyte	Marratia	salicina	MARATTIACEAE	Potato Fern		X		
Pteridophyte	Microsorum	commutatum	POLYPODIACEAE		X	X		AK360117
Pteridophyte	Microsorum	scolopendria	POLYPODIACEAE					
Pteridophyte	Nephrolepis	flexuosa	DAVALLIACEAE			X		
Pteridophyte	Nephrolepis	hirsutula	DAVALLIACEAE		AK360050			X
Pteridophyte	Ophioglossum	pendulum	OPHIOGLOSSACEAE			AK360080		
Pteridophyte	Psilotum	nudum	PSILOTACEAE			AK360077		X
Pteridophyte	Pteris	tripartita	PTERIDACEAE	Giant shaking brake	X	AK360078		
Pteridophyte	Radiogrammitis	cheesemanii	POLYPODIACEAE		X	X		
Pteridophyte	Schizaea	dichotoma	SCHIZAEACEAE	Comb Fern	AK360086	X	AK360108	AK360096
Pteridophyte	Sphenomeris	chinensis	DENNSTAEDTIACEAE					AK360110
Pteridophyte	Sphenomeris	chinensis	DENNSTAEDTIACEAE					AK360118
Pteridophyte	Trichomanes	caudatum	HYMENOPHYLLACEAE		X			
Pteridophyte	Trichomanes	dentatum	HYMENOPHYLLACEAE					
Pteridophyte	Trichomanes	digitatum	HYMENOPHYLLACEAE		X	X		
Pteridophyte	Trichomanes	maximum	HYMENOPHYLLACEAE		X			
Pteridophyte	Vaginularia	angustissima	VITTARIACEAE			X		AK360100

x = recorded during 2015 survey

AK = Auckland Museum voucher number (from 2015 survey or earlier)

APPENDIX 2

PHOTOPOINT DATA

Site Te Kou

RAROTONGA PHOTOPOINT MEASUREMENT SHEET

Photopoint No.:	PP1	Plot No.: (if relevant)	-	Tree Tag No.:	8047
Date:	12/05/2015	Recorder:	T J MARTIN	Photographer:	T J MARTIN
GPS Coordinates (NZTM):	S 21 14.455		W 159 46.644		
Date Established:	12/05/2015	Photograph No.:	0350		
Camera and Lens Details:	Nikon D90 1/160 F6.3				
Light:	overcast	Time:	1610	Compass bearing (mag):	175

Notes to help relocate (include diagrams on back of sheet, if necessary):

Photo taken beside tree fern that is about 5 m uphill of the track and 10 m before stream, when crossing the stream valley to get to the transmitter station on the summit. There are two tree ferns at this location – the photopoint is taken from the western-most tree fern that has kiekie climbing up it. The photograph is taken looking towards the summit, with the transmitter station central in the photograph.

Description of vegetation/features:
Foreground between the photopoint location and the stream: herbfield dominated by white-flowered ginger (Hedychium coronatum) with Paspalum conjugatum, Christella dentata, moumea ko'u (Blechnum societatum), and occasional kiekie.
Lower slopes beyond stream: same as above with occasional small neinei (Fitchia speciosa)
Upper slopes: Moumea ko'u fernland with scattered shrubs and small trees of neinei, occasional cherry guava (Psidium cattleianum).
Top of slope: Kaiatea (Weinmannia samoensis) and neinei over ferns.

Site Te Kou

RAROTONGA PHOTOPOINT MEASUREMENT SHEET

Photopoint No.:	PP2	Plot No.: (if relevant)	-	Tree Tag No.:	-
Date:	12/05/2015	Recorder:	T J MARTIN	Photographer:	T J MARTIN

GPS Coordinates (NZTM): S 21 14.456 W 159 46.641

Date Established: 12/05/2015 Photograph No.: 0351

Camera and Lens Details: Nikon D90 1/200 F8

Light: Partly cloudy Time: 1622 Compass bearing (mag): 215

Notes to help relocate (include diagrams on back of sheet, if necessary):
Photograph taken from the north bank of the stream where the track to the summit crosses the stream.

Description of vegetation/features:
Foreground: Wet peaty stream banks with *Paspalum conjugatum* grassland and white-flowered ginger, *Christella dentata*, *Melastoma denticulatum*, moumea ko'u. Small waterfall c. 1 m tall down vertical bank.
Mid-ground: Herbfield dominated by white-flowered ginger with neinei, kiekie, moumea ko'u, and, further upstream, an area of *Paspalum conjugatum* grassland (photograph centre).
Distance: Neinei shrubland with locally abundant tree ferns (*Cyathea* spp).

Site Te Kou

RAROTONGA PHOTOPOINT MEASUREMENT SHEET

Photopoint No.:	PP3	Plot No.: (if relevant)	-	Tree Tag No.:	
Date:	13/05/2015	Recorder:	T J MARTIN	Photographer:	T J MARTIN
GPS Coordinates (NZTM):	S 21 14.468		W 159 46.620		
Date Established:	13/05/2015	Photograph No.:	0403		
Camera and Lens Details:	Nikon D90 1/160 F6.3				
Light:	Overcast	Time:	0836	Compass bearing (mag):	195

Notes to help relocate (include diagrams on back of sheet, if necessary):

Photograph taken from the rainfall gauge station to the right of the track when ascending the final slope to the transmitter station.

Description of vegetation/features:
Foreground: Moumea ko'u fernland with occasional kiekie, *Melastoma denticulatum*, neinei, mile a minute, and *Paspalum conjugatum*.
Mid-ground: Neinei over moumea ko'u fernland with kiekie and occasional kaiatea.
Distance: Kaiatea-moumea ko'u treeland with neinei and kiekie.

Site Te Kou

RAROTONGA PHOTOPOINT MEASUREMENT SHEET

Photopoint No.:	PP4	Plot No.: (if relevant)	-	Tree Tag No.:	-
Date:	13/05/2015	Recorder:	T J MARTIN	Photographer:	T J MARTIN
GPS Coordinates (NZTM):	S 21 14.468		W 159 46.620		
Date Established:	13/05/2015	Photograph No.:	0404		
Camera and Lens Details:	Nikon D90 1/200 F7.1				
Light:	Overcast	Time:	0840	Compass bearing (mag):	000

Notes to help relocate (include diagrams on back of sheet, if necessary):

Same location as PP3. Photograph taken from the rainfall gauge station to the right of the track when ascending the final slope to the transmitter station.

Description of vegetation/features

Foreground: Kiekie-moumea ko'u shrubland
Facing hillslope (left): *Histiopteris incisa* fernland with occasional neinei, kaiatea, and kiekie
Facing hillslope (right): Kiekie shrubland with occasional neinei.
Ridgeline: Kaiatea treeland with large rose-apple (*Eugenia jambos*) at photograph centre.

Site Te Kou

RAROTONGA PHOTOPOINT MEASUREMENT SHEET

Photopoint No.:	PP5	Plot No.: (if relevant)	-	Tree Tag No.:	-
Date:		Recorder:	T J MARTIN	Photographer:	T J MARTIN
GPS Coordinates (NZTM):	S 21 14.470		W 159 46.607		
Date Established:	13/05/2015	Photograph No.:	0405		
Camera and Lens Details:	Nikon D90 1/200 F6.3				
Light:	overcast	Time:	0854	Compass bearing (mag):	-

Notes to help relocate (include diagrams on back of sheet, if necessary):

From rainfall gauge walk downslope through the fernland in a south-westerly direction (towards the peak of Te Atakura on horizon) until you come to a small kaiatea about 2 m tall, just before the slope abruptly increases in steepness. Photograph taken beside this small kaiatea with the high peak of Te Atakura at the horizontal centre of the photograph.

Description of vegetation/features:

Foreground: kiekie-moumea ko'u shrubland
Distance: Steep sided stream gully. Slopes a mosaic of kiekie shrubland, neinei shrubland, and moumea ko'u fernland, with tree ferns (Cyathea spp) locally abundant along the bottom of the stream valley and on the lower south-facing hillslopes. One patch of white-flowered ginger herbfield is visible on the lower north-facing hillslope (to the right of the stream.

Site Te Manga

RAROTONGA PHOTOPOINT MEASUREMENT SHEET

Photopoint No.:	PP6	Plot No.: (if relevant)	-	Tree Tag No.:	8044
Date:	19/05/2015	Recorder:	T J MARTIN	Photographer:	T J MARTIN

GPS Coordinates (NZTM): S 21 14.141 W 159 45.814

Date Established: 19/05/2015 Photograph No.: 0602

Camera and Lens Details: Nikon D90 1/1600 F3.5

Light: Sunny Time: 0900 Compass bearing (mag): 260

Notes to help relocate (include diagrams on back of sheet, if necessary):

On the final ascent of the eastern summit of Te Manga, find a large rata on the right hand side of the track. The tree tag is on the trunk of this rata. The photograph was taken 2 m to the east of the tree tag on the rata, looking back at the western peak of Te Manga.

Description of vegetation/features:
Foreground: Shrubland dominated by neinei, kiekie, and rata.
Distance (east facing slopes of western peak): Shrubland dominated by neinei and kiekie, with frequent kaiatea and rata, and occasional kaiatea ko'u and *Cyathea decurrens*.

Site <u>Te Manga</u>

RAROTONGA PHOTOPOINT MEASUREMENT SHEET

Photopoint No.:	PP7	Plot No.: (if relevant)	-	Tree Tag No.:	-
Date:	19/05/2015	Recorder:	T J MARTIN	Photographer:	T J MARTIN

GPS Coordinates (NZTM): S 21 14.144 W 159 45.798

Date Established: 19/05/2015 Photograph No.: 0603

Camera and Lens Details: Nikon D90 1/1250 F3.5

Light: Sunny Time: 0915 Compass bearing (mag): 125

Notes to help relocate (include diagrams on back of sheet, if necessary):

Photograph taken from bare patch of ground at the northern end of the eastern summit of Te Manga.
Photograph taken of view across eastern summit towards Te Atuakura.

Description of vegetation/features:
Foreground (left): Moumea ko'u fernland with kiekie, white-flowered ginger, Lycopodium cernuum, and Elaphoglossum savaiiense.
Foreground (right): Shrubland dominated by rata and kaiatea, with epiphytic mosses, lichens, and Belvisia mucronata.
Distance: upper slopes of Te Atuakura dominated by neinei and kiekie.

RAROTONGA PHOTOPOINT MEASUREMENT SHEET

Photopoint No.:	PP8	Plot No.: (if relevant)	-	Tree Tag No.:	-
Date:	19/05/2015	Recorder:	T J MARTIN	Photographer:	T J MARTIN
GPS Coordinates (NZTM):	S 21 14.147		W 159 45.803		
Date Established:	19/05/2015	Photograph No.:	0629		
Camera and Lens Details:	Nikon D60 1/500 F3.5				
Light:	sunny	Time:	0918	Compass bearing (mag):	130

Notes to help relocate (include diagrams on back of sheet, if necessary):

Photograph taken from southern end of the eastern summit of Te Manga, looking towards Te Atuakura

Description of vegetation/features:

Foreground (right): Shrubland dominated by kiekie
Ridgeline vegetation: Moumea ko'u fernland with kiekie, neinei, and kaiatea.
Upper east facing slopes (left of ridgeline): Shrubland dominated by neinei and kaiatea with moumea ko'u on ridges
Steep west-facing slopes (right of ridgeline): Neinei shrubland

RAROTONGA PHOTOPOINT MEASUREMENT SHEET

Photopoint No.:	PP9	Plot No.: (if relevant)	-	Tree Tag No.:	8046
Date:	20/05/2015	Recorder:	T J MARTIN	Photographer:	T J MARTIN
GPS Coordinates (NZTM):	S 21 14.085		W 159 45.839		
Date Established:	20/05/2015	Photograph No.:	0681		
Camera and Lens Details:	Nikon D90 1/200 F8				
Light:	Sunny	Time:	0915	Compass bearing (mag):	150

Notes to help relocate (include diagrams on back of sheet, if necessary):

North face of western summit. After descending the south-east face of the final pinnacle on the ascent of Te Manga, the start of the final ascent begins with a steep bank of exposed rock about 2 m tall. The photograph is taken from the top of this steep bank, looking up at the western summit.

Comments on changes to vegetation/features (compare with previous photographs):

Foreground: Shrubland dominated by kiekie with neinei (both dead and alive).
Distance (north-west facing slopes of western summit): Shrubland dominated by neinei, rata, and kaiatea. Note the exposed rock faces on the steepest, west-facing upper slopes, and the absence of larger trees on the steeply descending ridge (photograph right).

RAROTONGA PHOTOPOINT MEASUREMENT SHEET

Photopoint No.:	PP10	Plot No.: (if relevant)	-	Tree Tag No.:	8046
Date:	20/05/2015	Recorder:	T J MARTIN	Photographer:	T J MARTIN
GPS Coordinates (NZTM):	S 21 14.085		W 159 45.839		
Date Established:	20/05/2015	Photograph No.:	0682		
Camera and Lens Details:	Nikon D90 1/200 F10				
Light:	Sunny	Time:	0915	Compass bearing (mag):	150

Notes to help relocate (include diagrams on back of sheet, if necessary):

Same location as PP9. North face of western summit. After descending the south-east face of the final pinnacle on the ascent of Te Manga, the start of the final ascent begins with a steep bank of exposed rock about 2 m tall. The photograph is taken from the top of this steep bank, looking back at the south-east face of the pinnacle.

Comments on changes to vegetation/features (compare with previous photographs):

Foreground: Kiekie (left) and a *Glochidion,* in poor health with few leaves (right)
Distance: South-east face of pinnacle with shrubland dominated by rata, kaiatea, and neinei, over a ground-tier of *Arachniodes aristata*, kiekie, and *Elaphoglossum savaiiense*. Note the neinei that is emergent on the upper east facing slope of the pinnacle (to the right of the high point.

APPENDIX 3

PRELIMINARY LIST OF COLLECTIONS FOR NON-VASCULAR FLORA

Accession No	Family	Genus	Species	Field Collector Ref	Field Coll Date	Locality Description	Field Coll Latitude Precision	Field Coll Latitude from	Field Coll Longitude Precision	Field Coll Longitude from	Field Coll Altitude Precision	Field Coll Altitude from	Field Coll General Notes
AK358034	PANNARIACEAE	Degelia	durietzii	T J Martin CR 22	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle	± 10 m	21° 13' 33" South	± 10 m	159° 46' 53.6" West	± 50 m	500m	Epiphytic on large pua (Fagraea berteroana). Occasional, growing intermingled with mosses. P0077-78 DUPLICATE SENT TO: B
AK358035	GRAPHIDACEAE			T J Martin CR 47	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle	± 10 m	21° 13' 33" South	± 10 m	159° 46' 53.6" West	± 50 m	500m	Epiphytic on twig of rata (Metrosideros collina) in shrubland on ridge. DUPLICATE SENT TO: B
AK358036	GRAPHIDACEAE			T J Martin CR 28	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle	± 10 m	21° 13' 33" South	± 10 m	159° 46' 53.6" West	± 50 m	500m	Common on Freycinetia wilderi. P0087 DUPLICATE SENT TO: B
AK358037	GRAPHIDACEAE			T J Martin CR 29	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle	± 10 m	21° 13' 33" South	± 10 m	159° 46' 53.6" West	± 50 m	500m	Epiphytic on Freycinetia arborea in ground tier of cloud forest shrubland. P0088,0090 DUPLICATE SENT TO: B
AK358038	STICTACEAE	Sticta	caperata	T J Martin CR8	7-May-15	Cook Islands, Rarotonga, Maungatea, Look at track, slope forest between start of track and bluff	± 10 m	21° 13.2" South	± 10 m	159° 46' 47.2" West	± 50 m	148.1m	Occasional on lower trunk of mato (Homalium acuminatum). P0060 DUPLICATE SENT TO: B
AK358039	GRAPHIDACEAE			T J Martin CR11	7-May-15	Cook Islands, Rarotonga, Maungatea, Look at track, slope forest between start of track and bluff	± 10 m	21° 13.2" South	± 10 m	159° 46' 47.2" West	± 50 m	148.1m	On lower trunk of mato (Homalium acuminatum) in slope forest. Only seen at this location on one tree. P0063 DUPLICATE SENT TO: B
AK358040	GRAPHIDACEAE			T J Martin CR12	7-May-15	Cook Islands, Rarotonga, Maungatea, Look at track, slope forest between start of track and bluff	± 10 m	21° 13.2" South	± 10 m	159° 46' 47.2" West	± 50 m	148.1m	On lower trunk of mato (Homalium acuminatum) in slope forest. Only seen at this location on one tree. P0064 DUPLICATE SENT TO: B
AK358041	GRAPHIDACEAE			T J Martin CR57	10-May-15	Cook Islands, Rarotonga, Muri lagoon, southrn most islet named Ta'akuka, coastal forest, western end of island.	± 10 m	21° 15' 47.9" South	± 10 m	159° 43' 52.9" East	± 50 m	1m	Common on mature bark on lower trunk of Guettarda speciosa. In coastal forest dominated by Guettarda, Hibiscus tiliaceus, Hernandia nymphaeifolia, Cocos nucifera. DUPLICATE SENT TO: B
AK359525	LOBARIACEAE	Pseudocyphellaria		T J Martin CR 124	11-May-15	Cook Islands, Rarotonga, Te Kou, montane shrubland at summit	± 10 m	21° 14' 31.1" South	± 10 m	159° 46' 39.4" West		580m	Epiphytic on rata (Metrosideros collina agg), Uncommon, upper surface of thallus lime green, lower surface, creamy yellow, Medulla golden yellow.
AK359526	STICTACEAE	Sticta		T J Martin CR 168	15-May-15	Cook Islands, Rarotonga, north-western slopes of Maungaroa (509m high point), ridge tending NW-SE.	± 10 m	21° 13' 46.5" South	± 10 m	159° 48' 31.6" West		509m	Epiphytic on large multi-trunked pua (Fagraea berteroana) on steep ridge, dominated by pua and neinei (Fitchia speciosa). Occasional from here to summit of Maungaroa at 509m
AK359527	Indet. bryophyte		Indet. bryophyte	T J Martin CR 163	15-May-15	Cook Islands, Rarotonga, summit of Maungaroa	± 10 m	21° 13' 52.1" South	± 10 m	159° 48' 15.3" West		509m	Epiphytic on lower trunks of neinei (Fitchia speciosa) on windswept summit. Upper surface of thallus olive-green when fresh
AK359528	LOBARIACEAE	Pseudocyphellaria	homalosticta	T J Martin CR 166	15-May-15	Cook Islands, Rarotonga, summit of Maungaroa (509m)	± 10 m	21° 13' 52.1" South	± 10 m	159° 48' 15.3" West			Common on trunks of rata (Metrosideros collina agg.) on wind swept summit Grey-green thallus when fresh. Isidia abundant on thallus margins
AK359529	LOBARIACEAE	Pseudocyphellaria		T J Martin CR 162	15-May-15	Cook Islands, Rarotonga, summit of Maungaroa	± 10 m	21° 13' 52.1" South	± 10 m	159° 48' 15.3" West		509m	Frequent on trunks of neinei on wind and light exposed summit evettion. Thullus limey-green with bright gold edge and undersurface
AK359530	LOBARIACEAE	Pseudocyphellaria	homalosticta	T J Martin CR 125	11-May-15	Cook Islands, Rarotonga, Te Kou, montane shrubland at summit	± 10 m	21° 14' 31.1" South	± 10 m	159° 46' 39.4" West		580m	Common on rata (Metrosidenos collina agg.). Upper surface green to olive green. Lower browncto cream on edges
AK359531	LOBARIACEAE	Pseudocyphellaria	homalosticta	T J Martin CR 42	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle	± 10 m	21° 13' 33" South	± 10 m	159° 46' 53.6" West		499.9m	Epiphytic on branches of rata (Metrosideros collina agg.) on ridge. Adaxial surface tan through to olive green.
AK359532	LOBARIACEAE	Pseudocyphellaria	homalosticta	T J Martin CR 113	3-Jul-15	Cook Islands, Rarotonga, Te Kou, stream valley between north ridge and summit	± 10 m	21° 14' 29.8" South	± 10 m	159° 46' 37.9" West			Frequent epiphyte onFitchia speciosa in Fitchia speciosa-Weinmannia samoeisis-Blechnum spp shurbland. Upper green, isidiate margin lower brown-cream on edges.
AK359533	LOBARIACEAE			T J Martin CR 31	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle	± 10 m	21° 13' 33" South	± 10 m	159° 46' 53.6" West		500m	Epiphytic on neinei (Fitchia speciosa) on ridgeline. 1, 2, or 3 species here?
AK359534	LOBARIACEAE			T J Martin CR 36	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle	± 10 m	21° 13' 33" South	± 10 m	159° 46' 53.6" West		500m	Epiphytic on neinei (Fitchia speciosa) on ridge. Small, olivegreen.

Accession No	Family	Genus	Species	Field Collector Ref	Field Coll Date	Locality Description	Field Coll Latitude Precision	Field Coll Latitude from	Field Coll Longitude Precision	Field Coll Longitude from	Field Coll Altitude Precision	Field Coll Altitude from	Field Coll General Notes
AK359535	STICTACEAE	Sticta	caperata	T J Martin CR 121	13-May-15	Cook Islands, Rarotonga, Te Kou, stream valley between north ridge and summit	± 10 m	21° 14' 29.8" South	± 10 m	159° 46' 37.9" West		560m	Common as epiphyte on kaiatea (Weinmannia samoensis) firming bright green thallus to dinner plate in size.
AK359536	PHYSCIACEAE	Dirinaria		T J Martin CR 2	5-May-15	Cook Islands, Rarotonga, Muri, Are Meika guesthouse	± 10 m	21° 15' 33.1" South	± 10 m	159° 44' 8.9" West		0.2m	Occasional on lower, western base of mature Cocos nucifera on western boundary of property.
AK359537	STICTACEAE	Sticta	caperata	T J Martin CR 32	7-May-15	Cook Islands, Rarotonga, Muri, Are Meika guesthouse	± 10 m	21° 15' 33.1" South	± 10 m	159° 44' 8.9" West		0.2m	Epiphytic on neinei (Fitchia speciosa) on ridgeline.
AK359538	STICTACEAE	Sticta	caperata	T J Martin CR 19	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face	± 10 m	21° 13' 30.1" South	± 10 m	159° 46' 54.4" West		467m	Occasional on lower trunk of large pua (Fagraea beteroana) Festooned with mosses and ferns. Adaxial surface green grey with clusters of orangey brown apothecia. Numerous cyphellae on abaxial surface which is brown to cream at tips.
AK359539	STICTACEAE	Sticta	caperata	T J Martin CR 25	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle	± 10 m	21° 13' 33" South	± 10 m	159° 46' 53.6" West		500m	Epiphytic on large leaning trunks of pua (Fagraea berteroana) with abundant mosses and Humata banksii
AK359540	STICTACEAE	Sticta	fuliginosa	T J Martin CR 112	11-May-15	Cook Islands, Rarotonga, upper Takuvaine Valley, upper slope forest on ridge, Te Kou track	± 10 m	21° 14' 17.3" South	± 10 m	159° 46' 34.8" West			Tiny Sticta with thallus like small ears c.20mm across black upper beige underside with distinct 'moon craters' growing on lower trunk of large Fagraea berteroana hard against LHS of track when ascending.
AK359541	LOBARIACEAE	Pseudocyphellaria	argyracea	T J Martin CR 40	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle.	± 10 m	21° 13' 33" South	± 10 m	159° 46' 53.6" West		500m	Epiphytic on rata (Metrosideros collina agg),on ridge.Grwing intermingled with mosses. Adaxial surface a dark blue-grey green. Abaxial brown with white edges.
AK359542	TRICHOTHELIACEAE	Porina		T J Martin CR 13	7-May-15	Cook Islands, Rarotonga, base of Maungatea Bluff in slope forest on tallus slope	± 10 m	21° 13' 15.8" South	± 10 m	159° 46' 50.4" West			On lower trunk of mature mato (Homalium acuminatum) in dense shade.
AK359544	LOBARIACEAE			T J Martin CR 21	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face.	± 10 m	21° 13' 30.1" South	± 10 m	159° 46' 54.4" West		467m	Lobariaceae-Pseudocyphellaria. Occasional on lower epiphyte-festered trunk of large pua (Fagraen berteroana) Adaxial-browny/grey.
AK359545	LOBARIACEAE			T J Martin CR 20	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face.	± 10 m	21° 13' 30.1" South	± 10 m	159° 46' 54.4" West		467m	Lobariaceae-Pseudocyphellaria. Occasional on lower trunk of large pua (Fagraen beteroana), Adaxial surface grey-green. Adaxial tan-white at tips.
AK359546	LOBARIACEAE	Pseudocyphellaria		T J Martin CR 39	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle.	± 10 m	21° 13' 33" South	± 10 m	159° 46' 53.6" West		500m	Epiphytic on twig of rata (Metosideros collina agg.) in shrubland. Adaxial surface green to olive green. Numerous finger like projections along thallus edge.
AK359547	LOBARIACEAE	Pseudocyphellaria		T J Martin CR 69	7-May-15	Cook Islands, Rarotonga, Maungatea,ridge up from large slip on north face, just before first rock pinnacle.	± 10 m	21° 13' 33" South	± 10 m	159° 46' 53.6" West		500m	Epiphytic on small branch of rata (Metrosideros collina agg.) Adaxial surface grey green with areas of golden yellow medulla bursting through. Thallus edge also yellow.
AK359548	LOBARIACEAE	Pseudocyphellaria		T J Martin CR 136	14-May-15	Cook Islands, Rarotonga, Te Kou, stream valley between north ridge and summit	± 10 m	21° 14' 29.8" South	± 10 m	159° 46' 37.9" West		560m	Occasional on kaiatea (Weinmannia samoensis) Upper surface gun metal grey with medulla bursting throug in little patches. Medulla white.
AK359549	GRAPHIDACEAE			T J Martin CR 129	14-May-15	Cook Islands, Rarotonga, Muri, field with stream on inland side of coast road, opposite Muri Outlet II	± 10 m	21° 15' 34.7" South	± 10 m	159° 44' 2" West		5m	Abundent on lower 1m of trunk of Polynesian chestnut (Inocarpus fagifer)
AK359550	GRAPHIDACEAE			T J Martin CR 58	10-May-15	Cook Islands, Rarotonga, Muri Lagoon, southern most islet named Ta'akoka, coastal forest, easterly end of islet	± 10 m	21° 15' 51.9" South	± 10 m	159° 43' 49" West		1m	On bark on lower trunk of Guerttada speciosa. In coastal forest dominated by Guerttada and Hibiscus tiliaceus. Up to 3 species present (thallus cream, grey- brown or yellow cream)
AK359551	GRAPHIDACEAE			T J Martin CR 60	10-May-15	Cook Islands, Rarotonga, Muri, up road past Emanuela Christian School,Are Meika guesthouse, gardens.	± 10 m	21° 15' 32.9" South	± 10 m	159° 44' 9.9" West		0.2m	Occasional on lower trunk of mango (Mangifera indica) tree. Forming horizontal bands up to 25mm (high) by 100m long. Two species?
AK359552	GRAPHIDACEAE			T J Martin CR 61	10-May-15	Cook Islands, Rarotonga, Muri, up road past Emanuela Christian	± 10 m	21° 15' 32.9" South	± 10 m	159° 44' 9.9" West		0.2m	Occasional on lower trunk and branches of white flowered shrub (photo 0143) in lawn, 3 species?

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						School, Are Meika guesthouse, gardens.							Thallus a greeny-grey, tan or grey-brown)
AK359553	GRAPHIDACEAE			T J Martin CR 96	11-May-15	Cook Islands, Rarotonga, upper Takuvaine Valley, slope forest on ridge.	± 10 m	21° 14' 12.2" South	± 10 m	159° 46' 33.9" West		300m	On lower trunks of Fitchia speciosa in shade.
AK359554	GRAPHIDACEAE			T J Martin CR 150	15-May-15	Cook Islands, Rarotonga, Avarua, headquarters of National Environment service (NES)	± 10 m	21° 12' 24.2" South	± 10 m	159° 46' 27.7" West		5m	Epiphytic on upper trunk and brances of frangipani c. 3 m above ground. Tree on seaward side of NES building.
AK359555	STICTACEAE	Sticta	caperata	T J Martin CR 81	19-May-15	Cook Islands, Rarotonga, Te Manga (653m high point) summit vegetation on western peak.	± 10 m	21° 14' 8.2" South	± 10 m	159° 45' 50.1" West		645m	Epiphytic on kaiatea (Weinmannia samoensis in shrubland dominated by kaiatea, neinei (Fitchia speciosa), rata (Metrosideros collina agg.) and Blechnum societatum. Occasional Thullus eclongated, more pendulous than most Sticta seen in Rarotonga cloud forest.
AK359556	GRAPHIDACEAE			T J Martin CR 82	19-May-15	Cook Islands, Rarotonga, Te Manga (653m high point) summit vegetation on western peak.	± 10 m	21° 14' 8.2" South	± 10 m	159° 45' 50.1" West		645m	Epiphytic, Occasional on brances of kaiatea (Weinmannia samoensis) in high light, In shrubland dominated by kaiatea, neinei (Fitchia speciosa) and rata (Metrosideros collina agg.)
AK359557	LOBARIACEAE			T J Martin CR 202	19-May-15	Cook Islands, Rarotonga, Te Manga, saddle between eastern and western summits	± 10 m	21° 14' 8.4" South	± 10 m	159° 45' 49.7" West		645m	Occasional epiphyte on neinei (Fitchia speciosa) alongside ridgeline track. Cloud forest donimated by neinei and kaiatea (Weinmannia samoensis). Upper surface of thallus grey-green to brown-green when fresh. Isidia abundant.
AK359558	GRAPHIDACEAE			T J Martin CR 204	19-May-15	Cook Islands, Rarotonga, Te Manga, saddle between eastern and western summits	± 10 m	21° 14' 8.4" South	± 10 m	159° 45' 49.7" West		645m	Epiphytic on branches of neinei (Fitchia speciosa) in cloud forest dominated by neinei, kaiatea (Weimannia samoensis) and Blechaum societatum.
AK359559	GRAPHIDACEAE			T J Martin CR 59	10-May-15	Cook Islands, Rarotonga, Muri, Laggon, southern-most islet named Ta'a koka, western inland end, coastal forest.	± 10 m	21° 15' 47.9" South	± 10 m	159° 43' 52.9" West		1m	On branches of Au (Hibiscus tiliaceus) in shade, Trees used as seabird roosting site with strong smell of guano. Three species presetn with grey-brown, white, or grey-green thallus?
AK359560	GRAPHIDACEAE			T J Martin CR 116	11-May-15	Cook Islands, Rarotonga, Te Kou, stream valley between north ridge and summit	± 10 m	21° 14' 29.8" South	± 10 m	159° 46' 37.9" West			Several Graphid species growing on lower trunk and brances of Fitchia speciosa. Fitchia, Blechnum spp.
AK359561	GRAPHIDACEAE			T J Martin CR 38	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle.	± 10 m	21° 13' 33" South	± 10 m	159° 46' 53.6" West		500m	Epiphytic on kiekie (Freycinetia wilderi) on ridge. Other crustose spp. On same piece.
AK359562	GRAPHIDACEAE			T J Martin CR 33	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle.	± 10 m	21° 13' 33" South	± 10 m	159° 46' 53.6" West		500m	Epiphytic on neinei (Fitchia speciosa) on ridge line.
AK359563			Indet. lichen	T J Martin CR 18	7-May-15	Cook Islands, Rarotonga, base of Maungatea Bluff in slope forest on tallus slope.	± 10 m	21° 13' 15.8" South	± 10 m	159° 46' 50.4" West			On lower trunk of mature mato (Homalium acuminatum) in dense shade. Dark green, circular, with distinctive ring around circumference, Orangey brown apothecia. Squamulose.
AK359564			Indet. lichen	T J Martin CR 117	11-May-15	Cook Islands, Rarotonga, Te Kou, stream valley between north ridge and summit	± 10 m	21° 14' 29.8" South	± 10 m	159° 46' 37.9" West			Epiphytic on Fitchia speciosa Thallus tightly appressed to bark. Centrally dark green grading to grey on margins. Fitchia speciosa, Blechnum spp.
AK359565	LOBARIACEAE	Pseudocyphellaria		T J Martin CR 126	11-May-15	Cook Islands, Rarotonga, Te Kou, montane shrubland at summit	± 10 m	21° 14' 31.1" South	± 10 m	159° 46' 39.4" West		580m	Epiphytic on rata (Metrosideros collina agg). Uncommon. Very distinctive two tone appearance with olive green thallus and silvery margin.
AK359566			Indet. moss	T J Martin CR 41	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle.	± 10 m	21° 13' 33" South	± 10 m	159° 46' 53.6" West		500m	Epiphytic on lowertrunks of most trees, Abundant. Often intermingled with lichens (Lobariaceae) and ferns.

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AK359567	PHYSCIACEAE	Heterodermia	japonica	T J Martin CR 30	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle.	± 10 m	21° 13' 33" South	± 10 m	159° 46' 53.6" West		500m	Epiphytic on neinei (Fitchia speciosa) on ridgeline.
AK359568	PERTUSARIACEAE	Pertusaria		T J Martin CR 17	7-May-15	Cook Islands, Rarotonga, base of Maungatea Bluff in slope forest on tallus slope.	± 10 m	21° 13' 15.8" South	± 10 m	159° 46' 50.4" West			On lower trunk of mature mato (Homalium acuminatum) in dense shade.
AK359569	TRICHOTHELIACEAE	Porina		T J Martin CR 15	7-May-15	Cook Islands, Rarotonga, base of Maungatea Bluff in slope forest on tallus slope.	± 10 m	21° 13' 15.8" South	± 10 m	159° 46' 50.4" West			On lower trunk of mature mato (Homalium acuminatum) in dense shade.
AK359570	COLLEMATACEAE	Leptogium		T J Martin CR 120	13-May-15	Cook Islands, Rarotonga, Te Kou, stream valley between north ridge and summit	± 10 m	21° 14' 29.8" South	± 10 m	159° 46' 37.9" West			Occasional. Epiphytic on Fitchia speciosa. Apothecia orangey brown, and raised above thallus like mini thumb tacks.
AK359571	PANNARIACEAE	Degelia	gayana	T J Martin CR 122	13-May-15	Cook Islands, Rarotonga, Te Kou, stream valley between north ridge and summit	± 10 m	21° 14' 29.8" South	± 10 m	159° 46' 37.9" West			Epiphytic, Foliose lichen with light grey upper surface, Dark grey on lowere surface with beige margin. Epiphytic on kaiatea (Weimannia samoensis)
AK359572	GRAPHIDACEAE			T J Martin CR 214	19-May-15	Cook Islands, Rarotonga, Te Manga, saddle between east and west summits,	± 10 m	21° 14' 8.3" South	± 10 m	159° 45' 49.7" West		645m	Epiphytic on neinei (Fitchia speciosa) on ridgeline dominated by neinei and kaiatea (Weinmannia samoensis)
AK359574	GRAPHIDACEAE			T J Martin CR 201	20-May-15	Cook Islands, Rarotonga, Te Manga, saddle between east and west summits,	± 10 m	21° 14' 8.3" South	± 10 m	159° 45' 49.7" West		645m	Common on aerial stems of keikei (Freycinetia arborea) in cloud forest dominated by neinei (Fitchia speciosa)
AK359575	GRAPHIDACEAE			T J Martin CR 131	13-May-15	Cook Islands, Rarotonga, Te Kou, stream valley at summit, fernland	± 10 m	21° 14' 27.2" South	± 10 m	159° 46' 33.7" West		560m	Epiphytic on neinei (Fitchia speciosa) in montane fernland dominated by Blechnum spp.
AK359576	GRAPHIDACEAE			T J Martin CR 110, B T Maxwell, E T Apera	13-May-15	Cook Islands, Rarotonga, Te Kou, eastern end of ridge forming northern face of Te Kou, above Takuvaine Valley.	± 10 m	21° 14' 25.2" South	± 10 m	159° 46' 32.1" West		560m	Growing on stem of Freycinetia wilderi, in Weinmannia Samoasis-Fitchia speciosa-Freycinetia association on ridge, Mosses also common on stems as epiphytes.
AK359577	GRAPHIDACEAE			T J Martin CR 108	13-May-15	Cook Islands, Rarotonga, Te Kou, northern ridge above summit basin, close to where Te Kou track crosses ridge.	± 10 m	21° 14' 25" South	± 10 m	159° 46' 36.7" West		570m	On fallen twig from large rose apple (Eugenia jambos) tree.
AK359578	PARMELIACEAE	Parmotrema		T J Martin CR 100	12-May-15	Cook Islands, Rarotonga, Te Kou, derelict shed on peak to west of transmitter station.	± 10 m	21° 14' 29.2" South	± 10 m	159° 46' 41" West		594.7m	One of three lichen species growing on south facing wall of shed. Substrate-painted wood.
AK359580			Indet. lichen	T J Martin CR 169	15-May-15	Cook Islands, Rarotonga, north-western slopes of Maungaroa (509m high point), ridge tending NW-SE.	± 10 m	21° 13' 46.5" South	± 10 m	159° 48' 31.6" West		359.7m	Epiphytic on large multi-trunked pua (Fagraea berteroana) on steep ridge dominatd by puas and neinei (Fitchia speciosa). Thallus gun-metal grey when fresh. Growing intermixed with mosses and ?Heterodermia (CR 170)
AK359581			Indet. lichen	T J Martin CR 200, A W Wheatley	20-May-15	Cook Islands, Rarotonga, Te Manga track, lower slope forest, ridgeline	± 10 m	21° 13' 45.4" South	± 10 m	159° 45' 47.1" West		320m	Common on lower truks of mato (Homalium acuminattum) in dense slope forest on ridge. Forms large grey-green patches with distinctive convaluted appearance.
AK359582	PARMELIACEAE	Usnea		T J Martin CR 10	7-May-15	Cook Islands, Rarotonga, road end at start of Mauagatea Lookout track	± 10 m	21° 13' 1" South	± 10 m	159° 46' 48" West			occasional on lower trunk of mature Cocos nucifera.
AK359583			Indet. lichen	T J Martin CR 16	7-May-15	Cook Islands, Rarotonga, base of Maungatea Bluff in slope forest on tallus slope.	± 10 m	21° 13' 15.8" South	± 10 m	159° 46' 50.4" West			On lower trunk of mature mato (Homalium acuminatum) in dense shade. Dark green, circular, with distinctive ring around circumference, Orangey brown apothecia. Sqamulose.
AK359584	COLLEMATACEAE	Physma	byrsaeum	T J Martin CR 23	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle.	± 10 m	21° 13' 19.8" South	± 10 m	159° 46' 32.2" West		500m	Epiphytic on large pua (Fagraea berteroana). Rare.
AK359585			Indet. lichen	T J Martin CR 26	7-May-15	Cook Islands, Rarotonga, ridge up from large slip on north face	± 10 m	21° 13' 30.1" South	± 10 m	159° 46' 54.4" West		467m	Epiphytic on branc of pua (Fagraea berteroana). Crustose, colour a grenn tinged cream. Large black apothecia occasional
AK359586			Indet. lichen	T J Martin CR 27	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle.	± 10 m	21° 13' 19.8" South	± 10 m	159° 46' 32.2" West		500m	Crustose lichen. Epiphytic on branches of pua (Fagraea berteroana). Tan thallus with small black apothecial discs.
AK359587			Indet. lichen	T J Martin CR 34	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle.	± 10 m	21° 13' 19.8" South	± 10 m	159° 46' 32.2" West		500m	Crustose lichen. Epiphytic on neinei (Fitchia speciosa) on ridge.

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AK359588	PANNARIACEAE	Parmeliella	brisbanensis	T J Martin CR 35	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle.	± 10 m	21° 13' 19.8" South	± 10 m	159° 46' 32.2" West		500m	Epiphytic on neinei (Fitchia speciosa) forming thick round discus (dark grey) with distinctive black eydge.
AK359589			Indet. lichen	T J Martin CR 37	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle.	± 10 m	21° 13' 19.8" South	± 10 m	159° 46' 32.2" West		500m	Epiphytic on neinei)Fitchia speciosa) on ridge. Rare. Dark gre. Appearance like tongues of lava.
AK359590	COLLEMATACEAE	Physma	byrsaeum	T J Martin CR 45	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle.	± 10 m	21° 13' 19.8" South	± 10 m	159° 46' 32.2" West		500m	Epiphytic amongst dense moss on trunk of rata (Metrosideros collina agg.) on ridge. Occasional
AK359591	COLLEMATACEAE	Physma	byrsaeum	T J Martin CR 50	7-May-15	Cook Islands, Rarotonga, Maungatea, steep eastern most ridge overlooking Takuvaine Stream Valley and water intake.	± 10 m	21° 13' 31.1" South	± 10 m	159° 46' 50.1" West		457.8m	Occasional on lower shaded trunks of mato (Homalium acuminatum) on western side of ridge crest. Adaxial surface dark browny grey when fres. Fertile structures like acorn caps.
AK359592	PANNARIACEAE	Pannaria		T J Martin CR 101, B T Maxwell, E T Apera	12-May-15	Cook Islands, Rarotonga, Te Kou, derelict shed on peak to west of transmitter station.	± 10 m	21° 14' 29.2" South	± 10 m	159° 46' 41" West		594.7m	Or ?Parmielliella One of three lichen species growing on south-facing wall of shed. Substrate-painted plywood. Forming circular thallus-grey-dark grey when fresh.
AK359593	PANNARIACEAE	Parmeliella	mariana	T J Martin CR 114	11-May-15	Cook Islands, Rarotonga, Te Kou, stream valley between north ridge and summit	± 10 m	21° 14' 29.8" South	± 10 m	159° 46' 37.9" West			Epiphytic on Fitchia speciosa in Fitchia-Weinmannia-Blechnum shrubland.
AK359594			Indet. lichen	T J Martin CR 118	11-May-15	Cook Islands, Rarotonga, Te Kou, stream valley between north ridge and summit	± 10 m	21° 14' 29.8" South	± 10 m	159° 46' 37.9" West			Epiphytic on Fitchia speciosa thallus a dark browny green, filmy.
AK359595			Indet. lichen	T J Martin CR 119	11-May-15	Cook Islands, Rarotonga, Te Kou, stream valley between north ridge and summit	± 10 m	21° 14' 29.8" South	± 10 m	159° 46' 37.9" West			Foliose, thallus grey, roughly circular, with brown disc-like apothecia at centre. Epiphytic on Fitchia speciosa. Only one seen of this type on Te Kou.
AK359596	PANNARIACEAE	Degelia	gayana	T J Martin CR 127	11-May-15	Cook Islands, Rarotonga, Te Kou, montane shrubland at summit	± 10 m	21° 14' 31.1" South	± 10 m	159° 46' 39.4" West		580m	Occasional on rta (Metrosideos collina agg.) Appearance and texture somewhta like spilled grey paint.
AK359597			Indet. lichen	T J Martin CR 151, A W Wheatley	15-May-15	Cook Islands, Rarotonga, ridge ascending south-east towards Maungaroa (509m)	± 10 m	21° 13' 48.4" South	± 10 m	159° 48' 27.1" West		365.8m	Epiphytic on lower trunks of neinei (Fitchia speciosa) on narrow ridge dominated by neinei and pua (Fagraea berteroana)
AK359598			Indet. lichen	T J Martin CR 160, A W Wheatley	15-May-15	Cook Islands, Rarotonga, slopes of Maungaroa (509 m peak), main ridge running west from summit towards Raemaru	± 10 m	21° 13' 51.4" South	± 10 m	159° 48' 20" West		450m	On ridge under part shade. Growing in moss on tree trunk. associated with Neinei (Fitchia speciosa) and pua (Fagraea berteroana).
AK359599			Indet. lichen	T J Martin CR 164, A W Wheatley	15-May-15	Cook Islands, Rarotonga, summit of Maungaroa (509m)	± 10 m	21° 13' 52.1" South	± 10 m	159° 48' 15.3" West			Epiphytic on trunks of neinei (Fitchia speciosa) on windswept summit.
AK359600			Indet. lichen	T J Martin CR 165, A W Wheatley	15-May-15	Cook Islands, Rarotonga, summit of Maungaroa (509m)	± 10 m	21° 13' 52.1" South	± 10 m	159° 48' 15.3" West		509m	Epiphytic on lower trunks of neinei (Fitchia speciosa) on windswept summit.
AK359601			Indet. lichen	T J Martin CR 173, A W Wheatley	15-May-15	Cook Islands, Rarotonga, north-western slopes of Maungaroa (509m high point), ridge tending NW-SE.	± 10 m	21° 13' 46.5" South	± 10 m	159° 48' 31.6" West		359.7m	Epiphytic on large mutli-trunked pua (Fagraea berteroana) on steep ridge dominated by puas and neinei (Fitchia speciosa).Texture and appearance like spilled, dry gry paint.
AK359602			Indet. lichen	T J Martin CR 203	19-May-15	Cook Islands, Rarotonga, Te Manga, Saddle betweeen east and west summits	± 10 m	21° 14' 8.3" South	± 10 m	159° 45' 49.7" East		645m	Epiphytic on neinei (Fitchia speciosa). Forming roughly circular patches up to 50mm diameter. Thallus filmy, brown-green when fresh.
AK359603			Indet. lichen	T J Martin CR 205, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, saddle between eastern and western summits	± 10 m	21° 14' 8.4" South	± 10 m	159° 45' 49.7" West		645m	Epiphytic on branches of neinei (Fitchia speciosa) in cloud forest dominated by neinei, kaiatea (Weimannia samoensis) and Blechaum societatum.
AK359605			Indet. lichen	T J Martin CR 212, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, summit of eastern peak, shrubland	± 10 m	21° 14' 9" South	± 10 m	159° 45' 49" West		653m	Epiphytic of rata (Metrosideros collina agg.) Shrubland dominated by rata and Kaiatea (Weinmmania samoensis), growing on epiphytic mosses on small branch. Upper thallus grey when fresh.
AK359606	GRAPHIDACEAE			T J Martin CR 213	19-May-15	Cook Islands, Rarotonga, Te Manga, summit of eastern peak, shrubland.	± 10 m	21° 14' 9" South	± 10 m	159° 45' 49" West		653m	Epiphytic of rata (Metrosideros collina agg.) Shrubland dominated by rata and Kaiatea (Weinmmania samoensis. On outer twigs in full light.

Accession No	Family	Genus	Species	Field Collector Ref	Field Coll Date	Locality Description	Field Coll Latitude Precision	Field Coll Latitude from	Field Coll Longitude Precision	Field Coll Longitude from	Field Coll Altitude Precision	Field Coll Altitude from	Field Coll General Notes
AK359607	COLLEMATACEAE	Leptogium		T J Martin CR 215, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, saddle between east and west summits	± 10 m	21° 14' 8.3" South	± 10 m	159° 45' 49.7" West		645m	Epiphytic on neinei (Fitchia speciosa) on ridgeline. Intermingled with mosses. Thallus a dark greeny-brown when fresh. Numerous brown apothecial discs.
AK359608			Indet. moss	T J Martin CR 181, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, highest peak (eastern) at 65m, summit mossfield beside track log book dept in upturned cooking pot.	± 10 m	21° 14' 8.9" South	± 10 m	159° 45' 49.6" West		653m	One of several moss species forming a low compact sword of mosses on the eastern edge of the summit. Associated species ind, Blechum societatum, Freycinetia arborea,Arachnoides aristata.
AK359609			Indet. moss	T J Martin CR 184, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, highest peak (eastern) at 65m, summit mossfield beside track log book dept in upturned cooking pot.	± 10 m	21° 14' 8.9" South	± 10 m	159° 45' 49.6" West		653m	One of several moss species forming a low compact sword of mosses on the eastern edge of the summit. Associated species ind, Blechum societatum, Freycinetia arborea,Arachnoides aristata.
AK359610			Indet. moss	T J Martin CR193, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, highest peak (eastern) at 65m, summit mossfield beside track log book dept in upturned cooking pot.	± 10 m	21° 14' 8.9" South	± 10 m	159° 45' 49.6" West		653m	One of several moss species forming a low compact sword of mosses on the eastern edge of the summit. Associated species ind, Blechum societatum, Freycinetia arborea,Arachnoides aristata.
AK359611			Indet. moss	T J Martin CR 190, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, highest peak (eastern) at 65m, summit mossfield beside track log book dept in upturned cooking pot.	± 10 m	21° 14' 8.9" South	± 10 m	159° 45' 49.6" West		653m	One of several moss species forming a low compact sword of mosses on the eastern edge of the summit. Associated species ind, Blechum societatum, Freycinetia arborea,Arachnoides aristata.
AK359612			Indet. moss	T J Martin CR 186, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, highest peak (eastern) at 65m, summit mossfield beside track log book dept in upturned cooking pot.	± 10 m	21° 14' 8.9" South	± 10 m	159° 45' 49.6" West		653m	One of several moss species forming a low compact sword of mosses on the eastern edge of the summit. Associated species ind, Blechum societatum, Freycinetia arborea,Arachnoides aristata.
AK359613			Indet. moss	T J Martin CR 191, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, highest peak (eastern) at 65m, summit mossfield beside track log book dept in upturned cooking pot.	± 10 m	21° 14' 8.9" South	± 10 m	159° 45' 49.6" West		653m	One of several moss species forming a low compact sword of mosses on the eastern edge of the summit. Associated species ind, Blechum societatum, Freycinetia arborea, Arachnoides aristata.
AK359614			Indet. moss	T J Martin CR 189, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, highest peak (eastern) at 65m, summit mossfield beside track log book dept in upturned cooking pot.	± 10 m	21° 14' 8.9" South	± 10 m	159° 45' 49.6" West		653m	One of several moss species forming a low compact sword of mosses on the eastern edge of the summit. Associated species ind, Blechum societatum, Freycinetia arborea,Arachnoides aristata.
AK359615			Indet. moss	T J Martin CR 182, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, highest peak (eastern) at 65m, summit mossfield beside track log book dept in upturned cooking pot.	± 10 m	21° 14' 8.9" South	± 10 m	159° 45' 49.6" West		653m	One of several moss species forming a low compact sword of mosses on the eastern edge of the summit. Associated species ind, Blechum societatum, Freycinetia arborea,Arachnoides aristata.
AK359616			Indet. moss	T J Martin CR 188, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, highest peak (eastern) at 65m, summit mossfield beside track log book dept in upturned cooking pot.	± 10 m	21° 14' 8.9" South	± 10 m	159° 45' 49.6" West		653m	One of several moss species forming a low compact sword of mosses on the eastern edge of the summit. Associated species ind, Blechum societatum, Freycinetia arborea, Arachnoides aristata.
AK359617			Indet. moss	T J Martin CR 185A, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, highest peak (eastern) at 65m, summit mossfield beside track log book dept in upturned cooking pot	± 10 m	21° 14' 8.9" South	± 10 m	159° 45' 49.6" West		653m	One of several moss species forming a low compact sword of mosses on the eastern edge of the summit. Associated species include, Blechum societatum, Freycinetia arborea and Arachnoides aristata.
AK359618			Indet. moss	T J Martin CR 183A, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, highest peak (eastern) at 65m, summit mossfield beside track log book dept in upturned cooking pot.	± 10 m	21° 14' 8.9" South	± 10 m	159° 45' 49.6" West		653m	One of several moss species forming a low compact sword of mosses on the eastern edge of the summit. Associated species include: Blechum societatum, Freycinetia arborea,Arachnoides aristata.
AK359619			Indet. moss	T J Martin CR 187, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, highest peak (eastern) at 65m, summit mossfield beside track log book dept in upturned cooking pot.	± 10 m	21° 14' 8.9" South	± 10 m	159° 45' 49.6" West		653m	One of several moss species forming a low compact sword of mosses on the eastern edge of the summit. Associated species include Blechnum societatum, Freycinetia arborea, Arachnoides aristata.
AK359620			Indet. moss	T J Martin CR 192, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, highest peak (eastern) at 65m, summit mossfield beside track log book dept in upturned cooking pot.	± 10 m	21° 14' 8.9" South	± 10 m	159° 45' 49.6" West		653m	One of several moss species forming a low compact sword of mosses on the eastern edge of the summit. Associated species ind, Blechum societatum, Freycinetia arborea,Arachnoides aristata.

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AK359621			Indet. moss	T J Martin CR209A, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, summit of eastern peak, shrubland.	± 10 m	21° 14' 9" South	± 10 m	159° 45' 49" West		653m	Epiphytic on rta (Metrosideros collina agg.) in shrubland dominated by rata and ka'atea (Weinmannia samoensis)
AK359622			Indet. moss	T J Martin CR 210, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, summit of eastern peak, shrubland.	± 100 m	21° 14' 9" South	± 100 m	159° 45' 49" West		653m	Epiphytic on rata (Metrosideros collina agg.) in shrubland dominated by rata and kai'atea (Weinmannia samoensis) Also with epiphytic CR 182 and CR 191
AK359623	RAMALINACEAE	Ramalina	pacifica	T J Martin CR 7	7-May-15	Cook Islands, Rarotonga, road end at start of Mauagatea Lookout track	± 10 m	21° 13' 1" South	± 10 m	159° 46' 48" West			Common on south and western sides of base of mature Cocos nucifera, within 2m, of ground.
AK359624	RAMALINACEAE	Ramalina	peruviana	T J Martin CR 96	7-May-15	Cook Islands, Rarotonga, road end at start of Mauagatea Lookout track	± 10 m	21° 13' 1" South	± 10 m	159° 46' 48" West			Occasional on lower western and southern facing trunk of mature Cocos nucifera.
AK359625	RAMALINACEAE	Ramalina	peruviana	T J Martin CR 3	5-May-15	Cook Islands, Rarotonga, Muri, Are Meika Guesthouse	± 10 m	21° 15' 32.9" South	± 10 m	159° 44' 9.9" West		0.2m	Occasional on lower 2m trunk of mature Cocos nuifera.
AK359627	PANNARIACEAE	Parmeliella	brisbanensis	T J Martin CR 167, A W Wheatley	15-May-15	Cook Islands, Rarotonga, north-western slopes of Maungaroa (509m high point), ridge tending NW-SE.	± 10 m	21° 13' 46.5" South	± 10 m	159° 48' 31.6" West		359.7m	Epiphytic on large multi-trunked pua (Fagraea berteroana) on steep ridge dominatd by puas and neinei (Fitchia speciosa)
AK359628	PANNARIACEAE	Parmeliella	mariana	T J Martin CR 123	13-May-15	Cook Islands, Rarotonga, Te Kou, stream valley between north ridge and summit	± 10 m	21° 14' 29.8" South	± 10 m	159° 46' 37.9" West			As per CR113 Epiphytic on karatea (Weinmannia samoensis). Thallus grey with black margin. Pothecia small brown discs-not on thallus margin.
AK359629	PANNARIACEAE	Parmeliella	brisbanensis	T J Martin CR 206, A W Wheatley	20-May-15	Cook Islands, Rarotonga, Te Manga track, start of steep climb after crossing last pinnacle on ridgeline track.	± 10 m	21° 14' 5.1" South	± 10 m	159° 45' 50.3" West		533.4m	Pannaria & Lobariaceae. Epiphytic on dying Ma'ame (Glochidian concolor) c.3m tall on eastern side of track.
AK359630	TRAPELIACEAE	Placopsis		T J Martin CR 171, A W Wheatley	15-May-15	Cook Islands, Rarotonga, north-western slopes of Maungaroa (509m high point), ridge tending NW-SE.	± 10 m	21° 13' 46.5" South	± 10 m	159° 48' 31.6" West		359.7m	Epiphytic on large multi-trunked pua (Fagraea berteroana) on steep ridge dominatd by puas and neinei (Fitchia speciosa) Occasional. Thallus brown (upper) and dark browny-black (lower)
AK359631	PANNARIACEAE	Parmeliella	mariana	T J Martin CR 43	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle.	± 10 m	21° 13' 19.8" South	± 10 m	159° 46' 32.2" West		500m	Epiphytic on rata (Metrosideros collina agg.) on ridge. Thallus (adaxial) grey with black margin. Fertile with brown cup-like apothecia. Same species as TJ Martin CR35?
AK359632	CLADONIACEAE	Cladonia	darwinii	T J Martin CR 24	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle.	± 10 m	21° 13' 19.8" South	± 10 m	159° 46' 32.2" West		500m	Epiphytic on large horizontal trunk of pua (Fagraea berteroana) with mosses and Humata banksii occasional.
AK359633	PHYSCIACEAE	Physcia		T J Martin CR 68, A W Wheatley	12-May-15	Cook Islands, Rarotonga, Te Kou, derelict shed on peak to west of transmitter station.	± 10 m	21° 14' 29.2" South	± 10 m	159° 46' 41" West		594.7m	One of three lichen species growing on south-facing wall of shed. Substrate-painted plywood.
AK359634	PHYSCIACEAE	Pyxine	subcinerea	T J Martin CR 1	5-May-15	Cook Islands, Rarotonga, Muri, Are Meika Guesthouse	± 10 m	21° 15' 32.9" South	± 10 m	159° 44' 9.9" West		0.2m	Common on lower trunk of mature Cocos nucifera. Cocos on western boundary of property. Common.
AK359636	CLADONIACEAE	Cladonia	floerkeana	T J Martin CR 211, A W Wheatley	20-May-15	Cook Islands, Rarotonga, Te Manga track, top of last pinnacle before final ascent of western summit.	± 10 m	21° 14' 4.4" South	± 10 m	159° 45' 50.6" West		539.5m	Locally common on ground and rotting stump. Assoc. with masses & Elaphoglassum savaiiense Bright red fruiting bodies.
AK359637	CLADONIACEAE	Cladonia	floerkeana	T J Martin CR 128	13-May-15	Cook Islands, Rarotonga, Te Kou, eastern end of ridge forming northern face of Te Kou, above Takuvaine Valley.	± 10 m	21° 14' 25.2" South	± 10 m	159° 46' 32.1" West		560m	Locally common on remains of long dead trees-now stumps covered in lichens, moss, ferns and vaccinum. Fruiting bodies a bright red.
AK359638	PHYSCIACEAE	Heterodermia	hypocaesia	T J Martin CR 174a, A W Wheatley	15-May-15	Cook Islands, Rarotonga, north-western slopes of Maungaroa (509m high point), ridge tending NW-SE.	± 10 m	21° 13' 46.5" South	± 10 m	159° 48' 31.6" West		359.7m	Epiphytic on kiekie (Freycinetia arborea) on steep ridge dominated by neinei (Fitchia speciosa)

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AK359639	PHYSCIACEAE	Heterodermia	japonica	T J Martin CR 115	11-May-15	Cook Islands, Rarotonga, Te Kou, stream valley between north ridge and summit	± 10 m	21° 14' 29.8" South	± 10 m	159° 46' 37.9" West			?Megalospora with specimen. Epiphytic on Fitchia speciosa in Fitchia-Weinmannia-Blechnum shrubland. Upper surface of thallus white to light green when fresh.
AK359640	PHYSCIACEAE	Heterodermia	reagens	T J Martin CR 44	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle.	± 10 m	21° 13' 19.8" South	± 10 m	159° 46' 32.2" West		500m	Epiphytic on rata (Metrosideros collina agg.) on ridge. Occasional.
AK359641	PANNARIACEAE	Leioderma	sorediatum	T J Martin CR 46	7-May-15	Cook Islands, Rarotonga, Maungatea, ridge up from large slip on north face, just before first rock pinnacle.	± 10 m	21° 13' 19.8" South	± 10 m	159° 46' 32.2" West		500m	Epiphytic on small branch of rata, (Metrosideros collina agg.) Adaxial surface olive green edged with white. Abaxial dark brown with white edges.
AK359642	PHYSCIACEAE	Heterodermia	hypocaesia	T J Martin CR 208, A W Wheatley	20-May-15	Cook Islands, Rarotonga, Te Manga track, start of steep climb after crossing last pinnacle on ridgeline track.	± 10 m	21° 14' 5.1" South	± 10 m	159° 45' 50.3" West		533.4m	Epiphytic on dying Ma'ame (Glochidian concolor) c.3m tall on eastern side of track. Upper thallus a light greeny-grey when fresh. Occasional.
AK359643	PHYSCIACEAE	Heterodermia	hypocaesia	T J Martin CR 170, A W Wheatley	15-May-15	Cook Islands, Rarotonga, north-western slopes of Maungaroa (509m high point), ridge tending NW-SE.	± 10 m	21° 13' 46.5" South	± 10 m	159° 48' 31.6" West		359.7m	Epiphytic on large multi-trunked pua (Fagraea berteroana) on steep ridge dominatd by puas and neinei (Fitchia speciosa) Occasional or mossy surfaces of trunk. Thallus a light grey-green when fresh.
AK359689	RAMALINACEAE	Ramalina	pacifica	T J Martin CR 9	7-May-15	Cook Islands, Rarotonga, road end at start of Maungatea Lookout track	± 10 m	21° 13' 1" South	± 10 m	159° 46' 48" West			Occasional on lower western and southern facing trunk of mature cocos nucifera
AK359813	CLADONIACEAE	Cladonia	weymouthii	T J Martin CR 128A	13-May-15	Cook Islands, Rarotonga, Te Kou, eastern end of ridge forming northern face of Te Kou, above Takuvaine Valley.	± 10 m	21° 14' 25.2" South	± 10 m	159° 46' 32.1" West		560m	Locally common on remains of long dead trees-now stumps covered in lichens, moss, ferns and vaccinum. Fruiting bodies a bright red.
AK360122	LEPIDOZIACEAE	Telaranea		T J Martin CR 190, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, highest peak (eastern) at 65m, summit mossfield beside track log book in upturned cooking pot	± 10 m	21° 14' 8.9" South	± 10 m	159° 45' 49.6" West		653m	One of several moss species forming a low compact sword of mosses on the eastern edge of the summit. Associated species: Blechum societatum, Freycinetia arborea, Arachnoides aristata
AK360126	PTILIDIACEAE	Mastigophora	diclados	T J Martin CR 209A, A W Wheatley	19-May-15	Cook Islands, Rarotonga, Te Manga, summit of eastern peak, shrubland	± 10 m	21° 14' 9" South	± 10 m	159° 45' 49" West		653m	Epiphytic on rata (Metrosideros collina agg.) in shrubland dominated by rata and ka'atea (Weinmannia samoensis)
AK360128	LEJEUNEACEAE			T J Martin CR 166A	15-May-15	Cook Islands, Rarotonga, summit of Maungaroa (509m)	± 10 m	21° 13' 52.1" South	± 10 m	159° 48' 15.3" West			On Pseudocyphellaria homalosticta
AK360129	JUBULACEAE	Frullania		T J Martin CR 125A	11-May-15	Cook Islands, Rarotonga, Te Kou, montane shrubland at summit	± 10 m	21° 14' 31.1" South	± 10 m	159° 46' 39.4" West		580m	Frullania (brown) & Lejuenea (green). On Pseudocyphellaria homalosticta
AK360131	JUBULACEAE	Lopholejeunea		T J Martin CR 112A	11-May-15	Cook Islands, Rarotonga, upper Takuvaine Valley, upper slope forest on ridge, Te Kou track	± 10 m	21° 14' 17.3" South	± 10 m	159° 46' 34.8" West			Lopholejeunea & Lejeunea sp. On Sticta fuliginosa and mosses on bark of Fagraea berteroana

APPENDIX 4 - PEST PLANT CONTROL METHODS

Pest Plant	Control Method(s)	Chemical(s)	Chemical[1] & Application Rate	Timing	Remarks
African tulip tree (*Spathodea campanulata*)	Hand pull seedlings/small plants			Year round	
	Cut and treat stumps	Metsulfuron	5g/1 litre water, plus 2 ml surfactant	Year round	
	Drill and inject or frill and spray	Metsulfuron	5g/1 litre water, plus 2 ml surfactant	Year round	
Balloon vine (*Cardiosperma grandiflorum*)	Hand pull small vines and leave off the ground in other vegetation to rot.			Year round	
	Cut and treat stump	Glyphosate	333ml made up to 1 litre with water	Year round	Leave cut vegetation in host to die off.
	Cut stems at waist height, and allow stems to re-sprout, then foliar spray the regrowth	Glyphosate	333ml made up to 1 litre with water	Year round	Leave cut vegetation in host to die off. This method is most suited to larger infestations.
Cecropia, trumpet tree (*Cecropia palmata*)	Hand pull seedlings/small plants			Year round	
	Cut and treat stumps	Metsulfuron	5g/1 litre water, plus 2 ml surfactant	Year round	
	Drill and inject or frill and spray	Metsulfuron	5g/1 litre water, plus 2 ml surfactant	Year round	
Mile-a-minute (*Mikania micrantha*)	Hand pull seedlings and small plants.			Year round	Hang pulled plants off the ground in vegetation and leave to rot.
	Knapsack - foliar spray	Metsulfuron	5g/10 litres water	Year round	
Night blooming cestrum (*Cestrum nocturnum*)	Cut and treat stumps	Metsulfuron	5g/10 litres water	Year round	
Rose apple (*Syzygium jambos*)	Hand pull seedlings/small plants			Year round	
	Cut and treat stumps	Metsulfuron	5g/1 litre water, plus 2 ml surfactant	Year round	
	Drill and inject or frill and spray	Metsulfuron	5g/1 litre water, plus 2 ml surfactant	Year round	
Shoebutton ardisia (*Ardisia elliptica*)	Hand pull seedlings/small plants			Year round	
	Cut and treat stumps	Metsulfuron	5g/1 litre water, plus 2 ml	Year round	

Pest Plant	Control Method(s)	Chemical(s)	Chemical [1] & Application Rate	Timing	Remarks
			surfactant		
	Drill and inject or frill and spray	Metsulfuron	5g/1 litre water, plus 2 ml surfactant	Year round	
Strawberry guava (Psidium cattleianum)	Hand pull seedlings/small plants			Year round	
	Cut and treat stumps	Metsulfuron	5g/1 litre water, plus 2 ml surfactant	Year round	
	Drill and inject or frill and spray	Metsulfuron	5g/1 litre water, plus 2 ml surfactant	Year round	
White flowered ginger (Hedychium coronarium)	Hand pull seedlings and small rhizomes.			Year round	Do not leave pulled rhizomes on site as they will regrow. These must be carefully disposed off site.
	Cut above 'collar' and treat stems		1g metsulfuron/1L water	Year round	Cut stems should be stacked away from the exposed and treated rhizomes so these can be followed up on with future visits.

[1] Glyphosate concentration referred to in table above is 360g/L of active ingredient.