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The flora and vegetation of Dayrell Island, Herald Islets, northern Kermadec Island group

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Abstract
The flora, avifauna, lichenised mycobiota and vegetation of Dayrell I, northern Kermadec Is, is described based on a four-hour visit made there on 18 May 2011. Dayrell I has a flora and lichenised mycobiota of 80 taxa (one unidentified cyanobacterium, 10 marine algae, 21 lichens, four mosses, four ferns, and 40 flowering plants). Five vegetation associations are described including the first documented record of makatea from the Kermadec Is. The vegetation of Dayrell I was at the time of the visit recovering from the impact of Cyclone Bune which traversed the Kermadecs on 28 March 2011.

Keywords
Kermadec Is; Dayrell I; makatea; biota; vegetation associations; Cyclone Bune.

INTRODUCTION

Dayrell I (58 m a.s.l., 6.07 ha, 29°14′43.10″S, 177°51′26.14″W, Figs 1, 2) located 3.8 km NNE of Turtle Bay, Raoul I., is the northern most of the Herald Islets (the others of which are North, South and West Chanter, and in some accounts also Napier and Nugent (see Sykes 1977)). Although Dayrell I is briefly discussed (as part of the Herald Islets) by Sykes (1977) there has not been a specific account of its flora and vegetation published.

Whilst participating in the 2011 Auckland Museum Kermadec Biodiscovery expedition (Trnski & de Lange 2015) the senior author visited Dayrell I on 18 May 2011 in the company of two marine biologists. During that visit, lichenised mycobiota, flora and marine invertebrate specimens were collected, observations on the avifauna made, and rock samples, notes and images taken. Dayrell I, and nearby Napier I., Nugent, and the Chanters (which were also visited on the expedition), were found to support 3.54 ha of makatea, a hitherto unrecognised karst landform and ecosystem for the Kermadec Is and new to geopolitical New Zealand (de Lange 2011a). Prior to that visit the flora, fauna and vegetation of Dayrell I were investigated over two short visits in 1966 and 1984 by W.R. Sykes (pers. comm., December 2014). However, Sykes's notes from those visits were never published, though he did provide a summary listing of the vascular flora of that island (Sykes 1977). Aside from that listing it seems that nothing further has been published about the vegetation and flora of Dayrell I. Therefore, this paper provides an account of the flora, lichenized mycobiota, avifauna and vegetation of Dayrell I, as well as a description of the makatea.

GEOLOGY AND PHYSIOGRAPHY

The geology of Dayrell I has been described in detail by Brook (1998) who placed it and the nearby Chanters within his early Pleistocene-aged Herald Group, as two distinct formations, the Chanter and Dayrell Formations. The basal Chanter Formation Brook (1998) described as a submarine volcanogenic unit (comprising submarine lava flows, tephra and vent lithofacies on Dayrell), while the overlying Dayrell Formation he defined as a sedimentary, fossil-rich unit. Both units are exposed on Dayrell I, with the basal volcanogenic Chanter Formation forming roughly the bottom third of the island, and the Dayrell Formation the remainder (Fig. 3). It is the Dayrell Formation that includes *in situ* coral and limestone. The limestone is initially manifest on the lower slopes of the island as sporadic *in situ* coral heads and patch reefs perched on the underlying volcanogenic Chanter Formation. Further up the island the coral aggregates into a continuous encircling limestone composed of a coarse calcarenite comprising shells, eroded coral blocks and coral fragments. About a third of the limestone is buried by a cap of mantle-bedded airfall tephra that covers the upper 20 m or so of the island forming the summit cap (58 m a.s.l.).

The physiography of the island is precipitous. Aside from a small portion of the northern coastline Dayrell I is cliff girt. The cliffs of the southern, western and eastern sides of the island rise from the sea directly up to the summit. However, on the northern coastline the encircling cliffs are lower (30–35 m) and, due to erosion of the summit capping tephra, the limestone that forms the upper portion of the cliffs is exposed to the elements

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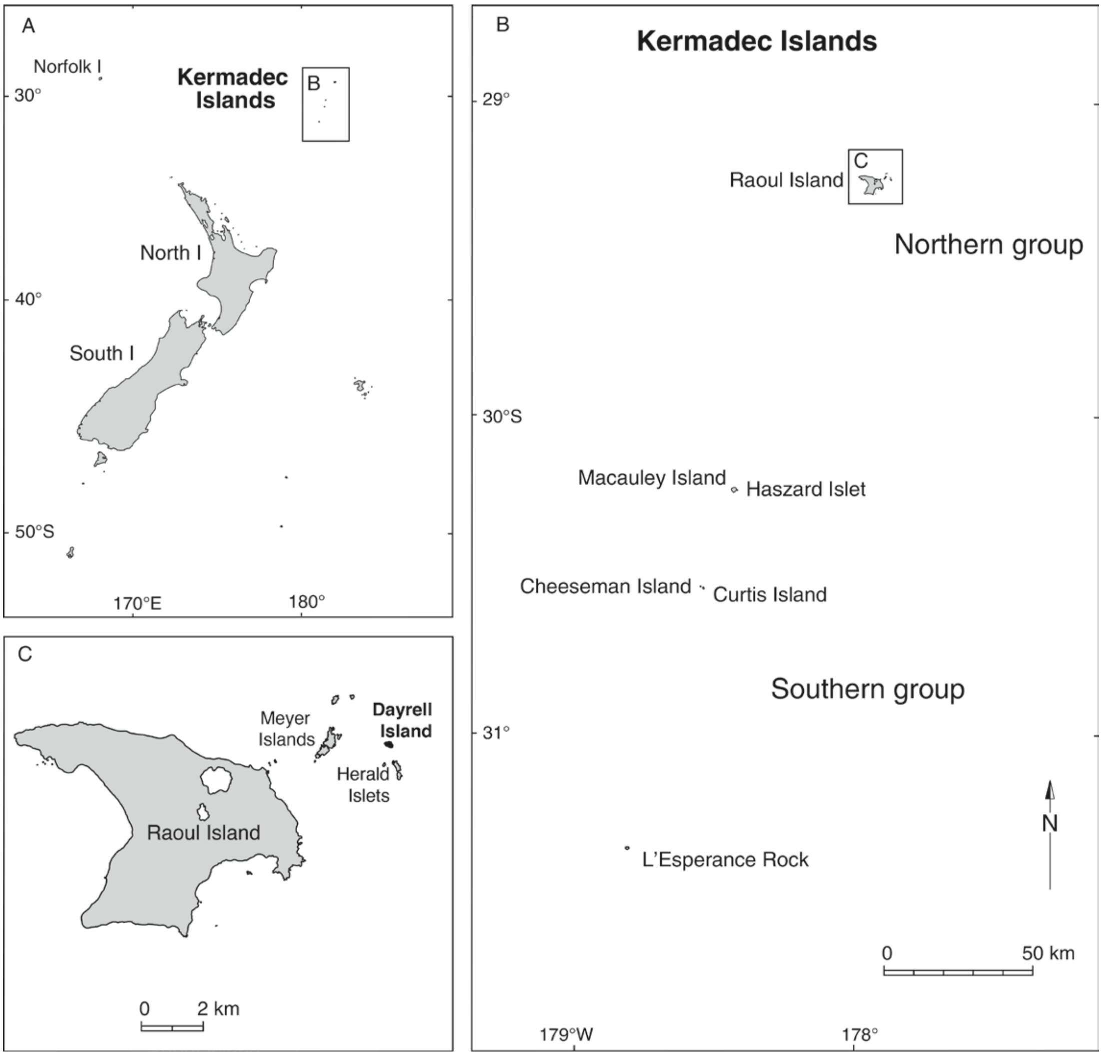

Figure 1. Location of Dayrell I within the Kermadec Islands group. A, location of the Kermadec Islands (B) with respect to New Zealand and Norfolk Island; B, the Kermadec Island group showing the Northern and Southern groups and location of Dayrell I (C); C, the location of Dayrell I in relation to Raoul I and adjacent smaller islands of the northern Kermadec group.

(Fig. 4); it is here that the karst landscape on which a distinct vegetation association known in the Pacific as 'makatea' (Mueller-Dombois & Fosberg 1998; Sykes 2016) has developed.

Makatea is described as a deeply dissected, pitted (in places razor sharp), porous, drought-prone, karst landscape (Mueller-Dombois & Fosberg 1998; Sykes 2016), which is often sparsely vegetated with low growing shrubs, vines, scrambling plants and herbs. On Dayrell I makatea occupies an area of 0.76 ha and is confined to the central northern two-thirds of the island. Here it is manifest as a miniature karst landscape, complete with sinkholes, and solution karren whose tops have often weathered into narrow razor-sharp turrets (Figs 5, 6). Makatea occupying a total area of 2.78 ha is also present on nearby Napier I (0.4 ha), Nugent (768 m^2) and the Chanters (North Chanter (1.4 ha), South Chanter (0.86 ha) and West Chanter (384 m^2) (de Lange 2011b,c). That makatea has not been reported previously for the Kermadec Is probably reflects that few ecologists have visited the Kermadec Is, and of those that have, they either did not make landfall on the islands supporting this landform, or if they had they did not seem to recognise it by this name. This omission is perhaps all the more understandable because the extent of makatea on the Kermadecs is minuscule (3.54 ha, 0.1% of the Kermadec Is total area), and all of it is confined to islands and islets that are very rarely visited by people. Nevertheless W.R. Sykes (pers. comm., December 2014) stated that he did recognise makatea on these islands but for various reasons failed to document it.

PREVIOUS BOTANICAL SURVEYS

Whilst it is likely that W.R.B. Oliver visited Dayrell I during his 10 month stay on the Kermadec Is (W.R. Sykes, pers. comm. December 2014) we can find no written account or herbarium specimens to prove this. The first known record of plants collected from Dayrell I that we could locate are those collections made by W.R. Sykes during his 1966 and 1984 visits. Although Sykes

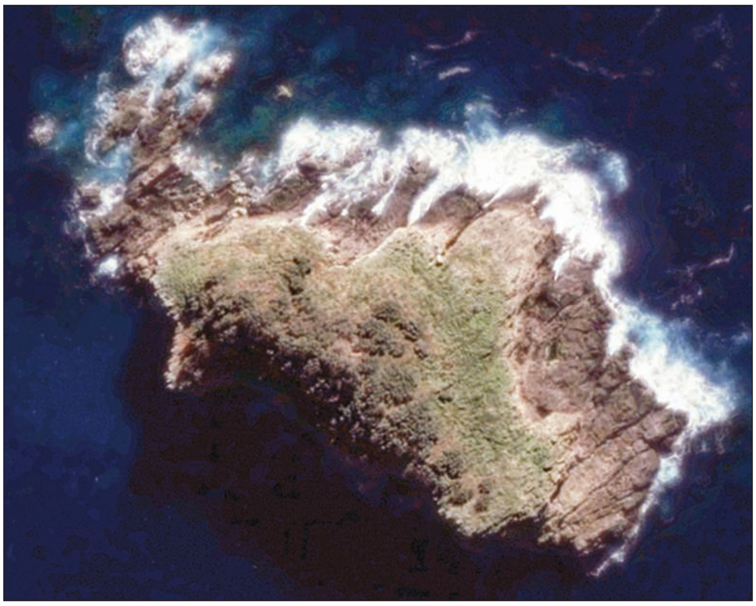

Figure 2. Dayrell I aerial image courtesy of the New Zealand Department of Conservation.

Figure 3. Dayrell as viewed from the north-eastern side of the island near the landing made on 18 May 2011. In this image the three main geological formations of the island (Brook 1998) can be seen; the shore platform and lower cliffs of the Chanter Formation and the limestone of the Dayrell Formation whose surface expression forms the makatea, which is partially overlaid by a cap of mantle-bedded airfall tephra on which the summit forest can be seen.

Figure 4. Dayrell I north-eastern cliffs composed of limestone, showing their bedding and pitted karstic surface which forms the makatea.

Figure 5. Makatea vegetation still recovering from the passage of Cyclone Bune – note the fronds of *Asplenium decurrens* growing in small sinkholes and dead *Cyperus insularis* and *Disphyma australe* subsp. *stricticaule.*

Figure 6. Makatea vegetation still recovering from the passage of Cyclone Bune showing masses of *Disphyma australe* subsp. *stricticaule* with numerous seedlings of *Senecio kermadecensis*, *Solanum americanum*, *S. nigrum* and *S. opacum*, and resprouting *Cyperus insularis*. Note nesting Kermadec petrels (*Pterodroma neglecta*).

collected only four species from Dayrell I he recorded a total of 17 indigenous taxa (Sykes 1977). While he did not formally report any naturalised taxa from the islands in his Kermadec Bulletin, Sykes (pers. comm. December 2014) observed six naturalised plants: five (*Erigeron bonariense*, *Dactylis glomerata*, *Lepidium didymum*, *Paspalum dilatatum* and *Symphyotrichum subulatum*) are accepted here as naturalised, while the sixth he noted, a grass *Digitaria setigera*, is treated here as indigenous. Aside from these vascular plants Sykes did not record or collect any algae, lichens or mosses from the island.

Other than Sykes's collections, notes and tabulation of the indigenous flora of Dayrell I (Sykes 1977, Table 8) there seem to have been no other published accounts of the flora or vegetation.

METHODS

On the morning of May 18, 2011, the senior author spent four hours on Dayrell I. The landing was made on the northern side of the island where a series of small ledges and a narrow cleft exists within the central encircling cliffs, so enabling easy access to the central vegetated portion of the island.

Marine algae were collected into a solution of 1% formalin in seawater, and samples were retained in this preservative until they could be air dried back in New Zealand. Mycobiota and bryophytes were collected into paper bags and envelopes, and air dried in transit to New Zealand on the *RV Braveheart* (de Lange 2011a). Vascular plants were lightly pressed in newspaper, wedged between cardboard, then lightly bound, placed in stout plastic bags, and preserved by pouring a solution of one-part ethanol to two parts acetic acid over them. In this way, they could be stored wet until they were able to be air dried back in New Zealand. These precautions were undertaken both to reduce biosecurity risks to New Zealand and to prevent specimens rotting in the humid weather conditions experienced during fieldwork on the Kermadec Is (de Lange 2011a-d).

Field observations on the avifauna, mycobiota, flora, vegetation associations and geology were recorded in a notebook and digital images taken to aid in later ecological interpretation. As time was limited qualitative rather than quantitative data were used to compile the vegetation associations recognised here, using the system described by Atkinson (1985).

Voucher specimens collected during the visit to the island are lodged in Auckland Museum (AK) and Unitec Institute of Technology Herbarium (UNITEC). Older voucher specimens in the Allan Herbarium, Landcare Research (CHR) were also examined. Herbarium acronyms follow Thiers (2020).

RESULTS

Mycobiota and Flora

A total of 80 taxa were recorded for Dayrell I (Appendix 1) and 75 of these are supported by herbarium vouchers in AK, CHR and UNITEC. The collections comprised:

one unidentified cyanobacterium, ten marine algae, 21 lichens, four mosses, four ferns, and 40 flowering plants. The collected specimens were lodged in the Auckland Museum Herbarium (AK) and the lichens at UNITECH. Only the cyanobacterium remain undetermined to family or lower rank, while of the ten marine algae collected (representing six taxa) two specimens were tentatively placed within *Porphyra sens.lat*. (at genus rank only) and *Clymene* (as *C. ?coleana*), while two more represent undetermined species of *Sargassum* and *Ulva* respectively.

Lichens, although widespread and common, were poorly sampled due to time constraints. Of the saxicolous lichens, determinations of several genera, particularly *Buellia*, proved especially difficult. In the case of *Buellia*, specimens collected while mostly approaching the descriptions and names available in Galloway (2007), often differed in spore length and width or thallus colour and it is quite likely that they represent other species from neighbouring island groups in the South Pacific or even new species (see Elix & de Lange 2017). Nevertheless, it is hoped that by documenting the presence of this genus on the island (and indeed the Kermadec Is), this may encourage further study of the collections made by those engaged in worldwide revisions of these lichens. The canopy branches of the island's summit forest of Kermadec pōhutukawa (*Metrosideros kermadecensis*) mostly supported a range of Parmeliaceae taxa. Of these, *Parmotrema cetratum* and *P. reticulatum* were especially conspicuous. Also noted on these trees were *Halegrapha mucronata*, *Heterodermia tremulans*, *H. speciosa*, *Ramalina celastri*, *R. leiodea*, *R. exiguella*, *R. pacifica*. Although a full assessment of the lichens present on the limestone outcrops of the makatea was not possible due to time constraints, *Ramalina microspora* was locally common on some exposures of this rock (for a full account of the Kermadec Is *Ramalina* see de Lange & Blanchon 2015).

Avifauna

The most commonly encountered bird was the Kermadec petrel (*Pterodroma neglecta*), numerous individuals of which were seen roosting in trees or on the ground (Figs 6, 7), or attending their nests (usually a slight scrape or hollowed out portion of vegetation (and then most often *Cyperus insularis*) in which a solitary egg had been deposited). Although Kermadec petrels were found throughout the makatea and forested portion of the island they were most common in the makatea. Less frequently seen were wedge-tailed shearwaters (*Puffinus pacificus pacificus*); mostly mature adults roosting on the ground within the forest, but also sparingly down-covered, moulting juvenile fledglings. Several adult red-tailed tropic birds (*Phaethon rubricauda*) were noted in shaded limestone overhangs, while a pair of Tasman boobies (*Sula dactylatra tasmani*) were seen roosting on the jagged limestone. Within the makatea and forest occasional Kermadec kākāriki (*Cyanoramphus

Figure 7. Dayrell I summit forest ground cover dominated by purslane (*Portulaca oleracea*) through which grew *Cotula australis*, *Digitaria setigera*, *Lachnagrostis littoralis* subsp. *littoralis*, *Lepturus repens Senecio kermadecensis* and *Solanum* spp. The green algae on the rocks is a species of *Prasiola*. Note nesting Kermadec petrels (*Pterodroma neglecta*).

novaezelandiae cyanurus) were seen, notably a pair scavenging the carcass of a Kermadec petrel. Similar feeding observations were also made from North Meyer a few days earlier (de Lange 2011b). Within the summit forest a pair of spotless crakes (*Porzana tabuensis*) were also encountered. These birds are now abundant on Raoul I. As the habitat on Dayrell I is limited it is likely that these birds have a transitory presence there rather than a permanent one. Also observed was a solitary great frigate bird (*Fregata minor*) circling the island summit forest. This was possibly the same bird that was noted on 17 May 2011 circling the summit of nearby Napier I.

Cyclone Damage

As with elsewhere in the Kermadec Is the vegetation cover of Dayrell I had been severely impacted by the passage of Cyclone Bune on the 28 March 2011 (de Lange 2011c, d, e; de Lange 2015a, b). At the time of the 18 May 2011 visit to Dayrell I 44 days had elapsed since the cyclone, so storm damage was still very evident, the cyclone leaving large areas of exposed, loose, eroding soil, wind blasted, defoliated (or nearly so) shrubs and trees and wind thrown Kermadec ngaio (*Myoporum rapense* subsp. *kermadecense*) and pōhutukawa (*Metrosideros kermadecensis*). Recovery from this destruction was evident by the numerous seedlings (mostly at the cotyledon stage) of *Cotula australis*, *Disphyma australe* subsp. *stricticaule*, *Chenopodium* spp. (cotyledon stage), *Gamochaeta* (cotyledon stage), *Parietaria debilis*, *Senecio kermadecensis*, *Solanum* spp. (cotyledon stage), and various grasses (*Digitaria setigera* and *Lachnagrostis littoralis* especially), while both ngaio and pōhutukawa were covered in epicormic growth. No cyclone damage was evident in the *Cyperus insularis* but many of the scrambling plants, such as *Canavalia rosea*, *Chenopodium trigonon* and *Disphyma* were >80% dead.

Vegetation Associations

The vegetation of Dayrell I appears to be naturally restricted to the upper portion of the island (Fig. 8). The area occupied roughly corresponds to the surface expression of the Dayrell Formation (Brook 1998). It

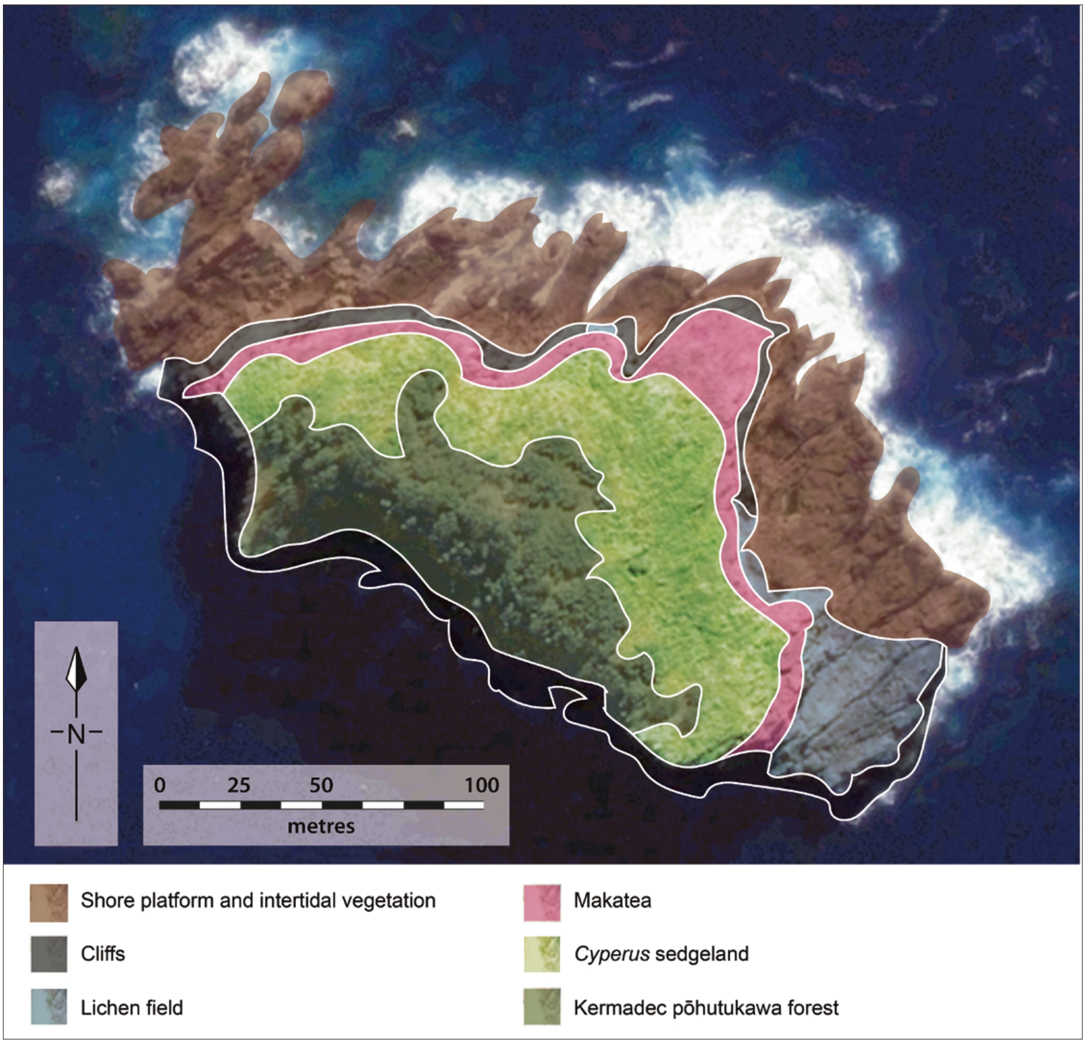

Figure 8. Vegetation associations of Dayrell I as discussed in text. Base image (see Fig. 2) courtesy of the New Zealand Department of Conservation.

is also likely that the extent of the vegetated area seen during the visit had been affected and reduced by the passage of Cyclone Bune. Six vegetation associations (Fig. 8) were observed in the field using the vegetation classification system of Atkinson (1985).

1. Shore Platform and Intertidal Vegetation

Because of strong surges experienced during the landing on Dayrell I a thorough study of the intertidal vegetation was impractical. Nevertheless a few collections and observations were made. The most commonly encountered seaweed was a species of *Sargassum* that formed yellow-brown, pliant, leathery tufts up to 60 mm tall and as much wide. This *Sargassum* is commonly seen on the exposed shores of the Kermadec Is, but it has yet to be identified below genus rank (W.A. Nelson, pers. comm. August 2011). The only associates of the *Sargassum* noted were a few minute thalli of a purple-pink seaweed (possibly a species of *Porphyra*), what may be *Clymene coleana* and in one place *Osmundaria colensoi*. Here too on the tops of Kermadec limpet (*Scutellastra kermadecensis*) exposed along the surge zone grew tufts of *Cladophora prolifera*. Within this zone where water was sweeping across the rocks and/or where pools had formed within a series of depressions and collapsed tunnels in the exposed lava, grew a sparse algal flora of three species: *Pterocladiella capillacea*, *Martensia fragilis* and *Caulerpa racemosa*. Higher up the island, in a series of shallow, brackish pools grew two filamentous 'algae', a species of *Ulva* and an undetermined cyanobacterium (W.A. Nelson, pers. comm. August 2011).

2. Cliffs

The cliff faces of Dayrell, particularly those on the southern side of the island, supported a distinct vegetation dominated by *Cyperus insularis*, *Lachnagrostis littoralis*, *Disphyma australe* subsp. *stricticaule*, *Chenopodium* spp. (which species could not be determined safely), augmented by occasional specimens of *Wahlenbergia vernicosa*, *Sonchus kirkii* and, especially in sites used as roosts by red-tailed tropicbird, *Digitaria setigera*, *Senecio kermadecensis* and *Polycarpon tetraphyllum*. Nearer the summit forest on the west and south-western facing cliffs occasional tufts of *Poa polyphylla* were also noted. This species, though common on Raoul I and present on Macauley I (de Lange 2015a), was otherwise only seen in these outer islands on the Meyers.

3. Lichenfield

On the north-eastern and eastern side of the island, where the Dayrell Formation overlies the volcanogenic Chanter Formation, the contact is delineated by a limestone cliff of some 2–6 m high. Here a diverse lichenfield was noted, however due to time constraints few specimens were collected. Of those seen, the most visually conspicuous on account of its bright orange-yellow colour was the foliose *Dufourea ligulata*, through which crustose 'dustings' of dark orange-red and yellow *Caloplaca* species (mostly *C. acheila*, *C.* cf. *lutea*, and *C.* cf. *sublobulata*) were commonly seen. In these same sites grew silvery-grey 'scabs' of *Buellia* cf. *stellulata*, and *Ramalina microspora*, while on the underlying igneous rock occasional specimens of *Buellia cranwelliae* and numerous patches of *B.* cf. *stellulata* were noted.

4. Makatea

Although much of the vegetation covering the makatea of Dayrell I (Figs 5, 6, 9, 10) had been severely damaged by Cyclone Bune it was evident that the usual vegetation covering this karst landscape would have been one dominated by the scramblers *Disphyma australe* subsp. *stricticaule*, *Canavalia rosea*, *Chenopodium triandrum*, *C. trigonon* subsp. *trigonon*, *Tetragonia tetragonoides*, and the vine *Sicyos mawhai*. Scarce associates of this 'scrambler' vegetation also included *Ficinia nodosa*, *Hypolepis dicksonioides*, *Scaevola gracilis* and *Ipomoea pes-caprae* subsp. *brasilense*. Shrubby plants within this vegetation included occasional *Coprosma petiolata* and numerous Kermadec ngaio. On the razorbacks and solution karren the fern *Asplenium decurrens* was the dominant vascular plant, reaching its greatest dominance on the sides of the solution flutes and runnels formed within the karrenfeld, and also at their bases where dark red-black rendzina soil has accumulated. Also growing on the limestone, though rather uncommonly, was the moss *Syntrichia phaea* whose colonies appeared as small black balls on the exposed limestone. In the runnels and miniature dolines, and on the associated rendzina the sedge *Cyperus insularis* was locally common. The most commonly encountered herb on the makatea, particularly in the limestone runnels and around petrel nests, was *Senecio kermadecensis* (though mostly seen during the visit as 10–30 mm tall seedlings) followed by *Cotula australis*. Less commonly seen, though their abundance was undoubtedly affected by the season and cyclone damage, was *Lepidium didymum*, *L. oleraceum*, purslane (*Portulaca oleracea*), *Solanum americanum*, *S. nigrum*, *S. opacum* and a single *Symphyotrichum subulatum*. Seedlings of *Parietaria debilis*, *Erigeron bonariensis* and an unidentified species of *Gamochaeta* were also occasionally observed on areas of eroded rendzina. The makatea also supported grasses of which the most commonly encountered were *Digitaria setigera*, *Eleusine indica*, *Lachnagrostis littoralis* subsp. *littoralis*, *Lepturus repens* and *Paspalum dilatatum*. The *Digitaria* and *Paspalum* were especially common where petrels and red-tailed tropic birds (*Phaethon rubricauda*) had been or were nesting.

5. *Cyperus insularis* sedgeland

Upslope of the makatea, where soil erosion and colluvium from the upper summit forest has covered the limestone (Fig. 10), *Cyperus insularis* is the dominant plant forming its own vegetation association. At the time of the field survey associated species were still in recovery from Cyclone Bune and so undoubtedly under-represented; those seen included occasional Kermadec ngaio and *Coprosma petiolata*, *Sicyos mawhai*, *Senecio kermadecensis* and *Solanum* spp. Much of this area was also occupied by nesting Kermadec petrels, whose nesting activities left patches of dead *Cyperus* or bare earth.

Figure 9. Makatea vegetation recovering from Cyclone Bune. It comprises *Cyperus insularis*, *Disphyma australe* subsp. *stricticaule* and occasional shrubs of Kermadec ngaio (*Myoporum rapense* subsp. *kermadecense*) and *Coprosma petiolata* in places where rendzina soil has accumulated to depths of up to 1 metre and the vegetation is sheltered by rock towers, sink holes and dolines. The shrubs were often festooned with *Canavalia rosea*, *Scaevola gracilis* and *Sicyos mawhai*.

Figure 10. View from summit slopes of Dayrell I looking north across *Cyperus* sedgeland that has developed on the colluvium that has crept down slope from the summit forest, and into the makatea vegetation.

6. Kermadec pōhutukawa forest

Above the makatea is a broad cap of mantle-bedded airfall tephra (Brook 1998). This area is entirely covered by an open, windshorn Kermadec pōhutukawa 'forest' (in places up to 6 m tall) (Figs 11, 12), through which occasional Kermadec ngaio and a single *Melicope ternata* were encountered. The understorey of this forest was sparse, comprising mainly scattered shrubs of *Coprosma petiolata* and, in one place, a single *C. repens*. Much of the ground cover was bare earth, a condition attributed in part to the effects of Cyclone Bune, but mostly to the ground nesting Kermadec petrels which dominated this area and whose nesting habits keep the vegetation sparse. Nevertheless, the most commonly encountered herbs and grasses in this area were purslane (Fig. 7), *Solanum* spp. (mostly cotyledon stage), *Digitaria setigera*, *Lachnagrostis littoralis* subsp. *littoralis*, *Lepturus repens*, and occasional tufts of *Poa polyphylla*. *Senecio kermadecensis* though present, was mostly found on the exposed south-eastern portion of this vegetation association, particularly along the contact between limestone and airfall tephra. A few mostly spent seeding plants of *Lepidium oleraceum* were also present in this vegetation, growing amongst purslane within an active Kermadec petrel nesting ground. Another uncommon associate of the purslane ground cover was the fern *Nephrolepis brownii*. In places, the bare earth was covered in patches of *Bryum dichotomum*. Here too grew *Fissidens leptocladus* and, in shaded places, patches of an unidentified filamentous green alga and another minute, fruticose one, possibly a species of *Prasiola*. This latter entity was especially common in areas where guano had accumulated. On the Kermadec pōhutukawa trunks and branch undersides the moss *Syrrhopodon armatus* was also common, and in one place a small patch of *Pyrrosia serpens*, a new fern record for the Kermadec Is grew (Brownsey *et al*. 2020).

DISCUSSION

Overall the indigenous vascular flora of Dayrell has grown from the 18 taxa recognised by Sykes to 43, an increase of 139% in the 34 years that have elapsed since Sykes's publication (Sykes 1977). As he did not give a complete listing of the exotic naturalised taxa a detailed analysis of the changes in the vascular flora between his visits and this one is difficult. Nevertheless, using his unpublished notebooks detailing visits made to the island

Figure 11. Interior of summit forest of Dayrell I The dominant tree here, Kermadec pōhutukawa (*Metrosideros kermadecensis*) is in the process of recovering from the effects of Cyclone Bune.

Figure 12. Interior of summit forest of Dayrell I looking west toward Raoul I. The dominant tree here is Kermadec pōhutukawa (*Metrosideros kermadecensis*), The forest is just starting to recover from the passage of Cyclone Bune. Note the numerous seedlings covering the exposed soil, mostly *Cotula australis* and *Senecio kermadecensis*; the mosses covering the exposed rocks are *Bryum dichotomum* and *Fissidens leptocladus*.

in 1966 and 1984 the following naturalised plants were recorded: *Digitaria setigera*, *Eleusine indica*, *Lepidium didymum* (as *Coronopus didymum*), *Polycarpon tetraphyllum* and *Symphyotrichum subulatum* (as *Aster subulatus*). All of these taxa were found in 2011, though of them we now regard *Digitaria setigera* as indigenous (see de Lange *et al*. 2013a; de Lange *et al*. 2018).

With respect to the naturalised vascular flora, in 2011, a further seven taxa were recorded, and, allowing for the change in biostatus for *Digitaria setigera* discussed below, these additions represent a 175% increase within the naturalised vascular flora of the island. Of the new additions to the flora, Sykes (1977) considered *Dactylis* to be very scarce on Raoul I, as indeed it still is, whilst *Paspalum dilatatum* was then noted only from Raoul and The Meyer Is. The spread of *Paspalum*, whose sticky fruits are so readily moved by birds, to Dayrell I is not surprising. The spread of *Dactylis* may also be bird assisted, possibly via movement of Kermadec kākāriki between Raoul and the Herald Islets.

Only seedlings of *Gamochaeta* were seen in 2011, and these failed to survive cultivation back in New Zealand. Vegetatively, the young plants most closely resembled *Gamochaeta pensylvanica* and *G. subfalcata*, which are the two most likely species to occur on Dayrell I, as both are common on nearby Raoul I (Sykes 1977, as *Gnaphalium pensylvanicum* Wild. and *G. subfalcatum* Cabrera).

The presence of purslane is interesting. Sykes (1977) considered that this species was still in an active expansion phase on the Kermadec Is, being reported by him only from Raoul I and North Meyer in the northern Kermadec Is. By May 2011 this species was now present on both Meyers, Napier, Egeria Rock (de Lange 2014), the other Herald Islets visited and Cheeseman I (de Lange 2015b), testimony to its ease of dispersion as was hinted at by Sykes (1977: 131).

Of the remaining naturalised plants, Sykes (1977) noted that *Erigeron bonariensis* and *Sonchus oleraceus* were present on all the Herald Islets he visited, yet neither species was recorded during his 1966 and 1984 visits to Dayrell I. He did not record *Solanum nigrum* from the northern Kermadecs group at all (Sykes, 1977).

Of the indigenous vascular plants recorded here, a few are either: new records for the Herald Islets and/or the northern Kermadec Islands group; confirmations of historically collected taxa (often with vague location details) that were accepted by Sykes (1977); or represent significant range extensions. Further, the naturalised status of one species, *Digitaria setigera,* awarded by Edgar & Connor (2010) is here questioned - see below.

Probably the most important of these indigenous plant records is *Lepturus repens*. This widespread tropical grass, which reaches its world southern limit on the Kermadec Is (Edgar & Connor 2010; Murray & de Lange 2013), was initially recorded from most of the Herald Islets and The Meyers in Table 8, by Sykes (1977: 191, Table 8) despite the implication (Sykes 1977: 171) that it was only recorded from one site on North Chanter. This error was later addressed by Sykes & West (1996) who confined this species to North Chanter and noted that those plants matched var. *cinereus* (Burcham) Fosberg, because 'the Kermadec plant is semi-prostrate'. Subsequent study by the senior author in Auckland of live plants collected from North Chanter found that the 'semi-prostrate' growth habit was soon lost in cultivation. Additional 2011 collections of this species from North Chanter, Dayrell and Napier Is were of plants that had an erect, tufted growth habit. Therefore, Murray & de Lange (2013) suggested that New Zealand plants are better referred to *L. repens sens. lat*. The discovery of *Lepturus* on the other islands and islets where Sykes had initially reported it in (Sykes 1977: 191, Table 8) suggests that his original observations, subsequently refuted in Sykes & West (1996), were probably correct.

Lepidium oleraceum, treated as *L. oleraceum* var. *frondosum* Kirk, was noted by Sykes (1977) as only present in the southern Kermadec Island group (Curtis and Cheeseman Is). *Lepidium* was subsequently reported from Macauley I and Hazard Islet (Barkla *et al*. 2008; de Lange 2015a; de Lange *et al*. 2013b). Recently de Lange *et al*. (2013b) referred most of the southern Kermadec Islands group *Lepidium* to a new, Kermadec endemic species *L. castellanum* de Lange et Heenan. In the same publication, they also treated *L. oleraceum* var. *frondosum* as a synonym of *L. oleraceum,* a species that they also accepted from the Kermadec Is, recording it from Dayrell and Napier Is in the northern Kermadec Islands group, and from Curtis I and L'Esperance Rock in the southern Kermadec Islands group.

In this paper, we follow de Lange *et al*. (2013a) and treat *Digitaria setigera* as indigenous. As the basis for that change in biostatus was not elaborated by de Lange *et al*. (2013b) the reasoning is given here. *Digitaria setigera* was initially treated as indigenous to the Kermadec Is by Cheeseman (1888, 1906, 1925) and Oliver (1910). It was Sykes (1977: 166–167, as *D. pruriens* (Trin.) Büse) who first treated this grass as naturalised. However, his comments about it being suited to long distance avian dispersal, its close association on the Kermadec Is with sea bird nesting sites and other general comments about its indigenous status in the Tropical Pacific implies that he may also have considered it indigenous to the Kermadecs. In this respect it is notable that Veldkamp (1973), who synonymised *D. pruriens* with *D. setigera*, included the Kermadec Is in this species' natural distribution without further comment. Irrespective, Edgar & Connor (2010) followed Sykes (1977) and Edgar & Shand (1987) in treating this grass as naturalised though without providing any justification for their decision. Beyond the speculation by Whistler (1995) that *D. setigera* might possibly be an ancient Polynesian introduction to the Pacific, he and others (Green 1994; Whistler 1995; Edgar & Connor 2010; R.O. Gardner, W.R. Sykes & W.A. Whistler, pers. comms. December 2013) all regard this grass as indigenous to tropical Asia, Malesia, the Pacific Islands and northern Australia. With respect to the Kermadec Is, the presence of this species on the nearby Norfolk I group, where Green (1994) considered it indigenous, strengthens the argument that *D. setigera* is also indigenous to the Kermadecs. Outside the Kermadecs within the New Zealand Botanical Region (Trnski & de Lange 2015), Edgar & Connor

(2010) noted that *D. setigera* had been collected in 1840 from the Bay of Islands by members of the U.S Exploring Expedition. This record was accepted by Edgar & Connor (2010) as further evidence of the naturalised status of this grass to the New Zealand Botanical Region. Gardner (2020) however, has suggested that this record, the sole one reported from New Zealand, is the result of a labelling error, noting that such errors on specimens collected during that expedition are 'all too common'. The only anomaly in the South Pacific occurrences of this grass seems to be Lord Howe I from where *D. setigera* is believed absent (Green 1994). Whilst its absence from there is unexpected this does not preclude an indigenous status in the adjacent island groups. Further, grasses are notoriously under collected and/or overlooked, so its apparent absence from Lord Howe may simply reflect that no one has yet found it there. Regarding decisions on biostatus, Heenan *et al*. (2009) noted the general failure of New Zealand botanists to fully explain their biostatus decisions, which they argue has resulted in the inappropriate relegation of a number of indigenous 'weedy' plants to 'naturalised' status. In this respect Sykes's observations of *D. setigera* on the Kermadecs, notably that it is 'associated with bird colonies' of the more remote outer islands in the northern Kermadecs, and that its exact distribution on Raoul I was unclear due to field confusion there with the more common and undeniably naturalised *D. ciliaris* (Retz.) Koel (Sykes 1977: 167) tend to argue for an indigenous status. In fact, nothing concrete was ever offered by Sykes (1977) to justify the subsequent naturalised status he suggested and which was then allotted to this species by Edgar & Connor (2010).

Coprosma repens and *Tetragonia implexicoma* (as *T. trigyna* Banks et Solander) were accepted for the Kermadecs by Sykes (1977) based on earlier historical records only. During 2011 both species were subsequently collected from the southern Kermadec Islands group (de Lange 2015a, b). In the northern Kermadec Islands group *C. repens* was previously known only from one collection made from the 'east coast of Raoul' by Cheeseman (Sykes 1977: 138). The discovery of this species on Dayrell, albeit as a single individual, supports the statement made by Sykes (1977) that Cheeseman's record was valid, and it also suggests that this species is probably present elsewhere in the northern Kermadec Islands group where it may have been overlooked through field confusion with the superficially similar *C. petiolata* (see comments by Sykes 1977). Similarly, Sykes (1977: 75) noted that *T. implexicoma* (as *T. trigyna*) had been collected from the 'north coast of Raoul' by Thomas Cheeseman but that he had not seen it there himself. While there seem to be no further records of that species from Raoul I, its discovery on Dayrell I suggests that it may be elsewhere in the northern Kermadec Island group.

Chenopodium triandrum is a new record for the Kermadec Is. As *Rhagodia triandra* (G. Forst.) Aellen this species had been recorded from the Kermadec Is by Sykes (1977). Later Sykes & West (1996) attributed the seed record of *C. allanii* Aellen and collections of *C. triandrum* (as *Rhagodia triandra*) accepted by Sykes (1977) to *Einadia trigonos* (Schult.) Paul.G. Wilson subsp. *trigonos*, which is here treated as *C. trigonon* Schult. subsp. *trigonon*. While *C. trigonon* subsp. *trigonon* is very common on most of the Kermadec Is (Sykes & West 1996), it is now evident that *C. triandrum* is also present, though only it would seem, on the Herald Islets, and Napier and Nugent. On none of these islands is it common, though as it often grows with the superficially similar *C. trigonon*, it may be more abundant, because without careful inspection it is easily mistaken for the other species.

The discovery of the fern *Pyrrosia serpens* on Dayrell I is also noteworthy. The presence of this species on the Kermadec Is was documented in detail by Brownsey *et al*. (2020). This is the first record from the Kermadec Is; all other *Pyrrosia* herbarium specimens seen from there to date are *P. elaeagnifolia*. On Dayrell I *Pyrrosia serpens* was collected as a low epiphyte on the basal portion of the trunk of a *Metrosideros kermadecensis* within the summit forest. Its discovery on the Kermadec Is extends its southward range from its previous reported southern limit of Pitcairn I (25º 04´S) to 29º 15´S on Dayrell I

Sykes (1977) did not provide a detailed account of the distribution of the bryophyte and lichen taxa he reported from the Kermadec Is, and they are missing from his Table 8. Therefore, we cannot determine any changes in the diversity and distribution of bryophytes and lichens between Sykes's visits to Dayrell I and the results reported here.

Of the mosses recorded from Dayrell I, two of these (the *Bryum* and *Fissidens*) are also found on the larger Meyer Is where they are common (de Lange & Beever 2015). It is surprising that *Syrrhopodon armatus,* so common on Dayrell, was not located on the Meyers (de Lange & Beever 2015). On Raoul I this species is very common in mid-slope, dense Kermadec pōhutukawa forest, so why it should be absent from the more extensive and denser forest cover of The Meyers yet present in the smaller, more open forest of Dayrell is unclear. The most plausible explanation is that *Syrrhopodon* is more likely overlooked on The Meyers rather than genuinely absent. Although *Syntrichia phaea* was erroneously recorded from the Kermadec Islands by Sykes (1977) and Beever *et al*. (1996), it was subsequently discovered on the islands (de Lange & Beever 2015), with records from Macauley and Dayrell Is. Interestingly this basicolous species was not recorded in 2011 from the makatea of the adjacent Chanters and Napier I. It may be genuinely absent from those islands, though it seems more likely that it was overlooked.

At present 91 lichenized fungi have been recorded for the Kermadecs Is (Sykes 1977; Galloway 2007; de Lange & Galloway 2015; de Lange 2014; de Lange 2015c, de Lange & Blanchon 2015; Elix & de Lange 2017). Of the 21species recorded here from Dayrell I, seven (*Buellia cranwelliae*, *Caloplaca* cf. *lutea*, *Halegrapha mucronata*, *Lecidiella elaeochroma*, *Parmotrema austrocetratum*, *P. cetratum*, *P. tinctorum* and *Teloschistes flavicans*) are additions to the documented lichens of the Kermadec Is (see above references). Even with these additions it should be stressed that the lichen mycobiota of Dayrell I remains poorly investigated. As with New Zealand (see Marshall *et al*. 2020 and references therein), the future focus of lichen collecting on the Kermadecs should be with crustose taxa, as these remain poorly collected from that island group and are where the greatest worldwide lichen diversity is anticipated to occur (Sipman & Aptroot 2001).

Finally, this paper, based as it is on four hours of dedicated collecting on a rarely visited island within the Kermadec Island group, highlights the importance of undertaking regular inspections of the outer islands, islets and rock stacks of the Kermadec archipelago. Prior to this visit there had been only two confirmed specialist botanical visits to Dayrell I in 1966 and 1984. Considering the importance of Dayrell I as a key site for such threatened plants as *Lepidium oleraceum* and *Senecio kermadecensis* and the ongoing risk of weed invasion from the nearby Meyers, this is insufficient. Further, as this paper has shown, the biota of Dayrell I is constantly changing. Therefore, to enable relevant management of the islands regular visits are needed to ensure that data available for the island are not antiquated.

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APPENDIX 1: Algae, vascular plants and lichenised mycobiota recorded from Dayrell Island

*	denotes taxa naturalised to the Kermadec Islands
AK	Auckland War Memorial Museum Herbarium
CHR	Allan Herbarium, Landcare Research
UNITEC	Unitec Herbarium

	Noted by Sykes (1977)	Family	Abundance	Voucher
Rhodophyta (5)				
Clymene coleana (W.A.Nelson) W.A.Nelson	No	Bangiaceae	uncommon	AK 327418
Martensia fragilis Harv.	No	Delesseriaceae	uncommon	AK 356856
Osmundaria colensoi (Hook.f. et Harv.) R.E.Norris	No	Rhodomelaceae	uncommon	AK 356523
?*Porphyra* sp.	No	Bangiaceae	uncommon	AK 327420
Pterocladiella capillacea (S.G. Gmel.) Santel et Hommers.	No	Gelidaceae	uncommon	AK 356522

	Noted by Sykes (1977)	Family	Abundance	Voucher
Chlorophyta (4)				
Caulerpa racemosa (Forssk.) J.Agardh	No	Caulerpaceae	uncommon	
Cladophora prolifera (Roth) Kuetz.	No	Cladophoraceae	common	AK 356536
Prasiola sp.	No	Prasiolaceae	common	AK 356606
Ulva sp.	No	Ulvaceae	abundant	AK 327416
Bryophytes (4)				
Bryum dichotomum Hedw.	No	Bryaceae	abundant	AK 326902
Fissidens leptocladus Rodway	No	Fissidentaceae	uncommon	AK 356604
Syntrichia phaea (Hook.f. et Wilson) R.H. Zander	No	Pottiaceae	uncommon	AK 326906
Syrrhopodon armatus Mitt.	No	Calymperaceae	abundant	AK 326907
Pteridophytes (4)				
Asplenium decurrens Wild.	Yes	Aspleniaceae	common	AK 356560
Hypolepis dicksonioides (Endl.) Hook.	No	Dennstaedtiaceae	one plant	AK 356403
Nephrolepis brownii (Desv.) Hovenkamp et Miyam.	No	Nephrolepidaceae	uncommon	AK 326587
Pyrrosia serpens (G. Forst.) Ching	No	Polypodiaceae	uncommon	AK 356559
Spermatophytes (40)				
Monocots II – Commelinids (9)				
Cyperus insularis Heenan et de Lange	Yes	Cyperaceae	abundant	AK 356857
Ficinia nodosa (Rottb.) Goetgh., Muasya et D.Simpson	Yes	Cyperaceae	uncommon	AK 356307
**Dactylis glomerata* L.	No	Poaceae	one plant	AK 356525
Digitaria setigera Roem. et Schult.	No	Poaceae	abundant	AK 326642
**Eleusine indica* (L.) Gaertn.	No	Poaceae	common	AK 326640
Lachnagrostis littoralis (Hack.) Edgar subsp. *littoralis*	Yes	Poaceae	common	AK 356557
Lepturus repens (G. Forst.) R.Br.	No	Poaceae	uncommon	AK 326590
Poa polyphylla Hack	Yes	Poaceae	uncommon	AK 356561
**Paspalum dilatatum* Poir.	No	Poaceae	uncommon	AK 356526
Core Eudicots (31)				
**Conyza bonariensis* (L.) Cronq.	No	Asteraceae	uncommon	AK 356528
Cotula australis (Spreng.) Hook.f.	Yes	Asteraceae	abundant	AK 356521
**Gamochaeta* sp.	No	Asteraceae	uncommon	
Senecio kermadecensis Belcher	Yes	Asteraceae	abundant	AK 326645
Sonchus kirkii Hamlin	No	Asteraceae	uncommon	AK 356520
**Sonchus oleraceus* L.	No	Asteraceae	uncommon	AK 356527
**Symphyotrichum subulatum* (Michx.) G.L.Nesom	No	Asteraceae	one plant	AK 326647
Disphyma australe subsp. *stricticaule* Chinnock	Yes	Aizoaceae	abundant	
Tetragonia implexicoma (Miq.) Hook.f.	No	Aizoaceae	uncommon	AK 356309
Tetragonia tetragonoides (Pall.) Kuntze	Yes	Aizoaceae	abundant	AK 326641
Chenopodium triandrum G.Forst.	No	Amaranthaceae	uncommon	AK 356407
Chenopodium trigonon Schult. subsp. *trigonon*	Yes	Amaranthaceae	common	AK 326644
**Lepidium didymum* L.	No	Brassicaceae	uncommon	AK 326646
Lepidium oleraceum G. Forst. ex Sparrm.	No	Brassicaceae	one plant	AK 326586
Wahlenbergia vernicosa J.A.Petterson	No	Campanulaceae	uncommon	AK 356558
**Polycarpon tetraphyllum* (L.) L.	No	Caryophyllaceae	abundant	AK 356537

	Noted by Sykes (1977)	Family	Abundance	Voucher
Ipomoea pes-caprae subsp. *brasiliensis* (L.) Ooststr.	No	Convolvulaceae	one plant	AK 326638
Sicyos mawhai I.Telford et P. Sebastian	Yes	Cucurbitaceae	common	AK 326639
Canavalia rosea (Sw.) DC.	No	Fabaceae	common	AK 356831
Scaevola gracilis Hook.f.	No	Goodeniaceae	one plant seen	AK 326637
Metrosideros kermadecensis W.R.B.Oliv.	Yes	Myrtaceae	abundant	AK 326643
**Portulaca oleracea* L.	No	Portulacaceae	abundant	AK 326648
Samolus repens var. *strictus* Cockayne	Yes	Primulaceae	uncommon	AK 356306
Coprosma petiolata Hook.f.	Yes	Rubiaceae	uncommon	CHR 193461
Coprosma repens A.Rich.	No	Rubiaceae	one plant	AK 326588
Melicope ternata J.R. Forst. et G.Forst.	No	Rutaceae	one tree	AK 356605
Myoporum rapense subsp. *kermadecense* (Sykes) Chinnock	Yes	Scrophulariaceae	abundant	AK 326643
Solanum americanum Mill.	Yes	Solanaceae	uncommon	AK 356308
**Solanum nigrum* L.	No	Solanaceae	common	AK 357088
**Solanum opacum* A.Braun et C.D.Bouché	No	Solanaceae	uncommon	AK 357089
Parietaria debilis G.Forst.	Yes	Urticaceae	common	AK 356529
Chromista – Ochrophyta (Phaeophyceae) (1)				
Sargassum sp.	No	Sargassaceae	common	AK 356405
Cyanobacteria (1)				
Indet.	No	Unknown	abundant	AK 327422
Mycobiota				
Lichens (21)				
Buellia cranwelliae Zahlbr.	No	Physciaceae	uncommon	UNITEC 6967
Buellia cf. *stellulata* (Taylor) Mudd	No	Physciaceae	common	UNITEC 6968
Caloplaca acheila Zahlbr.	No	Teloschistaceae	common	UNITEC 6965
Caloplaca cf. *lutea* (J.R.Laundon) D.J.Galloway	No	Teloschistaceae	common	
Caloplaca cf. *sublobulata* (Nyl.) Zahlbr.	No	Teloschistaceae	common	
Dufourea ligulata (Körb.) P.James	No	Teloschistaceae	common	UNITEC 6962
Halegrapha mucronata (Stirt.) Lücking	No	Graphidaceae	common	UNITEC 7033
Heterodermia speciosa (Wulfen) Trevis.	No	Physciaceae	common	AK 356830
Heterodermia tremulans (Müll.Arg.) W.L.Culb.	No	Physciaceae	common	AK 357571
Lecidella elaeochroma (Ach.) Hazsl.	No	Lecanoraceae	common	UNITEC 7012
Parmotrema austrocetratum Elix et J.Johnst.	No	Parmeliaceae	uncommon	UNITEC 6958
Parmotrema cetratum (Ach.) Hale	No	Parmeliaceae	common	UNITEC 6961
Parmotrema reticulatum (Taylor) M.Choisy	No	Parmeliaceae	common	UNITEC 6960
Parmotrema tinctorum (Despr. ex Nyl.) Hale	No	Parmeliaceae	uncommon	UNITEC 6959
Ramalina australiensis Nyl.	No	Ramalinaceae	uncommon	UNITEC 6953
Ramalina celastri (Spreng.) Krog et Swinscow	No	Ramalinaceae	uncommon	UNITEC 6955
Ramalina exiguella Stirt.	No	Ramalinaceae	common	AK 330754
Ramalina leiodea (Nyl.) Nyl.	No	Ramalinaceae	uncommon	UNITEC 6954
Ramalina microspora Kremp.	No	Ramalinaceae	common	AK 330753
Ramalina pacifica Asahina	No	Ramalinaceae	common	UNITEC 6957
Teloschistes flavicans (Sw.) Norman	No	Teloschistaceae	uncommon	UNITEC 6966