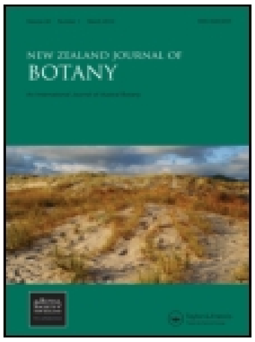


New Zealand Journal of Botany

ISSN: 0028-825X (Print) 1175-8643 (Online) Journal homepage: http://www.tandfonline.com/loi/tnzb20

Tea tree (Leptospermum) communities of the Waitakere Range, Auckland, New Zealand

A. E. Esler & Sandra J. Astridge

To cite this article: A. E. Esler & Sandra J. Astridge (1974) Tea tree (Leptospermum) communities of the Waitakere Range, Auckland, New Zealand, New Zealand Journal of Botany, 12:4, 485-501, DOI: 10.1080/0028825X.1974.10428635

To link to this article: http://dx.doi.org/10.1080/0028825X.1974.10428635

Tea Tree (*Leptospermum*) Communities of the Waitakere Range, Auckland, New Zealand

A. E. ESLER and SANDRA J. ASTRIDGE

Botany Division, DSIR, Private Bag, Auckland, New Zealand

(Received 25 July 1974)

ABSTRACT

In the Waitakere Range *Leptospermum* forms seral communities following the abandonment of farmland developed from forest containing kauri, podocarps, and hardwood species. The structure and composition of the communities are related to ages of stands, the coastal influence, topography, and cattle browsing. There are two main successional trends, one towards kauri forest, the other towards rimu dominance.

INTRODUCTION

Two species of *Leptospermum* are widespread in New Zealand—*L. scoparium* J. R. et G. Forst. (manuka or red tea tree) and *L. ericoides* A. Rich. (kanuka or white tea tree). Both are referred to here as tea tree where the species are not distinguished.

The wide distribution of tea tree in many habitats throughout New Zealand is a reflection of its versatility. Manuka grows from sea level to *c.* 1 600 m where it becomes a low bush. It occupies swampy soils as well as clays and free-draining sand. Kanuka is more fastidious, ascending to only *c.* 1 000 m and not able to thrive in very wet places or very infertile soils. It is also less tolerant of salt-laden wind.

Most tea tree shrubland has developed from bare ground or from short open vegetation. Its presence often indicates the destruction of previous vegetation by fire. Burning of tea tree usually results in re-invasion by the same species, the fire serving to clear the ground and provide the conditions for establishment of seedlings. Tea tree which is not burnt gives way to forest species although Burrell (1965) reported the permanency of kanuka communities in Otago. Cockayne (1907) implied that on Kapiti Island manuka stands had some degree of permanence. However, these have now been replaced by kanuka or forest (Esler 1967).

Biological Features of Tea Tree

The ecological role of tea tree is governed by a number of its biological features. The most significant are seed size and number, light requirements for establishment and growth, growth form, and longevity.

Grant (1967) reported that a single capsule (which is surrounded by a woody receptacle) of manuka contains about 300 seeds of which only about 60 are viable. From our observations 10 000–20 000 seeds weigh one gram. The seeds are shed irregularly for a year or more unless the capsules are stimulated by fire to open more evenly. The capsules of kanuka are very much smaller and more easily destroyed by fire; each has about 50 seeds. About 14 000 fully developed seeds or about 41 000 if the slimmer, non-viable seeds are included, weigh one gram. Seeds are shed in autumn, just a few months after flowering.

The small seed size aids dispersal and the vast output of seeds ensures coverage, but the paucity of endosperm is one of the factors preventing establishment of seedlings in deep shade. In these situations dependence on photosynthesis rather than on a supply of endosperm for initial growth is a limiting factor. Near tea tree stands seedlings occur in greatest numbers on land bared by fire or disturbed by soil movement. Seedling increase is very rapid and is accompanied by profuse branching. When young plants grow close together the foliage is confined to the upper parts of the plant to form a distinct and regular canopy. This form is promoted by the freedom of branching of the young shoots and the early death of the shaded twigs; possibly no other New Zealand plant has as many twigs. Young tea tree communities admit relatively little light to the ground and consequently there are very few associated species. As the community becomes older, competition results in vigorous self-thinning and at about this stage scattered individuals which established early and developed a spreading habit are over-topped and die, thus eliminating many of the older plants (Bellingham 1956, Esler 1967). The age range is further limited by the inability of tea tree to establish in its own shade. As the canopy flattens with age, crowns become less dense and the gaps between them increase. In the less shaded interior of the community plants of other species establish and may ultimately replace the tea tree. Replacement is often by over-topping and shading, particularly in manuka stands where the canopy seldom exceeds 12 m. Dominance by kanuka leads to much slower replacement as only a few forest trees have sufficiently rapid growth or adequate stature to reach above the canopy which may exceed 20 m. Sometimes tea tree gives way to other species before overtopping but the reasons are not apparent except where it has been affected by manuka blight.

Appreciation of these biological features clarifies much of the ecology of tea tree in the Waitakere Range.

Features of the Environment

The Waitakere Range is a dissected plateau with an average elevation of about 340 m rising to 460 m in the highest region. The cliff-bound southern and western margins rise abruptly from the sea. A scarp defines the eastern margin. The Waitakere swamp is taken as the northern boundary.

The Range is composed mostly of old andesitic materials of the Manukau Breccia Formation – lava, conglomerates, breccias, ash, and sand (Searle 1944). Some rocks have withstood weathering and erosion and have given rise to the cliffs, waterfalls, gorges, and rock stacks which are a feature of the landscape. This formation is bordered by Miocene sandstones and siltstones of the Waitemata Formation along the Manukau Harbour from Huia eastwards. On the eastern boundary of the range the Waitemata Formation meets the volcanic rocks in an irregular line, mostly outside the region under study.

Volcanic rocks have weathered to clays which become sticky in winter and hard in summer. Most topsoils have a thin organic layer overlying dark yellowish brown granular clay which grades into a very compact yellowish brown or brown subsoil. Soils from Waitemata rocks are mostly infertile brown granular clays but there are wide variations depending on the nature of the parent material. Some information on soils of the Cornwallis Peninsula is given by Atkinson (1959); and Mirams (1957) makes some brief remarks about soils of the Waitakere Range.

The climate is relatively mild and moist. In Auckland City (Albert Park), February, the hottest month, has a mean temperature of 20.5°C (mean daily range 17.0–24.1°C) and July, the coldest, 11.1°C (mean daily range 7.6–14.7°C). Ground frosts occur on an average of 3.4 days a year. Annual rainfall in Auckland is about 1 250 mm, and monthly falls of 90 mm in summer increase to a maximum of 140 mm in winter. In the Waitakere Range annual rainfall increases in a regular progression from 1 250 mm on the margins of the area to over 2 000 mm in the higher central parts (Mead 1972). Strong winds are relatively uncommon; the strongest are from the north-east, but west and south-west directions predominate. Sunshine hours are 2 093 per annum for Auckland, 47% of the possible total. In the higher parts of the Range sunshine hours are likely to be fewer than this. (Unless otherwise stated climate data are from New Zealand Meteorological Service 1966. Albert Park data are from observations 1909–1960).

Origin and Distribution of Tea Tree in the Waitakere Range

The conditions enabling tea tree to become established are not known for all areas in the Waitakere Range. Logging, burning by gumdiggers, and burning and grassing for farming have all played a part.

Removal of kauri (*Agathis australis*) began before the middle of last century. In some areas a second and third logging removed kauri previously considered to be of little value together with some other species which had previously been ignored, e.g., kahikatea (*Podocarpus dacrydioides*) for butter boxes, puriri (*Vitex lucens*) for building piles, totara (*Podocarpus totara* and *P. hallii*) for bridges and fence posts, and rimu (*Dacrydium cupressinum*) for general building purposes. Major milling operations ceased in the 1930s. Timber trees were removed from about three-quarters of the Range. The only forest remaining more or less intact was in the reserves and where timber could not be removed economically. After milling some forest was left to recover but much was burnt to develop farmland (Fig. 1). Some fires were accidental and some were lit to make land more accessible to gumdiggers. However, farming was not a successful enterprise because poor soils and high rainfall encouraged second growth species, particularly tea tree. It seems unlikely that a single burn, unless very thorough, would have cleared the existing vegetation sufficiently to allow tea tree to establish. Periodic burning would also have permitted tea tree (particularly manuka) to spread itself more evenly over the devastated area.

Tea tree communities cover about one-third of the Waitakere Range and are very widely distributed (Fig. 2). They are less extensive inland but no catchment is without significant amounts. The areas with least tea tree are those where there was little milling. In some inland places where there were single fires, tea tree may not have established because of the remoteness from seed sources and the vigour of broad-leaved shrubs developed under the higher rainfall.

The development of land for farming and its abandonment accounts for most of the extensive stands. Most of the coastal land was farmed (Fig. 1). There were also farms where tea tree now flourishes in many places along Piha Road, at the head of the Anawhata catchment, around the lower Nihotupu Dam, and on Scenic Drive.

Accidental fires promoted large areas of tea tree near the Nihotupu Auxiliary Dam (fires from 1899 to 1923) and in the region of Mt Donald McLean. When the mill in the Pararaha catchment was burnt down in 1881 some vegetation was destroyed. Fire swept the land again soon after Odlins ceased milling there in about the early 1930s. In the Piha and Karekare catchments at least, tea tree was cut for firewood in the 1930s.

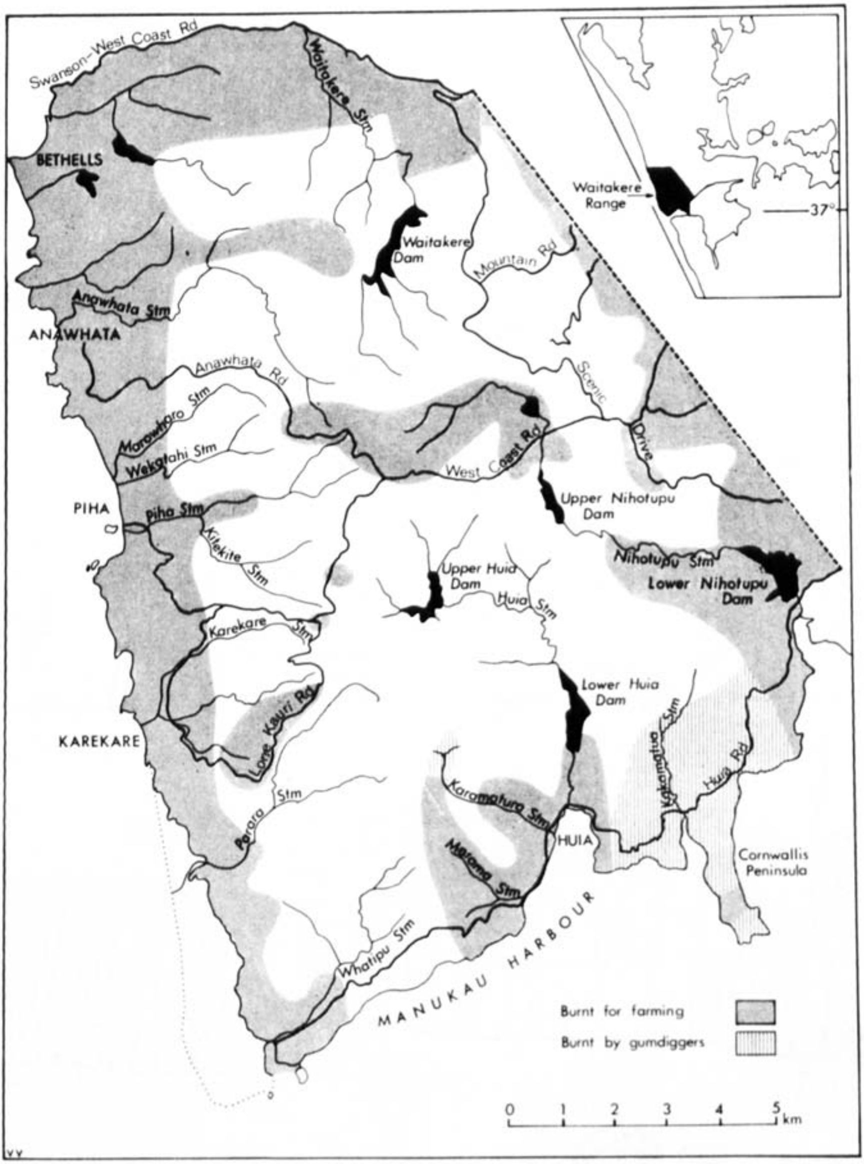


FIG. 1—Parts of the Waitakere Range where forest has been burnt to clear land for farming and gumdigging. Information kindly supplied by J. T. Diamond. (Parara to read Pararaha)

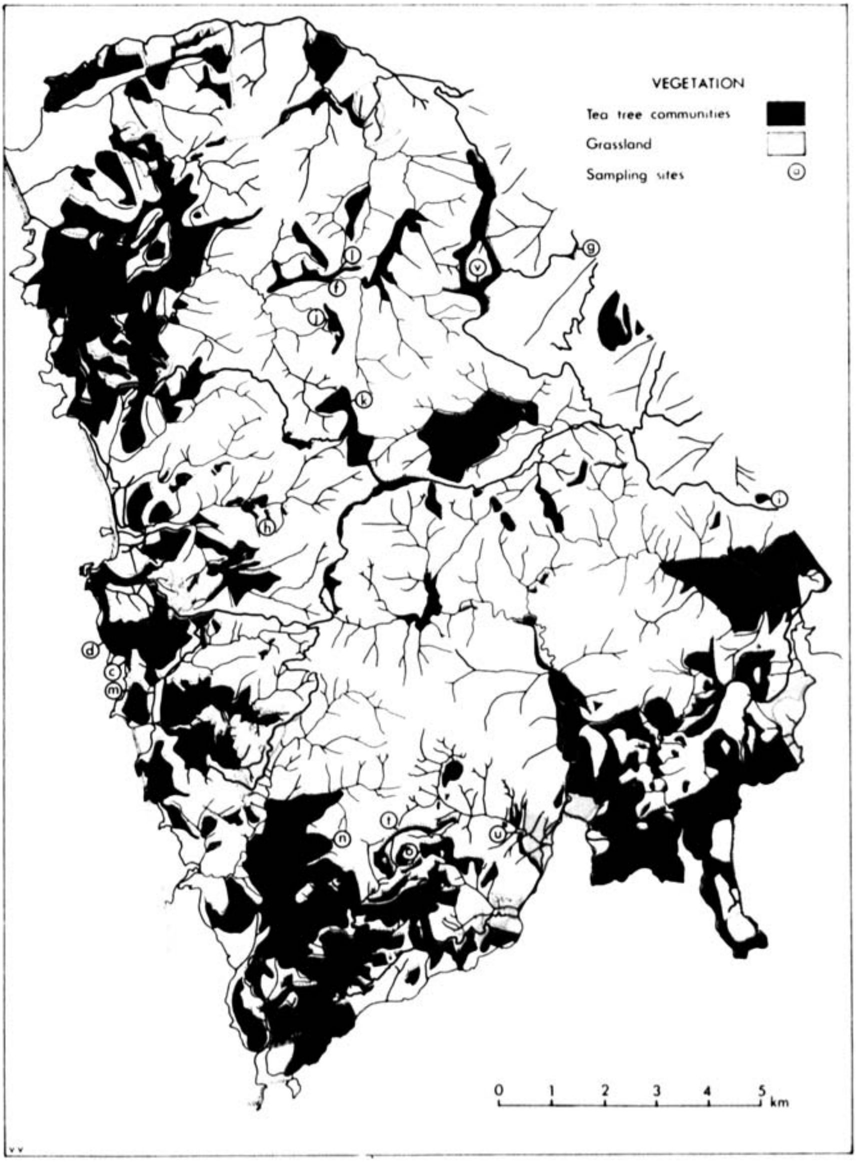


FIG. 2—Distribution of tea tree stands and grasslands of the Waitakere Range.

Notes on Sampling Sites in Fig. 3 (*Overleaf*)

These notes give location, altitude, topography, exposure, and approximate age of stand.

a. *Lone Kauri Rd* N41:013433. 180 m. Moderate slope to W, 1 km from coast, but not directly exposed to onshore wind. Previously farmed. About 6 years.
b. *Wesley Spragg Memorial.* N42:115413. 35 m. Slight slope to SW on Waitemata sandstone. 0.5 km from shore and affected by wind off Manukau Harbour. More than 30 years.
c. *Mercer Bay Track at junction with Ahuahu Track.* N41:999453. 195 m. Moderate slope to W on windswept coast, 1 km from shore. More than 20 years.
d. *Ahuahu Beacon.* N41:996455. 220 m. Moderate slope to SE, 0.5 km from shore but sheltered by ridge. More than 20 years.
e. *Gibbons Track.* N41:029385. 260 m. Nearly level ground on damp ridge crest near gully head. 40 years.
f. *Simla Track.* N41:032532. 330 m. Level crest of ridge. 20 years.
g. *Sharps Bush.* N41:088538. 130 m. Gentle slope to W on Waitemata sandstone. Land previously cleared for cultivation. 15 years.
h. *Centennial Track.* N41:030482. 160 m. In valley on side spur sloping to N. Possibly 70 years.
i. *Information Centre, Scenic Drive.* N42:128490. 200 m. Broad level spur. More than 40 years.
j. *Ridge Rd, near AUTC hut.* N41:036524. 250 m. Gentle slope to W in gully head near ridge. More than 25 years.
k. *Brownes Track.* N42:040507. 330 m. Gentle slope to W near ridge crest. More than 40 years.
l. *Fence Line Track.* N41: 039533. 300 m. Ridge with moderate slope to NE. More than 60 years.
m. *Ahuahu Track.* N41:999452. 300 m. Across moderate slope to E, 0.5 km from sea but sheltered by ridge. More than 25 years.
n. *Odlins Timber Track.* N41:041419. 330 m. On nearly level ridge on margin of logging track. More than 35 years.
o. *Donald McLean Track.* N41:064409. 330 m. Gentle slope on W side of ridge. More than 35 years.
p. *Farley Track.* N41:095432. 65 m. On gentle slope on NE side of ridge. More than 40 years.
q. *Whatipu Rd.* N41:037374. 50 m. On gentle slope to N at mouth of valley, 1 km from shore but fairly sheltered. Browsed by cattle. 50 years.
r. *Donald McLean Track.* N41:063405. 330 m. On fairly level ridge. More than 30 years.
s. *Parau Track.* N42:130460. 100 m. On plateau, probably on Waitemata sandstone. 35 years.
t. *Karamatura Forks.* N41:055416. 336 m. On broad, level ridge top. More than 60 years.
u. *Karamatura Valley.* N41:080419. 33 m. On moderate slope to NE. More than 35 years.
v. *Spraggs Bush.* N41:068533. 400 m. On gentle slop to SW. More than 60 years.

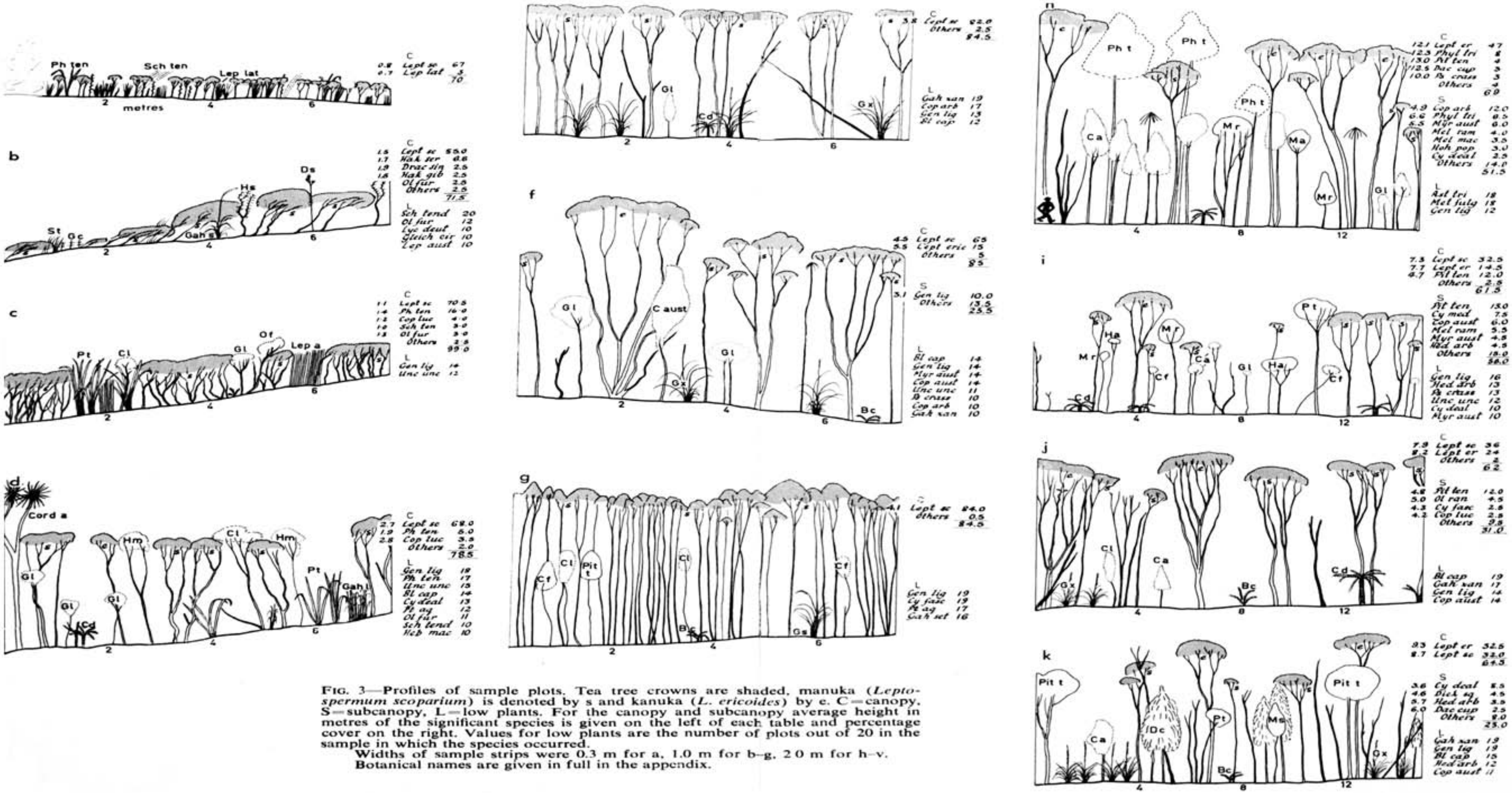
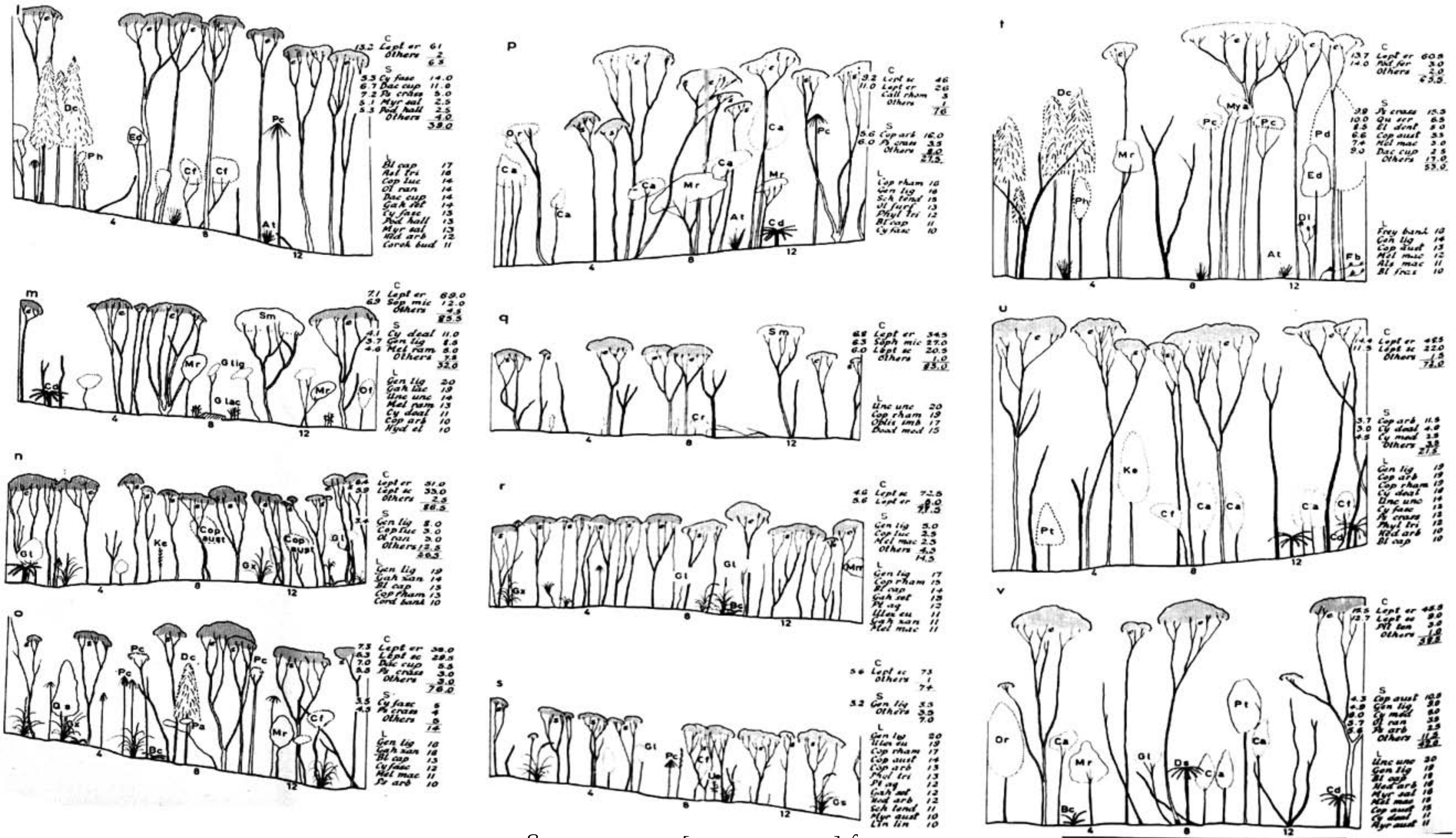


FIG. 3—Profiles of sample plots. Tea tree crowns are shaded, manuka (*Leptospermum scoparium*) is denoted by s and kanuka (*L. ericoides*) by e. C=canopy, S=subcanopy, L=low plants. For the canopy and subcanopy average height in metres of the significant species is given on the left of each table and percentage cover on the right. Values for low plants are the number of plots out of 20 in the sample in which the species occurred.

Widths of sample strips were 0.3 m for a, 1.0 m for b–g, 2.0 m for h–v.

Botanical names are given in full in the appendix.



Near the coast tea tree forms a fairly general cover interrupted only by young forest in some gullies and by a few groves of pohutukawa (*Metrosideros excelsa*). It is almost entirely absent from steep slopes. Coastal stands are dominated by manuka which is much more resistant to wind-borne salt than is kanuka. The manuka phase of succession here is prolonged because of the paucity of salt-resistant vegetation to replace it.

Further inland tea tree is most prevalent on ridges and there are several reasons for this. In these regions with higher rainfall fires would have burnt less intensively and the gullies were less likely to be burnt out. Vegetation in gullies would have regenerated more quickly also, often without tea tree finding a place in the succession. The ridges were much drier than the gullies and had inflammable kauri crowns left by the millers. A further factor accounting for some of the stands on the ridges is the destruction of ridge vegetation when logs were being removed. The ridges in some places were the focal points for the accumulation and transport of logs, particularly when the forest was remilled using haulers to bring the logs from the lower slopes. Earlier the logs were taken into the gullies to be flushed down the streams.

The Survey

A survey of tea tree communities on the Waitakere Range was carried out in four stages as follows.

1. *Reconnaissance surveys.* The Waitakere Range is well served with trampers' tracks. These traverse much of the tea tree country and were used in the reconnaissance surveys.

2. *Mapping the tea tree communities from aerial photographs.*

3. *Checking maps in the field.* Vegetation was mapped as tea tree if *Leptospermum* occupied one-half or more of the canopy. Fortunately, the distinctive close canopy of the tea tree made mapping relatively easy but some small areas of *Coprosma arborea* may have been recorded as tea tree in inaccessible areas where checking in the field was not possible.

4. *Sampling.* Each sample consisted of 20 plots equally spaced along a line in the stand chosen for examination. In stands less than 5.6 m tall the plots were 10 m apart and this was increased to 15 m in taller vegetation. Each plot had a radius of 3 m, the boundaries being determined by a 2 m pole held at arm's length from the centre of the plot.

For the canopy the following data were recorded: species in the canopy, average height of each species, amount of canopy contributed by each species–this was judged on a 0–5 scale, using half units where necessary.

The same records were made for the subcanopy where it was present. In a category called "low plants" the presence of all species in the lowest stratum was recorded.

For each sample the data were summarised as:

Average height of each species in the canopy and subcanopy and the contribution of each to the cover. Species regarded as significant were those contributing 2.5% or more to the cover in each layer.

Frequency of low plants, i.e., number of plots in which each species occurred. Only those species occurring in 10 or more plots were considered significant, but the value of less frequent species as indicators was not overlooked.

Frequency of all species. This analysis included plants recorded at all levels.

A profile diagram was drawn for each sample. In vegetation less than 5.6 m tall the strip was 7.5 m long and 1 m wide, except in sample a, Lone Kauri Rd, where the high density of plants necessitated a strip 0.3 m wide. In taller stands the length and width of the strip were doubled.

Dating the stands presented some difficulties. In a simple situation where there had been a fire and tea tree established immediately afterwards growth rings of a stem section near the ground should have indicated a reasonably accurate age. Unfortunately, growth rings of kanuka were not always clearly distinguishable and there was no certainty that the rings of manuka were truly annual. The approximate age of each stand is indicated in the notes on sampling sites, accompanying Fig. 2.

Results of the Survey

Results are presented on the vegetation map (Fig. 2), on the profile diagrams as cover, height, and frequency values (Fig. 3), and in the Appendix.

The diverse communities have many features in common quite apart from the predominance of tea tree in each of them. However, the differences between samples are more marked than the similarities. Diversity arises from varying ages of the stands, the coastal influence, topography (particularly altitude, aspect, and slope), and the influence of cattle. Soil differences undoubtedly play a part but this aspect was not studied in any detail.

Age of Stands

The 22 stands examined ranged in age from about 6 years (sample a, Lone Kauri Rd) to over 60 years (sample t, Karamatura Forks). Increase in age brings about changes in height, density of stems, denseness of the canopy, together with floristic changes of the dominant and subordinate species.

Growth rates of tea tree vary considerably but, unless limited by very infertile soil, dry soil, or wind, tea tree reaches a height of 1 m in 2 or 3 years ,4 m in 15 years, and 7 m in 20 years. At 20 years the faster growth and taller stature of kanuka becomes obvious and the suppression of manuka is common in mixed communities. Growth of manuka slows at about 20 years but some plants continue to grow for 50 years and reach 12 m before they lose their place in the canopy (sample t, Karamatura Forks; sample u, Karamatura Valley). Kanuka remains quite vigorous at 50 years and some trees appear to live for more than a century. The tallest kanuka encountered (18 m) is in sample v, Spraggs Bush, and of unknown age but more than 60 years.

Stem density in the youngest stand examined (sample a, Lone Kauri Rd) is about 8 per square metre and, in the oldest stands about 0.12 per square metre. Even at this low density tea tree forms more than one-half the canopy. At 15 years self-thinning has reduced density to a small fraction of the plants which had established. The thinning process continues plant by plant and limb by limb for the whole life of the stand. Where tall manuka and kanuka are growing in close association the manuka may be entirely eliminated soon after 20 years. This removal has probably already occurred in sample m, Ahuahu Track, and is happening in sample u, Karamatura Valley. In sample t, Karamatura Forks, mainly dead manuka remains below the kanuka canopy. The dead plants in profiles of samples (solid lines) are almost entirely manuka. We have no evidence of manuka blight being of any significance in the Waitakere Range.

Declining stem density makes room for more canopy spread but the survivors have limited capacity to do this. Consequently, at the end of the pioneering phase, more light enters the community at the edges of the crowns and promotes the subordinate plants (Cockayne 1928). *Blechnum capense* and *Geniostoma ligustrifolium* are soon followed by *Gahnia* spp. and *Coprosma* spp. Many others make an appearance at this stage but fail to become important components until later. For many species it is not the age of the community which favours their entry but conditions of the site. *Blechnum discolor*, for instance, can make an early entry if the soil is permanently wet.

The main influence of further opening of the canopy is the stimulation of plants which are already established and it is at this stage that the potential canopy species become prominent. In a stand where manuka is dominant (sample i, Information Centre, Scenic Drive) the subordinates gain ascendancy early in spite of their small stature. Where kanuka dominates some shrubs pass through several generations before the canopy deteriorates enough for them to reach the light (sample v, Spraggs Bush). Trees, on the other hand, can grow above the kanuka canopy (sample h, Centennial Track).

The Coastal Influence

The coastal vegetation is a curious assemblage of plants. Some grow there because they are tolerant of the conditions, others because they cannot grow successfully in any other habitat. Others are there primarily because the relatively more open coastal vegetation provides more spaces for establishment but the occurrence of some species in this habitat is unexplained. All these classes are represented in the shrublands. New Zealand flax (*Phormium tenax*) is in the tolerant category. The plants specific to the coast are *Cortaderia splendens*, *Astelia banksii*, *Hebe obtusata*, *Pteris saxatilis*, *Corokia cotoneaster*, and *Pseudopanax lessonii* (predominantly as hybrids with *P. crassifolius*). Kowhai (*Sophora microphylla* var. *fulvida*) in the Waitakere Range occurs most frequently on the coast and on rocky knolls inland. Both habitats provide the semi-open habitat that kowhai requires for its perpetuation. The reasons for *Gahnia lacera*, *Doodia media*, and *Polystichum richardii* being more plentiful near the coast are not apparent.

The balance between manuka and kanuka appears to be influenced by the degree of exposure to salt-laden winds. It is significant that in unprotected situations kanuka is absent, or nearly so (sample b, Wesley Spragg Memorial; sample c, Mercer Bay Track).

Structure of the tea tree communities also reflects the degree of exposure to wind. On coastal slopes tea tree is stunted to breast height and is almost impenetrable (sample c, Mercer Bay Track). This sample also has the greatest canopy cover of any stand examined. The dwarfing allows plants of short stature such as *Schoenus tendo* to contribute to the canopy which, in a little more than 20 years, has reached a height of only one metre. A nearby stand (sample d, Ahuahu Beacon) of similar vegetation probably established after the same fire but is three times as tall. It is in a more sheltered site and may have established a little earlier.

The vegetation in sample b, Wesley Spragg Memorial, is of a similar nature notwithstanding the fact that it lies within the more sheltered Manukau Harbour, is at a lower altitude and is on Waitemata sandstone. This soil factor may account for the quantities of *Dracophyllum sinclairii*, *Persoonia toru*, and *Gleichenia circinata* and the smaller amount of flax. The vegetation in this sample approaches what has been known as "gumland" vegetation.

Topographic Influences

Differences in floristic composition at the ends of the altitudinal range are very marked. However, there is no discernible gradient in composition in spite of regular increase in rainfall with altitude. This is because of the confounding effects of the coastal influence and the localised sources of seeds and spores to colonise tea tree stands. A few species such as *Quintinia serrata*, *Ixerba brexioides*, and *Cyathea smithii* are confined to the higher altitudes apparently by the moister conditions there. Others such as *Melicytus macrophyllus* are more abundant at higher levels but extend through the full altitudinal range where suitable moist habitats occur. In contrast *M. ramiflorus*, being much more tolerant of dry conditions, is more plentiful at lower altitudes. Others which appear to have restricted distribution because of the paucity of extensive moist sites near sea level are *Myrsine salicina*, *Blechnum discolor*, *B. fraseri*, and *Gahnia xanthocarpa*.

Aspect and slope affect the dryness of the habitat. Steep sunny slopes tend to have less tea tree and more "hard-site" species such as *Olearia furfuracea*, *Cyathodes fasciculata*, *Lycopodium deuterodensum*, *Morelotia affinis*, and *Gahnia pauciflorus*. The most ubiquitous of the shrubland species, *Geniostoma ligustrifolium*, is usually absent from these sites. The samples do not include such a community.

The less steep and more shady sites have abundant *Geniostoma ligustrifolium*, and it is here that the tree ferns, the podocarps, nikau palm (*Rhopalostylis sapida*), and supplejack (*Ripogonum scandens*) establish most freely (sample o, Donald McLean Track). Tea tree is also much taller in these situations. On sites that are fairly level and moist in summer there is abundant *Gahnia xanthocarpa* and a predominance of more stunted manuka (sample e, Gibbons Track). Better drainage promotes *Gahnia setifolia* and kanuka.

The Effects of Cattle

Cattle have roamed most of the Waitakere Range in the past but have now been excluded from Centennial Memorial Park except around Whatipu. From here they move as far north as Karekare. The effects of browsing and trampling are gross (sample q, Whatipu Rd.). The canopy is not directly affected but few trees and shrubs are able to establish beneath it. The most noticeable feature is the near absence of large-leaved shrubs – *Melicytus* spp., *Coprosma* spp., and *Geniostoma ligustrifolium* in particular – and the abundance of unpalatable *Coprosma rhamnoides* which flourishes in the absence of competitors. In some other parts of the Waitakere Range (e.g., sample u, Karamatura Valley) *C. arborea* seems to have increased similarly under these conditions. Other species becoming prominent where cattle have access are *Uncinia uncinata*, *Doodia media*, and *Oplismenus imbecillus*. Enough nikau survives to become prominent in the undergrowth in some places. In sample q, Whatipu Rd, ngaio (*Myoporum laetum*) and kowhai probably established amongst the young tea tree and grew above browse level while the stand was still young and unaffected by cattle.

Sample e, Gibbons Track, is also within range of cattle. Although no recent damage was noted the paucity of palatable species, other than *Geniostoma ligustrifolium*, suggests the influence of cattle.

The Future of Tea Tree Communities

All tea tree communities are transitional and some stands are now giving way to other communities. There are two main trends—one towards kauri, the other towards rimu dominance. The extent of the future kauri forest is fairly well determined because kauri establishes at an early stage of vegetational succession and all the potential kauri forests have rickers (i.e., poles) standing well above the tea tree canopy. Podocarps establish at a fairly advanced stage of the tea tree cycle and will continue to invade tea tree stands for a long time. In some places they will become dominant, this trend being enhanced by proximity to sources of seed. In most places podocarps, particularly rimu, will be prominent above a more continuous canopy of broad-leaved trees of smaller stature.

The slowest replacement of tea tree is on the westward slopes of the Range near the coast. The nature of the vegetation that will take the place of tea tree is still uncertain. A century from now, it is likely that in the absence of fires, there will still be some tea tree on the Waitakere Range but most will have given way to forest.

Acknowledgments

We are grateful to Mr A. D. Mead for the time he spent with us in the field during the reconnaissance survey and for historical details. The advice of Mr W. J. Beveridge and the field assistance from Mr Wilson Esler are appreciated. We are indebted to Mr J. T. Diamond for supplying the information for Fig. 1, Dr I. A. E. Atkinson and Miss Joan Radcliffe for their comments on the script, and Mrs V. Vendetti for drawing the maps.

APPENDIX. Flora of the tea tree stands. Figures are the number of plots out of 20 in which the species occurred
x = not in the plots but noted nearby.

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v
Adiantum cunninghamii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-
A. fulvum	-	-	1	5	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	1	-
Agathis australis	-	1	-	-	5	-	5	7	-	-	-	1	-	x	-	2	-	-	1	x	1	-
Alseuosmia macrophylla	-	-	-	-	-	-	-	5	-	x	-	3	-	-	3	-	-	-	-	12	-	1
Arthropodium cirratum	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Asplenium bulbiferum	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-
A. falcatum	-	-	-	-	-	-	-	2	x	-	-	-	3	-	-	-	-	-	-	2	-	2
A. flaccidum	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	2	-	3
A. lucidum	-	-	-	-	-	-	-	1	-	-	-	-	4	1	-	-	-	-	-	2	-	2
Astelia banksii	-	1	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
A. solandri	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	1	-	1
A. trinervia	-	-	-	-	1	1	-	18	-	1	1	16	-	2	7	-	-	1	-	9	1	-
Baumea juncea	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Beilschmiedia tawa	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	3	-	-
Blechnum capense	-	-	11	14	12	14	9	-	6	19	15	17	-	16	13	11	-	14	3	9	10	18
B. discolor	-	-	-	-	-	1	-	-	-	-	1	-	-	1	-	-	-	7	-	6	-	x
B. filiforme	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	x	-	-
B. fraseri	-	-	-	-	-	5	3	6	2	3	5	8	-	2	8	2	-	9	-	10	3	2
B. lanceolatum	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
B. minus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Brachyglottis repanda	-	-	-	1	-	-	-	2	-	-	-	-	6	7	-	6	-	-	-	x	1	2
Callitris rhomboidea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Carex breviculmis	-	-	1	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex flagellifera	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C. lambertiana	-	-	-	2	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Carmichaelia aligera	-	-	-	x	-	-	-	-	-	-	-	-	1	-	-	-	x	-	-	-	-	-
Carpodetus serratus	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	2	-
Centella uniflora	2	-	3	-	-	1	-	-	1	-	-	-	-	-	-	2	-	1	1	-	x	-
Clematis paniculata	-	-	-	1	-	5	-	5	2	1	6	2	6	8	1	3	-	2	1	3	-	4
Collospermum hastatum	-	-	-	-	-	-	-	-	x	-	-	-	1	1	-	-	-	-	-	1	-	-

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v
Coprosma arborea	-	-	1	1	17	10	-	14	10	3	2	2	10	1	5	13	3	6	14	1	20	-
C. australis	-	-	-	-	6	16	1	4	12	15	13	9	-	11	9	-	-	5	16	17	3	20
C. lucida	10	1	19	15	6	10	11	9	8	8	5	14	8	10	7	-	-	18	5	-	5	2
C. rhamnoides	-	-	-	1	1	1	1	-	9	1	-	-	-	13	2	16	19	15	17	1	18	-
C. robusta	-	-	1	-	-	-	1	-	3	-	-	-	-	-	-	3	-	-	-	-	-	-
Cordyline australis	2	-	3	11	-	2	-	1	x	-	x	-	3	2	1	1	4	-	-	-	-	-
C. banksii	-	-	-	-	2	6	3	x	-	3	2	2	2	16	4	1	-	7	-	3	-	-
C. pumilio	-	-	-	-	-	1	-	3	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Corokia buddleioides	-	-	-	-	-	-	-	4	-	-	-	11	-	2	5	-	-	x	-	4	1	-
C. cotoneaster	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Cortaderia atacamensis	-	-	1	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
C. splendens	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corynocarpus laevigatus	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyathea dealbata	4	-	5	13	5	9	-	13	10	4	16	8	12	9	12	3	3	9	7	8	18	14
C. medullaris	-	-	-	-	-	-	-	-	6	2	5	-	1	4	1	1	-	1	-	1	4	3
C. smithii	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	4
Cyathodes fasciculata	-	9	3	4	1	10	19	10	9	15	3	20	3	11	20	10	2	12	10	-	12	2
C. juniperina	-	2	-	-	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	2	-
Dacrydium cupressinum	-	-	-	-	1	-	3	4	-	3	5	18	-	2	8	2	-	3	2	10	x	2
Dendrobium cunninghamii	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-
Dianella nigra	-	3	-	2	2	1	11	6	4	1	3	7	6	4	5	5	1	4	-	1	6	-
Dichelachne crinita	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dichondra repens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-	-	-	-
Dicksonia squarrosa	-	-	1	-	-	1	1	-	3	2	9	-	-	1	8	1	-	1	-	10	1	10
Doodia media	-	-	-	1	-	-	-	-	-	-	-	-	6	-	-	-	15	-	-	-	-	-
Dracophyllum latifolium	-	-	-	-	-	-	-	1	-	-	-	x	-	-	-	-	-	-	-	4	-	-
D. sinclairii	-	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Drymoanthus adversus	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-
Dysoxylum spectabile	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Earina autumnalis	-	-	-	-	-	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v
E. mucronata	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Elaeocarpus dentatus	-	-	-	-	-	-	-	1	-	-	-	x	-	-	-	-	-	-	-	5	-	-
Freycinetia banksii	-	-	-	-	-	-	-	7	2	-	-	-	-	3	3	-	-	-	-	18	-	2
Gahnia lacera	2	-	4	6	5	-	-	3	-	-	-	-	19	-	-	2	9	-	-	1	-	-
G. pauciflora	-	-	-	-	1	-	-	-	-	1	-	3	-	-	-	-	-	-	-	-	-	-
G. setifolia	-	8	4	2	1	6	16	5	3	-	-	14	-	x	2	8	-	13	12	7	5	-
G. xanthocarpa	-	-	-	-	19	10	-	-	-	17	19	3	-	14	16	-	-	11	5	-	-	3
Galium propinquum	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Geniostoma ligustrifolium	2	3	20	17	14	20	19	12	16	16	20	4	20	20	16	18	6	16	20	14	19	20
Gleichenia circinata	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-
G. microphylla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Grammitis heterophylla	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-
Griselinia lucida	-	-	-	-	-	1	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hakea gibbosa	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. sericea	7	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Haloragis erecta	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
H. procumbens	-	4	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hebe macrocarpa	19	-	13	17	7	1	-	3	-	-	-	-	2	1	-	-	-	-	-	-	1	-
H. obtusata	-	-	2	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. stricta	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hedycarya arborea	-	-	-	-	1	4	1	10	17	4	15	12	8	6	2	2	1	9	14	4	10	16
Helichrysum glomeratum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-
Hoheria populnea	-	-	-	-	-	-	-	5	1	-	-	-	4	9	-	-	-	-	-	-	-	-
Hydrocotyle elongata	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	2	-	-	-	-	-
H. novae-zelandiae	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Hymenophyllum spp.	-	-	-	-	-	-	-	-	-	-	-	8	1	-	-	-	-	-	-	2	-	1
Ixerba brexioides	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	3	-	-
Knightia excelsa	-	1	-	-	4	2	-	7	7	3	1	11	x	7	2	9	-	2	x	5	5	5
Lepidosperma australe	11	10	9	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. laterale	17	x	-	-	-	-	-	-	-	-	-	-	1	-	-	2	-	-	3	-	-	-

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v
Leptospermum ericoides	-	1	-	2	1	10	3	20	13	16	14	20	20	19	13	12	17	7	5	20	17	20
L. scoparium	20	20	20	20	19	19	20	-	16	15	14	-	-	16	12	19	12	19	20	2	9	4
Libocedrus plumosa	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Lindsaea linearis	1	4	1	1	-	-	-	-	-	-	-	x	-	-	-	2	-	-	10	-	-	-
Litsea calicaris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-
Lobelia anceps	1	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lophomyrtus bullata	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-
Lycopodium billardieri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-
L. deuterodensum	-	10	-	-	-	-	7	-	-	x	-	9	-	-	-	4	-	x	-	-	2	-
L. volubile	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	4	-	-	1	-
Lygodium articulatum	-	-	3	1	-	-	-	4	-	1	-	1	-	-	1	-	-	-	2	2	6	3
Macropiper excelsum	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-
Melicytus macrophyllus	-	-	-	-	-	5	-	3	1	12	10	5	-	9	14	-	-	12	-	18	-	15
M. micranthus	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	1	-	-	-	-	-	-
M. ramiflorus	-	-	1	-	1	2	-	7	8	2	8	1	15	3	1	3	1	-	8	-	10	6
Metrosideros diffusa	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
M. fulgens	-	-	-	-	-	-	-	19	-	-	-	3	-	-	10	-	-	2	-	12	-	4
M. perforata	-	-	-	-	-	3	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	3
M. robusta	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Microlaena avenacea	-	-	-	-	-	-	-	-	-	1	-	x	-	-	-	-	-	-	-	2	-	-
M. stipoides	-	-	-	1	-	4	1	-	1	-	-	-	1	-	-	-	6	-	-	-	-	-
Mida salicifolia	-	-	-	-	-	-	-	2	-	-	-	2	-	-	-	-	-	-	-	-	-	-
Morelotia affinis	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	x	-	-	-
Myoporum laetum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Myrsine australis	-	-	-	6	2	17	2	14	14	9	8	7	7	6	8	1	4	8	11	8	7	13
M. salicina	-	-	-	-	-	-	-	-	-	5	1	15	-	3	5	-	-	1	-	5	-	16
Nertera dichrondraefolia	-	-	-	-	4	12	13	-	5	6	6	-	-	2	1	6	-	3	9	-	1	-
Nestegis lanceolata	-	-	-	-	-	-	-	3	-	1	-	3	-	-	1	x	-	-	-	3	-	-
N. montana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-
Notodanthonia sp.	2	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v
N. biannularis	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
N. gracilis	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-
N. racemosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-
Olearia furfuracea	8	15	19	11	12	x	2	4	-	2	-	3	6	10	2	13	1	3	x	-	4	-
O. rani	-	-	-	-	-	2	1	3	3	6	1	14	-	4	9	8	-	-	-	6	5	6
Oplismenus imbecillus	-	-	-	-	-	-	-	1	-	-	-	-	9	-	-	-	17	-	x	-	-	-
Paesia scaberula	-	-	-	-	-	2	-	-	-	-	-	-	-	1	1	-	-	8	-	-	-	-
Parsonsia heterophylla	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	2	-	-	-	1	-
Peperomia urvilleana	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Persoonia toru	-	2	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	x	-	-
Phormium tenax	7	1	19	19	3	1	-	-	-	-	-	-	3	-	1	-	-	1	-	-	-	-
Phyllocladus trichomanoides	-	5	-	-	1	-	2	15	-	-	-	-	-	-	-	14	1	1	13	-	12	-
Phymatodes diversifolium	-	-	-	-	1	-	-	1	-	-	-	-	5	-	-	-	-	-	-	3	-	-
P. scandens	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-
Pittosporum tenuifolium	-	-	-	-	-	13	1	2	15	17	-	6	-	-	-	-	-	1	4	-	-	13
Poa anceps	-	-	12	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-
Podocarpus dacrydioides	-	-	-	-	-	1	1	-	3	-	-	-	-	-	-	1	-	1	2	-	-	1
P. ferrugineus	-	-	-	-	-	-	-	1	-	-	-	9	-	2	-	-	-	1	-	6	3	2
P. hallii	-	-	-	-	-	3	-	-	-	1	-	14	-	-	4	1	-	-	x	7	1	-
P. totara	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polystichum richardii	-	-	-	2	-	-	-	-	-	-	-	-	4	-	-	-	3	-	-	-	-	-
Pomaderris phylicifolia	5	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pseudopanax anomalus	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	x	-	-
P. arboreus	-	-	x	-	-	3	6	1	-	5	5	-	-	x	11	10	-	10	-	1	1	12
P. crassifolius & hybrids	-	-	1	5	9	14	1	6	15	9	3	14	2	10	17	16	-	14	10	14	12	13
Pseudowintera axillaris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Pteridium aquilinum	2	1	2	12	1	8	17	-	8	6	-	7	6	1	4	2	-	12	12	-	2	-
Pteris saxatilis	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	3	-	-	-	-	-
Pterostylis banksii	-	-	-	-	-	1	2	1	x	-	-	-	-	-	1	-	-	1	1	-	-	2
Quintinia serrata	-	-	-	-	-	-	-	-	-	-	1	2	-	1	4	-	-	-	-	13	-	-

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v
Rhabdothamnus solandri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-
Rhopalostylis sapida	-	-	-	-	-	-	-	2	8	x	3	x	9	2	1	-	x	-	3	1	9	3
Ripogonum scandens	-	-	-	-	-	-	-	-	2	4	9	-	-	x	2	-	-	1	-	7	1	7
Rubus australis	-	-	-	-	-	1	-	-	-	3	2	-	-	-	-	-	-	-	-	x	1	6
R. cissoides	-	-	-	-	-	-	-	3	1	2	2	1	-	-	3	1	-	1	-	1	8	3
R. fruticosus	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rumohra adiantiformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	2
Schefflera digitata	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Schoenus apogon	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. maschalinus	-	-	1	-	-	-	-	-	x	-	-	-	-	-	-	-	1	-	-	-	-	-
S. tendo	13	20	16	10	11	-	2	1	-	-	-	-	-	-	-	15	4	-	11	-	x	-
Senecio kirkii	-	-	-	-	-	-	-	-	-	1	-	7	-	-	-	3	-	-	-	-	1	1
Sophora microphylla	-	-	-	-	-	-	-	-	-	-	-	-	13	-	-	-	14	-	-	-	-	-
Tetrapathaea tetrandra	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Thelypteris penniger	-	-	-	-	-	-	-	-	-	-	2	-	-	1	-	-	-	-	x	-	1	-
Tmesipteris tannensis	-	-	-	-	-	-	-	-	-	-	3	-	-	-	2	-	-	-	-	1	-	1
Trichomanes reniforme	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	x	-	-
Ulex europaeus	-	1	1	2	3	6	5	-	-	1	-	-	-	6	-	2	3	14	20	-	-	-
Uncinia banksii	-	-	-	-	-	1	-	2	-	-	-	1	-	-	-	2	2	-	-	-	x	-
U. uncinata	-	-	12	15	3	11	-	1	12	7	5	1	14	5	-	6	20	8	6	2	14	20
Wahlenbergia gracilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-

References

ATKINSON, I. A. E. 1959: Soils and the growth of *Pinus radiata* at Cornwallis, Auckland. *N.Z. Journal of Science 2:* 443–72.

BELLINGHAM, N. O. 1956: Some *Leptospermum* communities on Marotiri Island. *Tane 7:* 23–8.

BURRELL, JULIET 1965: Ecology of *Leptospermum* in Otago. *N.Z. Journal of Botany 3:* 3–16.

COCKAYNE, L. 1907: Report on a botanical survey of Kapiti Island. *Appendix to Journal of the House of Representatives (New Zealand) C8.* 23 pp.

——— 1928: "The Vegetation of New Zealand". 2nd ed. Engelmann, Leipzig. 456 pp.

ESLER, A. E. 1967: The vegetation of Kapiti Island. *N.Z. Journal of Botany 5:* 353–93.

GRANT, D. A. 1967: Factors affecting the establishment of manuka (*Leptospermum scoparium*). *Proceedings of the 20th New Zealand Weed and Pest Control Conference* 129–34.

MEAD, A. D. 1972: "The Native Flora of the Waitakere Range, Auckland". 2nd ed. Printed by Impex Press, Auckland, New Zealand. 23 pp.

MIRAMS, R. V. 1957: Aspects of the natural regeneration of the kauri (*Agathis australis* Salisb.). *Transactions of the Royal Society of New Zealand 84:* 661–80.

NEW ZEALAND METEOROLOGICAL SERVICE 1966: Summaries of climatological observations at New Zealand stations to 1960. *New Zealand Meteorological Service Miscellaneous Publications 122.* 59 pp.

SEARLE, E. J. 1944: Geology of the Southern Waitakere Hills region west of Auckland City. *Transactions and Proceedings of the Royal Society of New Zealand 74:* 49–70.