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Vegetation of the Kaimanawa Ranges

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Abstract

THE Kaimanawa Ranges occupy an area between the volcanic plateau and the axis ranges of the North Island of New Zealand, and being thus sheltered from prevailing winds are drier and sunnier than the surrounding mountains except at their northern extremity. Most of the surface has been covered with ash to a depth of several feet from the Taupo eruptions, the latest of which occurred within the last 2,000 years and destroyed the previous vegetation over a large part of the area. Regeneration is most advanced nearest the eruption vents where both podocarp and beech forest has re-established itself, but to the south and east forest becomes intermittent and red tussock dominates extensive areas. At the southern extremity, towards the margin of the ash showers, forest islands having affinities with Rangataua and Ruahine forests to the west and east are probably relics of pre-eruption forests.

Maori burning within the last 300–400 years and more recently European burning and grazing and the browsing of introduced deer have affected the vegetation patterns and composition.

LOCALITY

KAIMANAWA is a general term for the series of ranges which lie between the central volcanoes of the North Island and the axis ranges, but the name is loosely applied. The "Kaimanawa Survey District" lies on the southern periphery and the "Kaimanawa" trig is also outside the main mountain system. For the purpose of this survey the Kaimanawa Ranges (Map 1) are considered to be the high country which lies between the Inland Patea Road, the Desert Road, the southern boundary of the exotic plantations on the Kaingaroa Plains, and the trough occupied by the Taharua and Oamaru tributaries of the Mohaka River and the upper courses of the Ngaruroro and Taruarau Rivers. This trough thus separates the Kaweka and Kaimanawa range systems.

This gives an area roughly oblong, 55 miles by 25, extending from 38° 50′ S to 39° 30′ S and from 175° 45′ E to 176° 12′ E.

TOPOGRAPHY (Map 2)

Published maps do not fully indicate the topographical patterns, but they can be considered as falling into four topographic units.

(1) The northern portion consists of a continuous narrow greywacke ridge, on the eastern side of which lies a number of conical peaks (Fig. 1) connected by obscure saddles, this portion thus resembling the Ahimanawa Range, which

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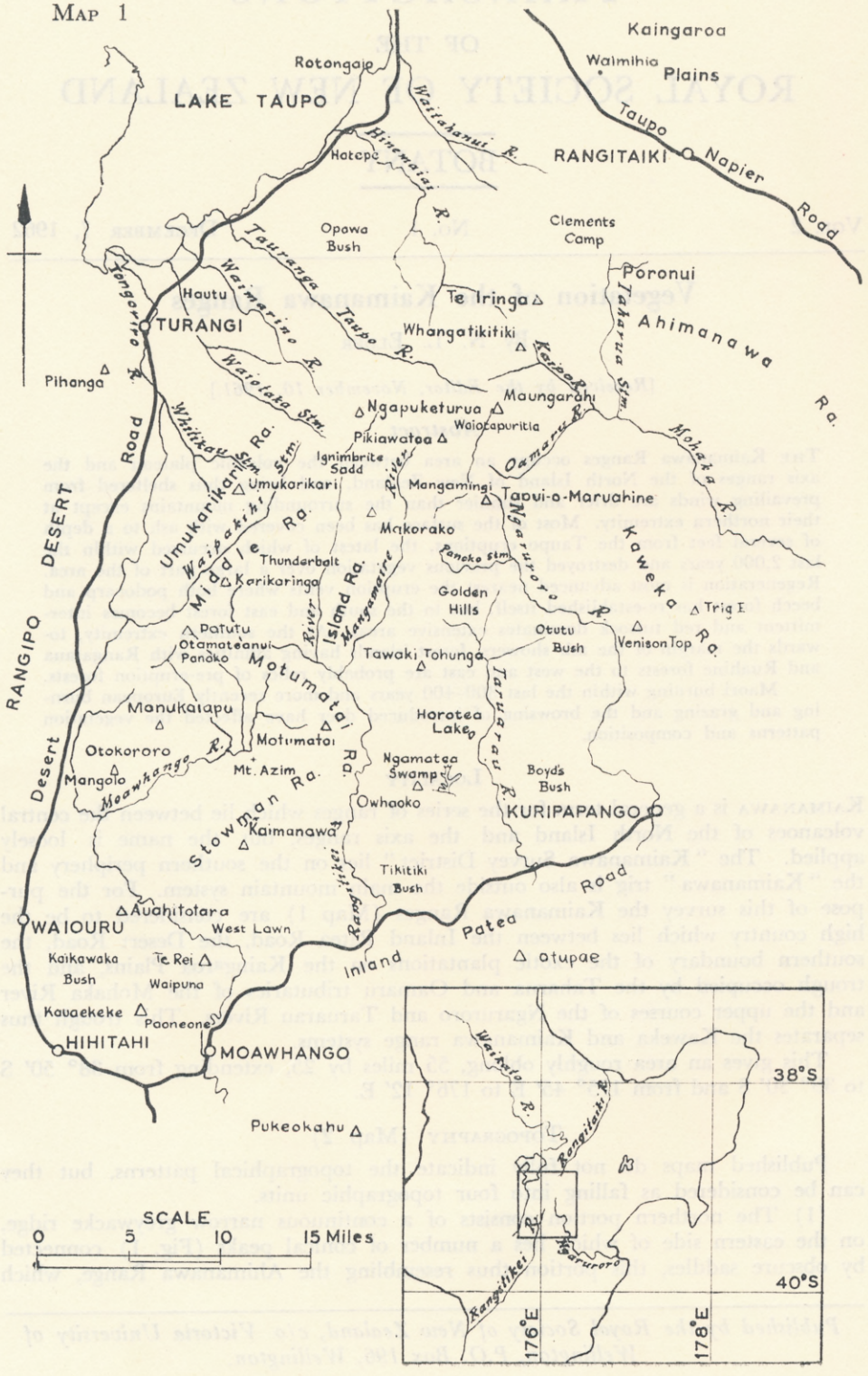
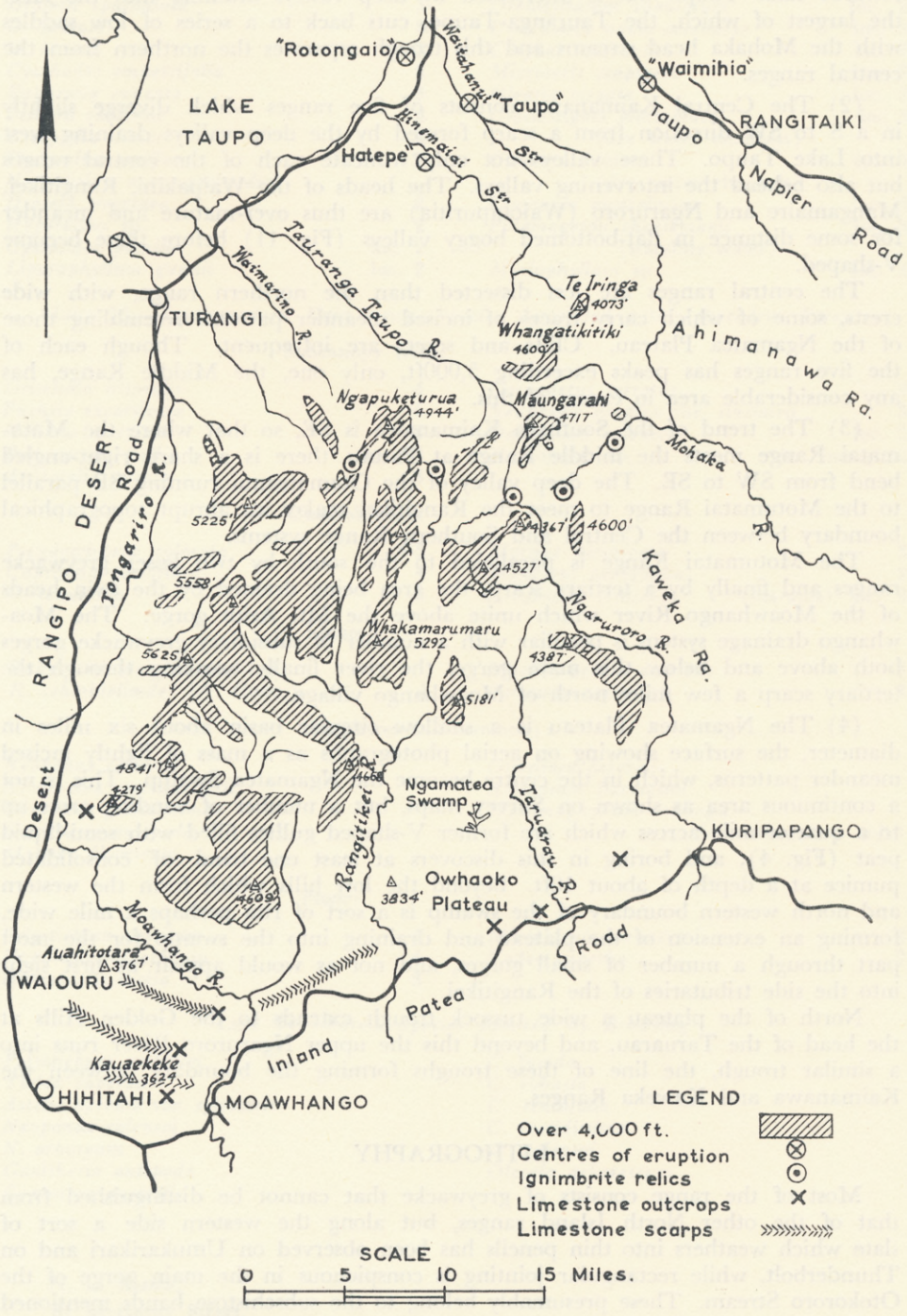
MAP 1


Kaingaroa
Plains
Walmihia
Rotongaio
LAKE TAUPO
Waitahanui R.
Hinemaiai R.
Hatepe
RANGITAIKI
Taupo
Napier
Road
Opawa
Bush
Clements
Camp
Poronui
Tauranga Taupo R.
Waimarino R.
Hautu
Te Iringa
TURANGI
Whangatikitiki
Karioi
Tahorua Stm.
Ahimanawa
Ra.
Pihanga
Waiotaka Stm.
Ngapuketurua
Maungarahi
Waiotapuritia
Oamaru R.
Mohaka R.
Pikiawatea
Ignimbrite
Sadd
Umukarikari Stm.
Umukarikari
Waipakihi Stm.
Middle Ra.
Mangamingi
Tapui-o-Maruahine
Makorako
Ngaruroro R.
Kaweka Ra.
Thunderbolt
Karikaringa
Island Ra.
Mangamaire River
Panoko Stm.
Golden
Hills
Trig E
Patutu
Otamatea
Panoko
Motumatai Ra.
Tawaki
Tohunga
Otutu
Bush
Venison Top
RANGIPO DESERT
Manukaiapu
Horotea
Lake
Motumatai
Otokororo
Mangolo
Mt. Azim
Ngamatea
Swamp
Boyds
Bush
Owhaoko
KURIPAPANGO
Stowman Ra.
Kaimanawa
Tikitiki
Bush
Rangitikei R.
Road
Auahitotara
WAIOURU
West Lawn
Patea
Inland
Otupae
Kaikawaka
Bush
Te Rei
Waipuna
Kauaekeke
Paoneone
HIHITAHI
MOAWHANGO
Pukeokahu
SCALE
0 5 10 15 Miles
Wairoa R.
Rangitaiki R.
Ngaruroro R.
Rangitikei R.
38°S
40°S
176°E
178°E

MAP 2


"Rotongaio"
Waitahanui
"Taupo"
"Waimihia"
LAKE TAUPO
Hinemaiai Str.
Hatepe
Taupo
RANGITAIKI
Napier Road
Taurangi Taupo R.
Waimarino R.
Te Iringa 4073'
Whangatikitiki 4600'
Ahimanawa Ra.
TURANGI
Ngapuketurua 4944'
Maungarahi 4717'
Mohaka R.
RANGIPO DESERT
Desert Road
Tongariro R.
5225'
4600'
4527'
5558'
Kaweka Ra.
Ngaruroro R.
Whakamarumaru 5292'
5625'
4387'
5181'
4841'
4279'
4668'
Ngamatea Swamp
Rangitikei R.
Taruarau R.
KURIPAPANGO
Owhaoko 3834' Plateau
4609'
Moawhango R.
Auahitotara 3767'
WAIOURU
Road
Patea
Inland
Kauaekeke 3629'
HIHITAHI
MOAWHANGO
LEGEND
Over 4,000 ft.
Centres of eruption
Ignimbrite relics
Limestone outcrops
Limestone scarps
SCALE
0 5 10 15 Miles.

also drains into the Mohaka River. On the western side the land slopes down towards Lake Taupo but is intersected by deep valleys draining into the lake, the largest of which, the Tauranga-Taupo, cuts back to a series of low saddles with the Mohaka head streams and this trough separates the northern from the central ranges.

(2) The Central Kaimanawa consists of five ranges which diverge slightly in a S to SW direction from a scarp formed by the deep valleys draining west into Lake Taupo. These valleys not only truncate each of the central ranges but also behead the intervening valleys. The heads of the Waipakihi, Rangitikei, Mangamaire and Ngarurоro (Waiotapuritia) are thus over-mature and meander for some distance in flat-bottomed boggy valleys (Fig. 11) before these become V-shaped.

The central ranges are less dissected than the northern range, with wide crests, some of which carry traces of incised meander patterns resembling those of the Ngamatea Plateau. Cliffs and screes are infrequent. Though each of the five ranges has peaks exceeding 5,000ft, only one, the Middle Range, has any considerable area in excess of this.

(3) The trend of the Southern Kaimanawa is SE, so that where the Motumatai Range meets the middle Range at Patutu there is a sharp right-angled bend from SW to SE. The deep valley of the Otamateanui running SE parallel to the Motumatai Range to meet the Rangitikei makes an abrupt topographical boundary between the Central and Southern Range systems.

The Motumatai Range is paralleled to the south by two lesser greywacke ranges and finally by a tertiary scarp, the area being drained by the twin heads of the Moawhango River which unite above the Mt. Azim gorge. The Moawhango drainage system is peculiar with a number of subsidiary greywacke gorges both above and below this main gorge, the river finally breaking through the tertiary scarp a few miles north of Moawhango village.

(4) The Ngamatea Plateau is a shallow circular basin about six miles in diameter, the surface showing on aerial photographs as a mass of lightly incised meander patterns, which in the centre become the Ngamatea Swamp. This is not a continuous area as shown on Survey maps, but a number of winding arms up to a quarter mile across which are former V-shaped gullies filled with semi-liquid peat (Fig. 4), and boring in this discovers at least one band of consolidated pumice at a depth of about 10ft. Beyond the low hills which form the western and north western boundary of the swamp is a sort of rim perhaps a mile wide, forming an extension of the plateau and draining into the swamp for the most part through a number of small gorges, and not as would appear at first sight into the side tributaries of the Rangitikei.

North of the plateau a wide tussock trough extends to the Golden Hills at the head of the Taruarau, and beyond this the upper Ngarurоro River runs into a similar trough, the line of these troughs forming the boundary between the Kaimanawa and Kaweka Ranges.

LITHOGRAPHY

Most of the range consists of greywacke that cannot be distinguished from that of the other North Island ranges, but along the western side a sort of slate which weathers into thin pencils has been observed on Umukarikari and on Thunderbolt, while rectangular jointing is conspicuous in the main gorge of the Otokororo Stream. These presumably belong to the subschistose bands mentioned by Grange as occurring in that area.

The tertiary deposits of the Moawhango form a prominent scarp 1,000 feet

in height running east from near Waiouru to the Rangitikei River, with scattered deposits continuing across the Ngamatea Plateau near the line of the Inland Patea Road. These consist of limestones and mudstones with a south-westerly slope. North of this shallow deposits of mudstones and limestones with a series of narrow bands of combustible coal, the greatest 7in thick, occur immediately upstream of the greywacke Mt Azim Gorge.

Patetere ignimbrite flanks the Northern Kaimanawa greywacke on both sides, extending down the Taharua River across the head of the Mohaka and up the Oamaru Valley as far as the Waitawhero tributary. On the western side ignimbrite is exposed as far south as the Waimarino and extends about three miles further into the upper Hinemaiai basin than is shown on the Tokaanu sheet of the Geological Survey. The river is slotted into spectacular cascades over three of these bands, the second of which has a fall of 240ft.

There is also a line of ignimbrite deposits south of this at a higher elevation (see Map 2), the largest of perhaps a couple of acres at Ignimbrite Saddle (3,960ft, Fig. 7) at the head of the Waimarino River, small hummocks at the head of the Mangamaire (3,900ft) where it was first recorded by McKay (1901), and a third forming a conspicuous castellated mound above the confluence where the Ngarurоro begins (3,100ft). About 4 miles down the Ngarurоro near the Te Matia confluence the river runs over a reef of what may also be ignimbrite.

ASH SHOWERS

The Taupo showers have been investigated by Baumgart (1954). He distinguishes four main showers and locates their sources, which lie in a cluster near the NE corner of the lake. His detailed investigation plots the distribution of ash over part of the Kaimanawa Range as far as the Tauranga-Taupo valley. The earliest of the "Taupo" series, the Waimihia shower, fell over 3,000 years ago on a strongly developed topsoil indicating a considerable period of quiescence since the deposit from the earlier Tongariro showers. The Waimihia shower covered the whole of the Kaimanawa Ranges and extended east as far as the coast of Poverty Bay, hence its alternative name of the Gisborne shower.

After a further period of quiescence three eruptions took place within a short interval, Hatepe, Rotongaio and the "Taupo shower" proper, the source of the last being about four miles up the Waitahanui Valley. The first two covered no great area, but deposited a considerable depth of ash close to their vents. The effect of these and the Waimihia shower has no appreciable bearing on the present-day vegetation, but the final Taupo shower has preserved abundant evidence, in the form of charred buried timber, that it fell at a considerable temperature, estimated as of the order of 250° C, at any rate within the radius of 30 miles, on forest which had established itself over much of the Waimihia ash, though there is little evidence of vegetation on the Rotongaio deposit, which in turn had fallen on bare, deeply gullied ash from the preceding shower.

In the case of the Taupo eruption, "shower" is a misnomer, at any rate in the vicinity of the vent. Ash profiles show a strong planing effect upon the underlying deposits, so that locally it behaved more like an ignimbrite flow exerting considerable lateral force.

The Taupo ash was deposited to a depth of 6in or more over an area of 8,800 square miles, within a radius of 60 miles from the vent with an extension eastwards to 90 miles, giving a pear-shaped outline. This includes the whole of the Kaimanawa, Kaweka and Ahimanawa Ranges with part of the Huiarau Range. The deposits become finer and shallower towards the margin, but there is one anomaly towards the south-west, where they become deeper and coarser; to account for this Baumgart suggests the possibility of a simultaneous eruption from a vent somewhere in the Rangipo Desert.

In the northern half of the Kaimanawa Ranges charred wood occurs in abundance in the pumice and also at the southern extremity in ash terraces where the Inland Patea Road crosses the Taruarau River.

At the present day the higher and more exposed ridges are for the most part bare of pumice. Their surface is typically of rock fragments carrying a sparse vegetation, but occasionally hummocks of pumice 2–3 feet high can be found, carrying a conspicuously denser vegetation. Frost striations and polygons are also developed on a large scale (Fig. 7) and appear to depend on a mixture of volcanic ash with greywacke fragments. These striations are actively working down-slope into unbroken tussock (Fig. 6) and elsewhere much of the exposed rock mantle is unweathered. This suggests a comparison with the Kaweka Range, from which much of the overlying pumice has been stripped by grazing and burning; in the Kaimanawa Ranges the indications are that browsing and particularly trampling by deer had a similar effect on the pumice blanket.

On the slopes of the range ash increases in depth and is remarkably stable, carrying a close cover of vegetation, and as slopes ease out it reaches a considerable depth. Gullies on the Taupo face have ash cliffs 300ft high, and within the range pumice wash forms characteristic terraces (particularly in the Waipakihi, Rangitikei and Ngaruroro valleys), which increase in height downstream to as much as 200 feet above the waterway (Fig. 10).

CLIMATE

Such factors as temperature, rainfall, evaporation, amount of sunshine and duration of snow cover have obvious effects on the distribution and composition of high country vegetation, but the difficulty of obtaining data on these is obvious and the need for it is only recently becoming apparent. The difficulty is acute in the case of the Kaimanawa and Kaweka Ranges, which together extend over one of the largest uninhabited areas of the North Island. Recording stations across the Inland Patea give a fair idea of the distribution of rainfall up to an elevation of 3,000ft in the southern part of the range, but in the north the stations round Lake Taupo lie in its basin and give no indication of the conditions in the ranges lying immediately above them.

Some conclusions about cloud and snow cover can be drawn by observation from the lower country around them, but most information depends on guessing from the topography and from the vegetation itself what the conditions are likely to be. Not unnaturally, with so large a margin of possible error, such estimates have tended to err on the conservative side and one illustration of this is a calculation not many years ago that the average discharge of the Tongariro River after allowing for evaporation was 37% higher than the total of the precipitation estimated for its catchment.

The need for the fuller utilization of hydro-electric resources and the growing awareness of the need for soil conservation and river control is now leading to investigation of hydrology in the high country and of its vegetation as a protection from erosion, and in consequence of this some information, mainly of rainfall, is already becoming available. Of particular relevance to the Kaimanawa Ranges is the recent hydrological survey of the Tongariro catchment for the Ministry of Works (Sutcliffe and Rangeley, 1960). This does not extend into the area of apparent highest rainfall, but gives valuable evidence of a steep increase of precipitation with altitude. From this the crest of the Middle Range (which had been reckoned to have a rainfall of under 100in from the appearance of its vegetation) is now given 140in.

(This illustrates the need for an upgrading of earlier estimates based on vegetation. For instance the Tararua Range at the time of a botanical survey

was given a maximum rainfall of 100–150in. Recordings on the drier side of the range now give over 160in at 2,400ft and over 200in at 4,800ft. Likewise gauges recently installed on the Kaweka Range, the driest section of the axis ranges, suggest a figure of the order of 120in at 5,600ft as against an earlier estimate of 70 + inches.)

In relating the climate of the Kaimanawa Ranges to the surrounding topography the most important feature is the bulk of the central volcanoes (Ruapehu, 9,175ft) which overshadow them to the west at a distance of 10 miles and shield all but the extreme northern portion from the prevailing westerly winds. They are shielded from the southerly winds by the Ruahine Range, and this appears to reduce the winter snowfall, while the Huiarau and Kaweka ranges screen them from the easterly winds which give heavy rainfalls on the Hawke's Bay side during tropical disturbances.

The main exposures of the Kaimanawa Ranges are thus from the south-west up the Rangitikei Valley and from the north across the Kaingaroa Plains, though it also appears that the lower ranges beyond Lake Taupo are not an effective barrier, so that a considerable proportion of the Kaimanawa rainfall comes from the north-westerly quarter. The low rainfall of the Inland Patea even up to an altitude of 3,000ft is evidence against an appreciable south-westerly component.

Estimates based on the vegetation show a sharply defined boundary between an area of high rainfall, or at any rate of high humidity in the Northern Kaimanawa Range and the drier central ranges. These closely resemble the Kaweka Range in their vegetation, which indicates a dry, sunny, and windless climate as compared with the other North Island ranges.

However, the conditions cannot be identical. The Kaweka Range receives a considerable proportion of its rain and cloud from a southerly quarter, and some intense rainfalls from the east, whereas in the Kaimanawa Ranges rain and cloud appear to come mainly from the north.

The distribution of rainfall is now known along the southern and western margin of the area. It ranges from as low as 40in on the Ngamatea Plateau to 45–60in across the rest of the Inland Patea, the 60in isohyet roughly following the boundary between the southern and central areas which has been determined on replacement of forest by tussock grassland. Rainfall increases to 90in at the head of the Rangipo "Desert" with a further increase to 100 + inches half way down the Desert Road before falling away to below 60in at the southern margin of Lake Taupo.

In the interior of the range rainfall is estimated to exceed 100in over most of the Umukarikari Range and to exceed 140in along the crest of the higher Middle Range from Patutu to above the head of the Waipakihi River. North of this the vegetation indicates that the highest humidities, if not precipitations, occur in spite of lower altitudes, but no information of rainfall is available.

HISTORY

The history of the range in so far as it affects the vegetation established since the last Taupo eruption, may be divided into Maori occupation, European settlement, and botanical and geological exploration and investigation.

Local tradition (Grace, 1961) connects permanent settlement round Lake Taupo with the arrival of the latest migrants from the Pacific; at first by driving the earlier inhabitants away from the coast, later in stages over a period of 200 years or so (p. 132) by tribes claiming descent from the Arawa canoe. Those of the earlier comers as retained their identity were forced into the higher and less hospitable country bordering the main ranges.

If the date of this last migration may be taken as 1350 A.D. and that kumara was then introduced into New Zealand, cultivation round the lake and in a few favoured sites away from it, as for example Paengaroa at the head of the Mohaka, had been going on for 300 years or more before the arrival of the first Europeans (Ward, 1956). In the higher country hunting techniques would have likewise affected forest margins.

Established routes ran along the boundaries of the area, and the present-day roads, the Napier-Taupo, Inland Patea, and Desert Roads follow the general line of these. There was also a route from the Mohaka River which followed the Oamaru-Ngaruroro-Taruarau boundary before cutting across the Ngamatea Plateau to the Rangitikei River. Flakes of obsidian have been picked up at several points on this route. Several routes also ran from east to west across the upper basin of the Moawhango, and another traditional cross-country route followed the Tauranga-Taupo valley.

Merino sheep were introduced round Lake Taupo by the Grace family in 1856, but were killed out, partly by wild dogs, during the Maori wars. Alfred Cox took up a lease south of the Napier-Taupo road in 1867-70, and the Birch brothers brought the first sheep to the Inland Patea in 1868.

The first written information comes from visits by Bidwill to Taupo in 1839 and by the missionary-botanist Colenso in 1847. The surveyors, Percy Smith and Cussens, traversed the country in the 1870's and 1880's. Alexander McKay's report on the geology of the Kaimanawa Ranges appeared in 1901. In 1911 B. C. Aston made two botanical visits to the Upper Moawhango and the Waipakihi Valley, but a comprehensive botanical survey only began in 1931 and has continued intermittently (because of the comparative remoteness of the area) up to the present.

FIRE

The general occurrence of charred timber buried under the latest ash shower indicates that it fell at a considerable temperature within at least a 30-mile radius of the vent. Charred timber also occurs occasionally towards the margin of the shower.

This and the patchwork patterns of forest and tussock outside the central area suggest that peripheral fires may have followed the eruption.

Maori occupation was accompanied by the use of fire to encourage the spread of bracken, whose rhizome was a staple food, and with the introduction of kumara and later of the European potato a system of shifting cultivation of forest clearings was extensive at lower levels. The margin of beech forest at higher altitudes was also affected by the practice of burning the adjacent tussock in the hunting of kiore (*Rattus exulans*).

Bidwill (1952) describes the process of forest burning in some detail round Taupo, and his estimates of a lakeside population of 5,000 gives an indication of the scale on which it was carried out. His description (p. 66) of the decrease in vigour of fern after repeated burning, its ultimate replacement by an open tussock association, and of the abandonment of potato cultivation after the third year is precise. He quotes Chapman as considering that all the scrubland round Taupo had resulted from burning, but disagrees on the ground that as potatoes had only been introduced 50 years previously the period was too short.

The introduction of the potato would have accelerated the rate of forest clearing, and to this extent Bidwill's criticism is justified. Firth (1959) makes the following illuminating comment (p. 488):

> "The results of the introduction of the potato bring out with clarity the manner in which new culture items affected the economic life and even the

environment of the native. The potato is of such a hardy nature that it can be grown in all districts and, moreover, is prolific, yielding a plentiful return for the labour expended. Hence it was speedily introduced into districts which, like Tuhoe, had formerly possessed no cultivated foods and also tended to replace the kumara amongst other tribes. Again it effectively supplanted the aruhe, the fern root (*Pteridium esculentum*), as one of the staple vegetable foods. Forest products were also neglected in its favour with interesting results. Formerly, the forest had been strictly preserved as being the source of berries, birds and rats; now, however, with the coming of the new food plant, this care became unnecessary, and year after year inroads were made upon it for potato cultivations. In some districts the forest destruction was quite marked."

Elsewhere (p. 65) he quotes Swainson that, in 1857, 8,000 people in the area of the Bay of Plenty had under cultivation nearly 3,000 acres in wheat, 3,000 in potatoes, 2,000 in maize, as against 1,000 acres in kumara, and it must be remembered that a proportion of these crops were grown under a system of shifting cultivation.

Elsdon Best (1924) describes in detail two methods of forest clearing for kumara cultivation, in one of which the canopy trees were left standing and only the understory burnt. This was the method used round Taupo and locally termed "whakaota". This method was used for potatoes in the neighbouring Ahimanawa forest margins up to 1900 (Sunderland, 1957) and perhaps as recently as 1950 (N. Weeks, pers. comm.). It is clear that a kumara technique was used for potatoes.

Fletcher (1914) gives evidence of the replacement of forest by scrub to the north of the lake over a period which he then estimated as 300 years. (This corresponds with the arrival of the Ngatituwharetoa tribe, but it should be noted that they had found a pre-fleet tribe, the Ngatihotu, in occupation. As kumara only arrived with the fleet, the latter may not have been concerned with forest cultivation, fern-root being their staple foodstuff.)

According to one of Fletcher's informants, evidence of the Oruanui forest having extended from Atiamuri on the Waikato River to the lake at Rangitira Point was visible as recently as 1845, while another informant gave traditional evidence that about 1775 forest extended eastwards from the Waikato River at Aratiatia on to the margin of the Kaingaroa Plain to include the Opepe Bush, and further south Motukino, reaching the lake at Waitahanui. At the present day islands of podocarp forest, such as Matangatera and Motupuka link this with the Opawa Bush, so that in fact it seems likely that podocarp forest was continuous round the whole of Lake Taupo before Maori occupation.

Hill (1911) adds further information about the original forest margin on the Kaingaroa Plain, while Henry (1954, 1955) gives supporting evidence from the Atiamuri area of former heavy forest on what is now scrubland and even on the inhospitable hollows known as frost flats.

The capture of kiore is described in some detail by Elsdon Best (1942):

"The Maori knew when rats would be numerous in the land; they knew this by observing the flower and mast of the beech trees; when these foretold a plentiful season, then it was known that the rats would be numerous . . .

"When forest foods grew scarce numbers of rats would betake themselves to the open lands supporting mainly scrub and fern, such land is described by the term 'parae' (level or undulating open country). When the beech mast came to an end then rats often sought such 'parae', where they lived in holes or burrows; when they became numerous at such places the fern would be burned off, at least in some cases. After the fire the natives would search diligently the burnt

area and dig the rats out of their holes; at such times quite a number would often be found in one hole."

Mr. Batley, of Moawhango, comments:

". . . (This) might well apply to such areas as Mangaohane, Owhaoko and Oruamatua where the native rat was always abundant and formed an important food-item in pre-European days."

Place names in the upper Moawhango indicating fire (ahi) such as Auahitotara and Nga Motu o te Ahi Maire are of some historical and possibly ecological interest.

Pre-European fires affecting beech forest are repeatedly mentioned by Colenso in his early missionary journeys, as for instance in 1847 near Poronui and on the edge of the Rangipo Plain, and in 1851 near Kuripapango, and he also records fern fires near Matuku on the Inland Patea. Percy Smith in 1871 describes the Tikitiki Bush (Fig. 3) as a thicket of dense 20-year-old regeneration (this has recently been confirmed by tree-ring counts).

Thus local evidence of pre-European fires is widespread.

However, with the coming of Europeans and the early introduction of sheep on the Inland Patea, the regular burning of tussock has affected practically all these forest margins and many islands of beech forest have regenerated since being swept by fire, most of them about the 1880's. Even well into the range between the Mangamaire and Rangitikei Rivers the area known as Mesopotamia and the whole face of the Mangamaire up to the timberline of the Makorako Range have been burnt and the forest partly or completely replaced by subalpine scrub, tussock or frequently a carpet of *Celmisia spectabilis.*

FAUNA

INDIGENOUS. Birds are generally plentiful, surprisingly so for beech forest, though individual estimates of their abundance have fluctuated over the past 20 years. Tui, bellbird, parakeets, fantail, morepork, rifleman, whitehead and warbler (the latter as high as 5,000ft in subalpine scrub) are common in forest, and robins are frequent, while in podocarp forest such as the Opawa Bush pigeons and kaka are plentiful. Paradise ducks are common on open river beds, and pipit on all open ground. Kiwi have been heard and their probings seen, wekas heard and whio (blue mountain duck) are frequent in several rivers. Black shag colonies have been seen in the Waiotaka and a pied shag in the Oamaru. Shining cuckoos are numerous in summer. Harrier hawks are common in open country and a nest has been found in scrub at 4,000ft. Sparrow hawks have been encountered occasionally. The former abundance of kiore on the Inland Patea has already been mentioned and kakapo were also hunted here. Moa bones have been collected at Waipuna (Moawhango).

INTRODUCED. PIG. Though the earliest introduced animal, most of the country is too high for pig, and as the low country towards the lake is comparatively accessible to hunters they are not of great significance.

SHEEP. Sheep were run round the northern end of the ranges as early as the 1850's and were introduced on the Inland Patea in 1868. Stocking here was fairly heavy in the early stages, but is now considerably reduced. Owhaoko station (also known as Ngamatea, the names being interchangeable) still musters to the head of the Ngaruroro and Mangamaire Rivers and even the crest of the Makorako Range, but the whole of the head basin of the Moawhango River is now unstocked. There are still traces of some old fences, but most of the country is unfenced. Stray sheep are encountered only infrequently on the margins of the range and they hardly seem to have established themselves in wild flocks on the scale of the Kawekas.

WILD HORSES. R. T. Batley's diary (1876) notes that tracks of horses were seen on the Motumatai Range, so wild horses seem to have been established in the upper Moawhango tussock for over 80 years. At the present day they have only been seen in small numbers, but their close-grazing pattern is evident, and over so long a period must be taken to have modified the vegetation of the upper Moawhango, perhaps considerably.

The name "Brumby Ford" on the Hinemaiai River a little above the new hydro-electric dam indicates that they range on the scrub-tussock flats further up the valley, though none have actually been seen in the last ten years.

CATTLE. Wild cattle occur on the forest margin of the Hinemaiai and have also been reported in the Tauranga-Taupo valley.

GOATS. Goats have recently (1956) been liberated near the Te Rei forest.

RABBITS. I do not know the history of rabbits to the north of the range, but their arrival on the Inland Patea is a curious story. In January, 1900, R. T. Batley informed the Rabbit Inspector at Waipukurau (Hawke's Bay) that rabbits had appeared across the Rangitikei River on the Mokai Patea Plateau, having apparently taken advantage of a recently cut track to gain access to the Ruahine Range. Shortly after this they spread across the river into the tussock country of the Inland Patea, where they had increased to such numbers by about 1920 that grazing leases over large areas of native land were said to have been allowed to fall in.

Mr Nicholls, of the Forest Research Institute, has called my attention to a description by B. C. Aston (1911b) of a heavy concentration of rabbits as early as 1910 on the tussock flats at the head of the Waipakihi. Although he gives evidence of exceptionally heavy damage to the vegetation and states this had reached the stage where it would have been impossible to visualize the original plant cover no suspicion of this has been aroused in botanical examinations of this basin from 1933 onwards.

Rabbiting has been steadily carried on in the tussock country since the 1920's, and only scattered pockets of rabbits have been noticed from 1930 onwards, with no indication of them over wide areas.

MICE. The widespread occurrence of mice in or near beech forest over a period of 10 months from the winter of 1955 included the Kaimanawa as well as the Ruahine and Kaweka Ranges. As this followed the heavy mast-fall of the autumn of that year it may prove to be a significant phenomenon. No previous records of forest-ranging mice are recorded for the central North Island, and it is possible that they are filling the niche formerly occupied by the native rat.

RED DEER (*Cervus elaphus*). The nearest early red deer liberations recorded are Matapiro (Hawke's Bay) in 1883, Tongariro in 1896 and 1905, and Galatea in 1897. Forbes (1924) shows "Kuripapanga-Kaimanawa Mountains" as the main area occupied by his Hawke's Bay herd, so that the Kaimanawa Ranges were presumably colonized from the eastern (Matapiro) liberation, which was incidentally the largest one (11 animals), rather than from the northern or western sides. The initial spread was rather slow, the first stag being sighted on Ngamatea station in 1903 (Masters, p. 17). By 1930 deer were abundant with well-developed track systems and forest undergrowth heavily browsed (List 14) but with dead standing *Neopanax* still conspicuous, a useful indicator of the stage of browsing pressure. The population had probably reached or passed its peak in 1930 as a traverse of the range three years later, in company with J. H. Gibbs, an experienced bushman and hunter, produced his comment that the numbers were decreasing, with tracks falling into disuse and browsed shrubs making fresh growth. However, large mobs of 40-50 were then seen browsing in the open

near forest margins. About 1938 Ngamatea station was forced to close its back country because of competition of deer for feed.

Deer-culling operations began in the Kaimanawas in the 1937-1938 season, and the following tallies give some indication of the decline in population since then, for which shooting is unlikely to be the sole factor:—

Season	Duration in Months	Deer Shot
1937–38	11	7,200
1940–41	13 (plus Kaweka)	2,975
(War years)		
1944–45	8	1,519
1945–46	12	1,686
1946–47	8	1,745
1947–48	6	1,065
1948–49	8	1,193

A traverse of the range in 1938-39 sighted few deer, and another in 1947 only sighted half-a-dozen in nine days' travelling.

JAPANESE DEER (*Cervus nippon*). Although from casual observation it is difficult to distinguish between red and Japanese (or sika) deer the pattern of their spread has been very different, while their behaviour and to some degree their choice of habitat affect both their impact on the vegetation and the problem of their control.

Whereas red deer had spread widely throughout the Kaimanawa Ranges from outside liberation points to reach a high population certainly not later than 1930 (it is curious, however, that Aston makes no reference to them as late as 1911), Japanese deer, liberated on Poronui in 1905, showed no corresponding tendency and as recently as 1945 appeared to be still confined to the vicinity of the Ruatea Valley, which had become known locally as Jap Creek. By this time red deer were through all the surrounding country and had long passed their peak population.

About this time, 40 years after their liberation, Japanese deer began to spread rapidly, at first down the Mohaka and from there along the Hawke's Bay face of the Kaweka Range, then a little later to the north, across the Kaingaroa Plain in the Huiarau Range.

When Logan made a survey of their distribution in 1957 they had also established themselves in the Ruahine Range, down the western face of the Kaimanawa Ranges and across the Rangipo Desert on the flanks of Ruapehu.

The reason for their initial movement is not obvious. Though the density of animals in their home area was high their condition was good and signs of overgrazing were absent. Disturbance due to hunting is a possibility. Their spread has mainly been into forest previously eaten out by red deer in which red beech is dominant, and into adjacent scrubland. They appear able to thrive in forest recovering from overgrazing. On account of their elusive habits hunting is less effective than against red deer, and in fact by reducing browsing competition may produce favourable conditions for the build up of populations of Japanese deer.

As far as their effect on vegetation can be distinguished they appear to congregate in larger numbers and browse more intensively than red deer.

OPOSSUM (*Trichosurus vulpecula*). From information supplied by Mr Pracey, of the Opossum Investigation Unit, only one liberation (Oamaru) is known within the range. As recently as 1954 opossum were still spreading into the range, particularly up the Rangitikei River from Aorangi (Ruahine) liberations. A light to scattered population is widespread,

To date traces of browsing on *Fuchsia* or *Aristotelia* have seldom been seen, though the eating of petiole sheaths of *Neopanax* has been recorded sporadically and a Forest Survey team reports (December, 1959) traces of bark biting on *Pseudowintera* in the Whitikau Valley, which indicates an excessive local concentration.

VEGETATION

(In order to simplify the text common names are used for the various species of *Nothofagus*; also for the two species of tall tussock at present included under *Danthonia raoulii* where the nomenclature is admittedly inadequate. For the same reason only the more important or significant species are referred to in discussing the various communities and lists of associated species are transferred to appendices.)

NATURAL AREAS

The general pattern is of an arc of higher and steeper country to the north and west on which, in spite of its proximity to the origin of the Taupo pumice shower, forest has largely regained its footing, while to the south and east easier, lower country forms another arc dominated by red tussock (*Danthonia* sp.) with discontinuous islands of forest. (Map 3.)

The forested areas can be subdivided according to the dominance in the upper zone of silver beech (*Nothofagus menziesii*) or mountain beech (*N. solanderi* var. *cliffortioides*) into a northern (wetter) and central (drier) zone.

Red tussock is dominant to the east and south of this, but can be subdivided on the dominants of the forest islands into southern, with islands of beech, and south-western, with islands of cedar (*Libocedrus bidwillii*); the latter is of some ecological importance as it lies between the *Libocedrus* forest of the western side of the volcanic plateau and that of the western Ruahine Range.

The subdivisions thus become:

1. NORTHERN KAIMANAWA. Silver and red beech (*Nothofagus fusca*) dominant.
2. CENTRAL KAIMANAWA. Mountain beech dominant.
3. SOUTHERN KAIMANAWA. Red tussock dominant with islands of beech forest (mainly mountain beech).
4. SOUTH-WESTERN KAIMANAWA. Red tussock dominant with islands of *Libocedrus* forest. (Map 4.)

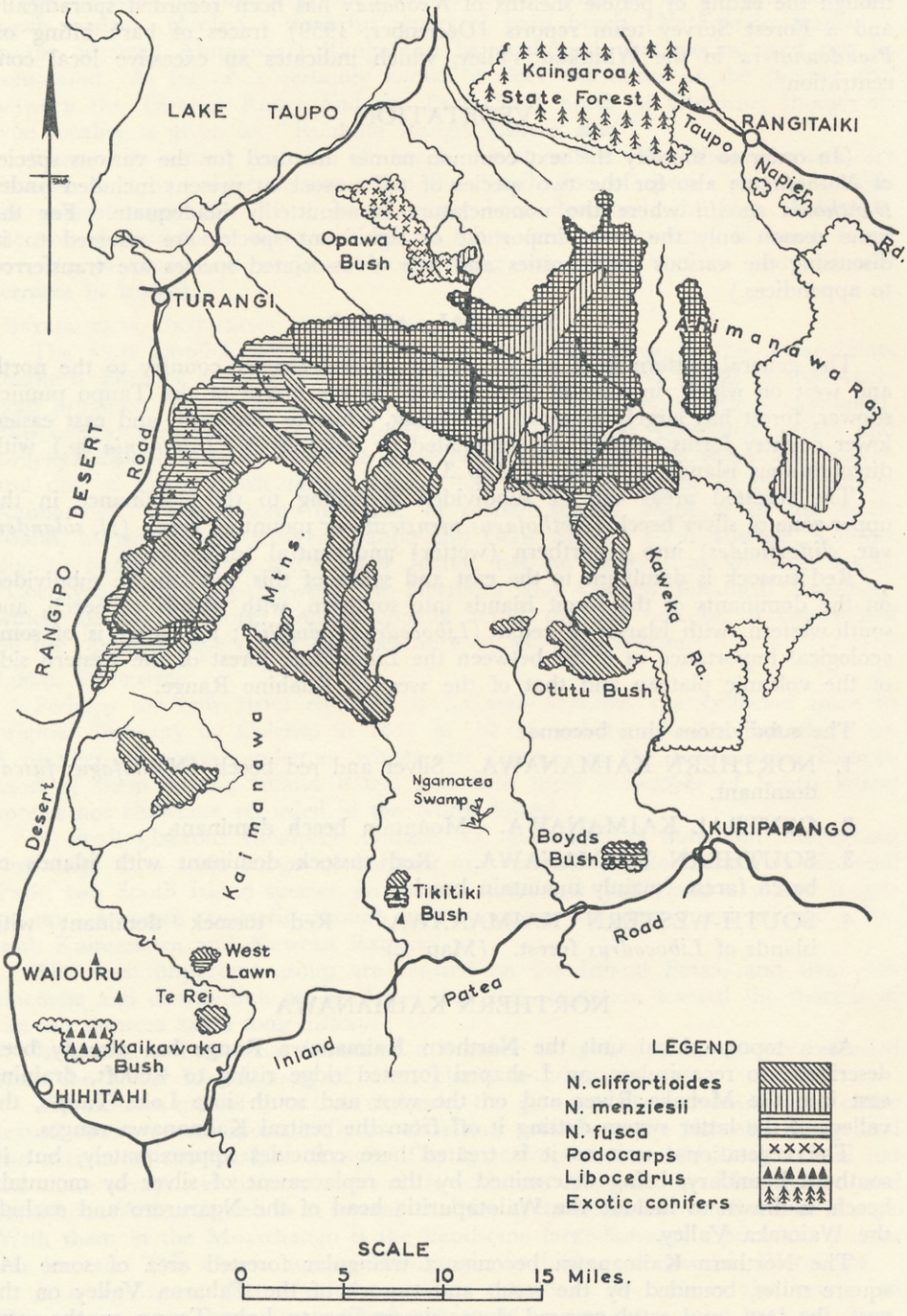
NORTHERN KAIMANAWA

As a topographical unit the Northern Kaimanawa Range has already been described: to recapitulate, an L-shaped forested ridge rising to 4,600ft, draining east into the Mohaka River and on the west and south into Lake Taupo, the valleys of the latter system cutting it off from the central Kaimanawa ranges.

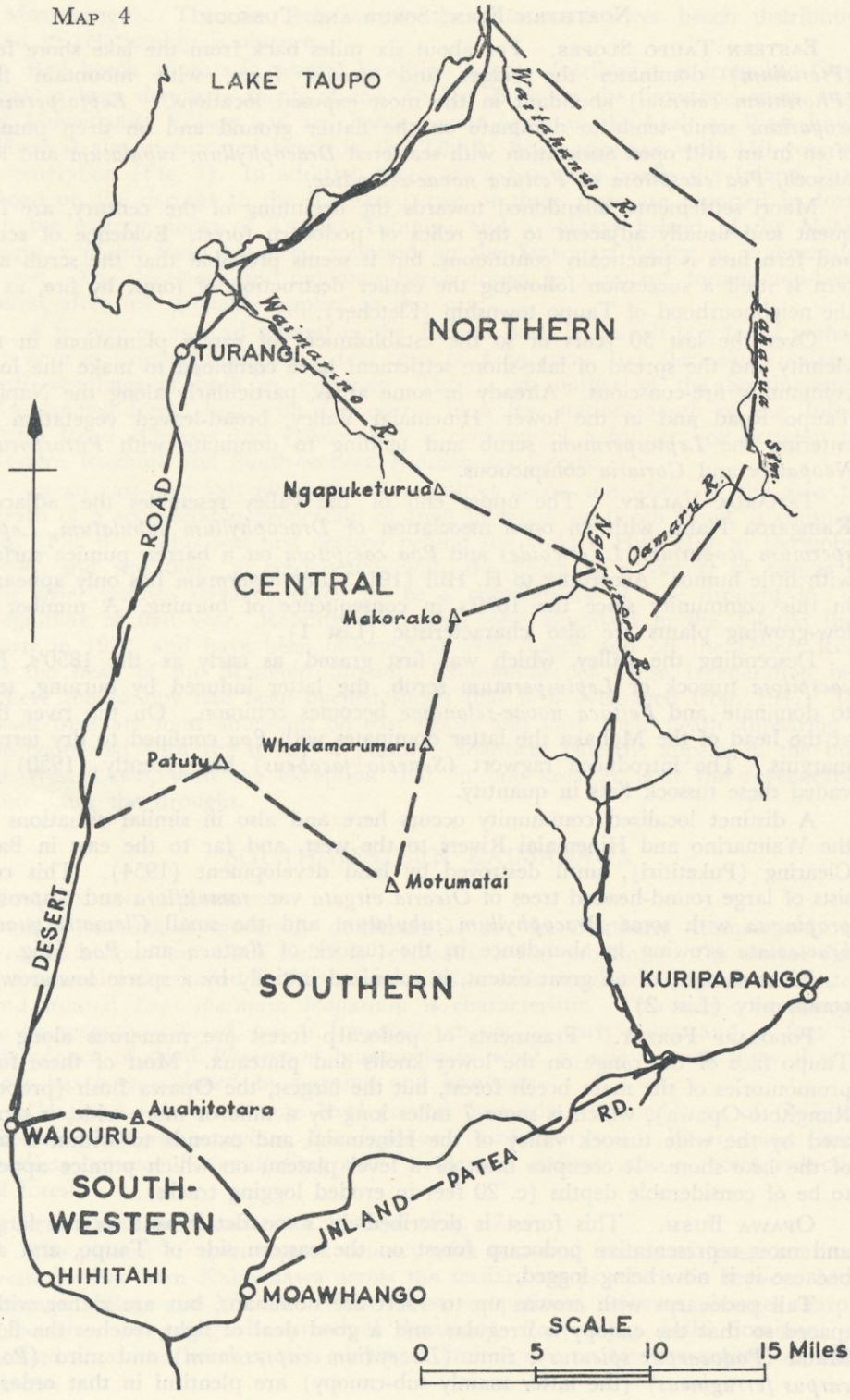
The vegetational unit as it is treated here coincides approximately, but its southern boundary, being determined by the replacement of silver by mountain beech, is drawn to include the Waiotapuritia head of the Ngarurоro and exclude the Waiotaka Valley.

The Northern Kaimanawa becomes a triangular forested area of some 140 square miles, bounded by the scrub and tussock of the Taharua Valley on the east, the fern- and scrub-covered slopes descending to Lake Taupo on the west, and the tussock between Ngapuketurua and the upper Ngarurоro forming part of its southern boundary.

MAP 3


LAKE TAUPO
Kaingaroa State Forest
RANGITAIKI
Taupo
Napier Rd.
Opawa Bush
TURANGI
Ahimanawa Ra.
RANGIPO DESERT
Road
Kaimanawa Mtns.
Kaweka Ra.
Otutu Bush
Ngamatea Swamp
Boyds Bush
KURIPAPANGO
Tikitiki Bush
Road
Patea
Inland
Desert
Kaimanawa
WAIOURU
West Lawn
Te Rei
Kaikawaka Bush
HIHITAHI
LEGEND
N. cliffortioides
N. menziesii
N. fusca
Podocarps
Libocedrus
Exotic conifers
SCALE
0 5 10 15 Miles.

MAP 4


LAKE TAUPO
Waitahanui R.
Waimarino R.
NORTHERN
TURANGI
Taharua Stm.
ROAD
Ngapuketurua
Oamaru R.
Ngaruroro R.
CENTRAL
Makorako
Whakamarumaru
Patuty
DESERT
Motumatai
SOUTHERN
KURIPAPANGO
Auahitotara
WAIOURU
RD.
PATEA
INLAND
SOUTH-
WESTERN
HIHITAHI
MOAWHANGO
SCALE
0 5 10 15 Miles

NORTHERN FERN, SCRUB AND TUSSOCK

EASTERN TAUPO SLOPES. For about six miles back from the lake shore fern (*Pteridium*) dominates the ridges and steeper faces, with mountain flax (*Phormium colensoi*) abundant in the most exposed locations. *Leptospermum scoparium* scrub tends to dominate on the flatter ground and on deep pumice often in an arid open association with scattered *Dracophyllum subulatum* and low tussock, *Poa caespitosa* or *Festuca novae-zelandiae*.

Maori settlements, abandoned towards the beginning of the century, are frequent and usually adjacent to the relics of podocarp forest. Evidence of scrub and fern fires is practically continuous, but it seems probable that the scrub and fern is itself a succession following the earlier destruction of forest by fire, as in the neighbourhood of Taupo township (Fletcher).

Over the last 30 years or so the establishment of exotic plantations in the vicinity and the spread of lake-shore settlement have combined to make the local community fire-conscious. Already in some areas, particularly along the Napier-Taupo Road and in the lower Hinemaiai Valley, broad-leaved vegetation is entering the *Leptospermum* scrub and tending to dominate with *Pittosporum, Neopanax* and *Coriaria* conspicuous.

TAHARUA VALLEY. The upper end of the valley resembles the adjacent Kaingaroa Plains with an open association of *Dracophyllum subulatum, Leptospermum scoparium, L. ericoides* and *Poa caespitosa* on a barren pumice surface with little humus. According to H. Hill (1911) *Leptospermum* has only appeared in this community since the 1870's in consequence of burning. A number of low-growing plants are also characteristic (List 1).

Descending the valley, which was first grazed as early as the 1850's, *Poa caespitosa* tussock or *Leptospermum* scrub, the latter induced by burning, tend to dominate and *Festuca novae-zelandiae* becomes common. On the river flats at the head of the Mohaka the latter dominates with *Poa* confined to dry terrace margins. The introduced ragwort (*Senecio jacobeus*) has recently (1950) invaded these tussock flats in quantity.

A distinct localized community occurs here and also in similar situations on the Waimarino and Hinemaiai Rivers to the west, and far to the east in Ball's Clearing (Puketitiri), until destroyed by land development (1954). This consists of large round-headed trees of *Olearia virgata* var. *ramuliflora* and *Coprosma propinqua* with some *Dracophyllum subulatum* and the small *Clematis quadribracteolata* growing in abundance in the tussock of *Festuca* and *Poa* (Fig. 1).

River shingle, of no great extent, is colonized initially by a sparse low-growing community (List 2).

PODOCARP FOREST. Fragments of podocarp forest are numerous along the Taupo face of the range on the lower knolls and plateaux. Most of these form promontories of the main beech forest, but the largest, the Opawa Bush (properly Rangitoto-Opawa), which is some 7 miles long by a mile or more wide, is separated by the wide tussock valley of the Hinemaiai and extends to within a mile of the lake shore. It occupies most of a level plateau on which pumice appears to be of considerable depths (c. 20 feet in eroded logging tracks).

OPAWA BUSH. This forest is described in some detail as it is the largest and most representative podocarp forest on the eastern side of Taupo, and also because it is now being logged.

Tall podocarps with crowns up to 150ft are dominant, but are rather widely spaced so that the canopy is irregular and a good deal of light reaches the floor. Matai (*Podocarpus spicatus*), rimu (*Dacrydium cupressinum*) and miro (*Podocarpus ferrugineus*) (the latter mainly sub-canopy) are plentiful in that order of

abundance. Kahikatea (*P. dacrydioides*) is also frequent, but totara (*P. totara*) rather rare. The latter, however, has probably been cut out selectively over a long period. The remains of adzed slabs not only in the ruins of adjacent Maori settlements but also in the forest itself and occasionally old cut stumps indicate that it had preferential use.

Both black and white maire (*Gymnelaea cunninghamii* and *G. lanceolata*) are frequent as sub-canopy trees and their seedlings common as are those of *Knightia excelsa* though no adults were recorded.

Large trees of red beech are common throughout the forest forming a lower canopy between the podocarp crowns, and there are a few pure stands. Here more light reaches the floor and *Cyathodes fasciculata, Myrsine australis* together with beech saplings form a distinct community.

In the main forest there is a wide variety of undershrubs whose composition indicates that a good deal of light reaches the floor (List 3). A narrow-leaved form of *Rubus cissoides* is abundant here.

FOREST MARGINS. Towards the edge of the Opawa plateau the forest margins consist of interesting communities which show a vigorous growth outwards. A dense narrow screen of *Leptospermum ericoides* which is infrequent elsewhere is 15–20ft high and contains much drawn-up *Neopanax arboreum* and *Pittosporum tenuifolium.* Behind this on the eastern and southern margins there is a dense belt of pole *Weinmannia racemosa* in which young podocarps, infrequent in the main forest, are plentiful.

On the western boundary the place of *Weinmannia* is taken by a distinct and striking community dominated by silver beech (up to 27in diameter) with *Olearia rani, Pimelea tomentosa* and podocarp seedlings plentiful. (Elsewhere in the area silver beech is a common pioneer species on the margins of red beech as well as of podocarp forest.) An interesting indication of its rate of advance on the margin of the Opawa Bush is that at one point this forest has overgrown a small Maori settlement through the ruins of buildings.

NORTHERN BEECH FOREST

This is the main type of forest and falls into three communities:

(1) Red beech dominant.

(2) Silver beech dominant.

(3) Silver/mountain beech ecotone.

(1) RED BEECH FOREST. Red beech, with silver beech subdominant and usually sub-canopy, dominates the forest from the outer boundary, which approximately follows the 2,000ft contour to 3,700ft, but it is confined to the drier sites on the slopes above Poronui (Taharua), where silver beech replaces it on the valley floors. Undergrowth is generally sparse, but evidence of long occupation by deer can account for this (List 4). The rarity of *Podocarpus hallii, P. ferrugineus* and *Weinmannia racemosa,* the latter being confined to the margins of pumice cliffs, the comparative absence of the heaths *Cyathodes* spp. and the restriction of the ground ferns *Blechnum discolor* and *Dicksonia lanata* to well drained sites contrast with red beech forest elsewhere in the central North Island in which these are common components; the distribution of ground ferns and in some areas red beech itself indicate that conditions are wet for red beech forest.

The change from podocarp islands and promontories on the Taupo side to beech forest is very sharp and the infrequency of *Dacrydium cupressinum* and *Podocarpus spicatus* once the latter is entered is striking.

The occurrence of a northern podocarp, *Phyllocladus glaucus*, in a limited area near the head of the Waimarino, where it is frequent, is an extension of its previously known range.

Although continuous red beech forest extends on one side to the Tongariro River and on the other down the Mohaka it is poorly represented and absent from considerable areas of the Central and Southern Kaimanawas between these river systems. Consequently the boundary of the Northern Kaimanawa east of Ngapuketura may be taken as that of red, as well as of silver, beech. This pattern is paralleled in the adjacent part of the Kaweka Range, though not so sharply, as both beeches appear intermittently for some distance down the Ngarururoro Valley.

As the boundary is approached silver beech tends to dominate, red beech to occur sporadically in all-aged stands in sheltered basins or on drier ridges; both species are finally replaced by mountain beech.

An exception to the general state of the forest is the basin at the northern end where the New Zealand Forest Service are conducting interesting experiments at Clement's Camp with the aim of establishing a managed beech forest. The canopy is being opened in stages to encourage regeneration, selected trees being felled and removed as fencing material, so that the floor is not as disturbed as it would be by logging. In addition to beech regeneration a striking feature is the abundance and variety of undergrowth, including palatable species which are scarce away from the workings. The disturbance of deer by operations is having evident results.

(2) SILVER BEECH FOREST. From the upper limit of red beech forest at about 3,700ft silver beech is the sole dominant over most of the area reaching its maximum altitude on Whangatikitiki at 4,600ft and Maungarahi at 4,500ft. As already mentioned, it replaces red beech at lower altitudes on the Taharua face.

In general silver beech forest is composed of mature trees with a close even canopy, but towards the southern boundary, particularly round Pikiawatea, large overmature trees with a somewhat broken canopy and considerable areas of windthrow which tend to be invaded by pole mountain beech grade into the silver-mountain beech ecotone, which is described below.

Shrubs are sparse (List 5), but that this is partly due to deer is shown by the list of associated cliff species distinguished rather for palatability (List 14) than for natural rupestral habit. Several of these are also common as ephiphytes, which are particularly conspicuous on the western slopes of Maungarahi. A solitary ephiphytic tussock of *Danthonia cunninghamii* calls for mention, as this is the only record of its occurrence in the whole of the Kaimanawa Ranges.

Filmy ferns and bryophytes clothe tree trunks and branches in abundance and *Hymenophyllum multifidum* and the upright moss *Dendroligotrichum dendroides* form closed communities over extensive areas of the floor, while colonies of *Sphagnum* are common in hollows at lower altitudes. This dense floor cover appears to follow the abandonment of forest by deer after it has been heavily browsed to the virtual elimination of palatable shrubs.

Beech seedlings are scarce within the forest, but where the canopy has been broken a dense growth of saplings in light pools is characteristic, sometimes including a few red beech saplings well above their usual range. One clearing round Te Iringa trig. (4,073ft) is occupied by pole silver beech already forming a canopy and cut stumps indicate that this has taken place since the survey in the 1880's.

FOREST MARGIN. At the head of the Waiotapuritia (Ngarururoro) Valley where pure silver beech forest abuts on red tussock there is a distinct marginal

belt of dense *Phyllocladus alpinus* 50-300 yards wide with scattered *Dacrydium bidwillii* as a small tree and a marginal underscrub of *Dacrydium subulatum* and *Pittosporum anomalum* which is locally common. The *Phyllocladus* on its inner margin is drawn up and frequently dead, while beech saplings are common. At first sight this suggests a rapidly advancing ecotone, but the slow growth-rate of *Phyllocladus* (110 rings to 1in) shows that the marginal fringe is a long-standing one.

(3) SILVER/MOUNTAIN BEECH ECOTONE. Mountain beech takes the place of silver beech in the Kaweka Range to the east and in most of the Central Kaimanawa Range to the south. The ecotone with the Kaweka stretches beyond the Oamaru boundary into that range, but the southern ecotone makes the complete transition in the length of the Waiotapuritia Valley (4 miles).

Mountain beech first appears (apart from small swamp communities and scattered trees on stream and forest margins) on the peaks above the Kaipo Valley where it is mainly associated with silver beech but forms pure stands in limited areas above 4,100ft. A similar pattern occurs to the west at the head of the Waimarino River. On Maungarahi though pure silver beech forms the timberline on the western side, mountain beech forms the timberline on the east. Going south from the trig. mountain beech appears within half a mile, at first as a narrow belt of young pole timber, which widens until four miles south at the end of the ridge it is dominant above 3,600ft and common below this (Fig. 2). Silver beech may dominate on shady faces up to 4,000ft but usually in groups of overmature trees.

Above 3,600ft the pattern is of younger mountain beech replacing older silver beech in the canopy, but at the same time saplings and seedlings of the latter frequently dominate the undergrowth below a mountain beech canopy. The same pattern has been noted on the Kaweka side of the ecotone and elsewhere at about 4,000–4,200ft.

The lower forest margins along the tussock valley also show the progressive entry of mountain beech from 3,400ft at the head to 3,250ft at the confluence where the Ngaruroro River begins.

The *Phyllocladus/Dacrydium* margin of silver beech forest which has been previously mentioned ceases abruptly at the incoming of mountain beech, whose saplings give on to tussock mixed with a good deal of *Dracophyllum subulatum*. *Phyllocladus* persists, however, in the narrow gullies that intersect the pumice terraces at intervals and in these forms pure stands (Fig. 2). One curious feature of the junction joint of silver beech and mountain beech margins is the repeated occurrence of a few saplings of hybrids between the latter and red beech although red beech is only a minor constituent of the immediate forest.

Red beech dominates in limited areas lower down the valley but the belt of mountain beech broadening both from above and below pinches both red and silver beech out on the western side beyond which mountain beech is a pure dominant for the whole length of the Central Kaimanawas. Silver beech at its extreme limit on the western side of the Ngaruroro confluence is in a narrow wedge of all-aged trees, saplings and seedlings, at an altitude of 3,600ft.

Below the confluence the outlying forest island under Tapui o Marua Hine, the prominent peak across the Ngaruroro Valley from the Oamaru Saddle, contains all three species of beech distributed by altitude.

SUB-ALPINE SCRUB. The flat summit of Maungarahi (4,717ft) is the only area of any extent that lies above the timber line. There is also a small area on Pikiawatea. Maungarahi is covered by a low scrub of particular interest in that in January, 1939, there was evidence near the trig. of a recent fire, leaving an open community dominated by a *Hebe* swarm, consisting of *Hebe odora,*

H. tetragona and *H. venustula* with abundant hybrids. Fresh gullying of the pumice surface was also conspicuous. Within ten years mixed scrub in which *Hebe* was no longer dominant and hybrids infrequent was approaching a closed community. (A similar succession has been observed in the Central Kaweka Range on Venison Top between 1930 and 1952, also following a fire above the timber line.) The composition of the scrub on Maungarahi otherwise has no characteristic distinguishing it from the subalpine scrub elsewhere in the Kaimanawa Ranges (List 10, cf. also Lists 8 and 9).

WAIOTAPURITIA TUSSOCK (Fig. 2). This valley is essentially a northern prolongation of the Inland Patea tussock. Red tussock, except where it has been thinned by burning, forms a dense cover on the valley floor and the lower terraces, which are frequently boggy, sparser red tussock giving way to low *Poa* tussock on the higher, often extremely arid terraces. There is a striking scrub-forest community along the stream banks composed of glaucous-green *Phyllocladus alpinus,* bright-green *Hebe parviflora* var. *arborea* (the round-headed form that is abundant in the central North Island ranges) and dark-green *Dacrydium bidwillii,* which grows here in the unusual form of a 10–12ft multitrunked tree. Large bushes of *Coprosma propinqua* and *C. parviflora* with interlaced *Aristotelia fruticosa* and the locally abundant *Pittosporum anomalum* are associated undershrubs, together with *Dracophyllum subulatum* and occasional *Leptospermum scoparium.* The latter is not plentiful near the valley floor, but where burns have run up the higher slopes may dominate an induced scrub formation.

It should be put on record that on a recent visit the flats of this valley which are several hundred yards wide showed evidence of having been covered by a recent flood, probably the exceptional flood of February, 1958. Though no serious scouring was seen here or downstream in the main Ngarururoro Valley, the flats in the adjacent Tauranga-Taupo are reported to have been buried under a deposit of logs and pumice wash.

CENTRAL KAIMANAWA

FOREST. Most of the forested area of the Central Kaimanawa is separated from the forest of the Northern Kaimanawa by a belt of tussock which follows the scarp across the heads of the Rangitikei and Mangamaire Valleys and continues into the Ngarururoro Valley.

Along the western face forest is continuous from the Waimarino boundary along the slopes of the Umukarikari Range into the lower Waipakihi Valley, but the high and extensive Middle Range almost completely separates this from the forest of the Rangitikei Valley. This forest has distinct characteristics, as has that of the lower Waipakihi, so that it is convenient to subdivide the Central Kaimanawa forests according to the three river systems:

1. Tongariro (Upper Waikato) Forest.
2. Waipakihi Forest.
3. Rangitikei Forest.

(1) TONGARIRO FOREST. The Waimarino boundary marks the complete replacement of silver by mountain beech. The altitudinal forest belts are here well defined, a podocarp/hardwood belt below 3,000ft, a red beech belt above this to 3,800ft, and mountain beech to the timberline at 4,400ft.

In the podocarp belt *Podocarpus spicatus* is the commonest species with a certain amount of *P. ferrugineus* and *P. totara,* but *Dacrydium cupressinum* is comparatively rare. There has been a considerable amount of selective logging of *Podocarpus spicatus* in the Waiotaka and Whitikau valleys. *Gymnelaea*

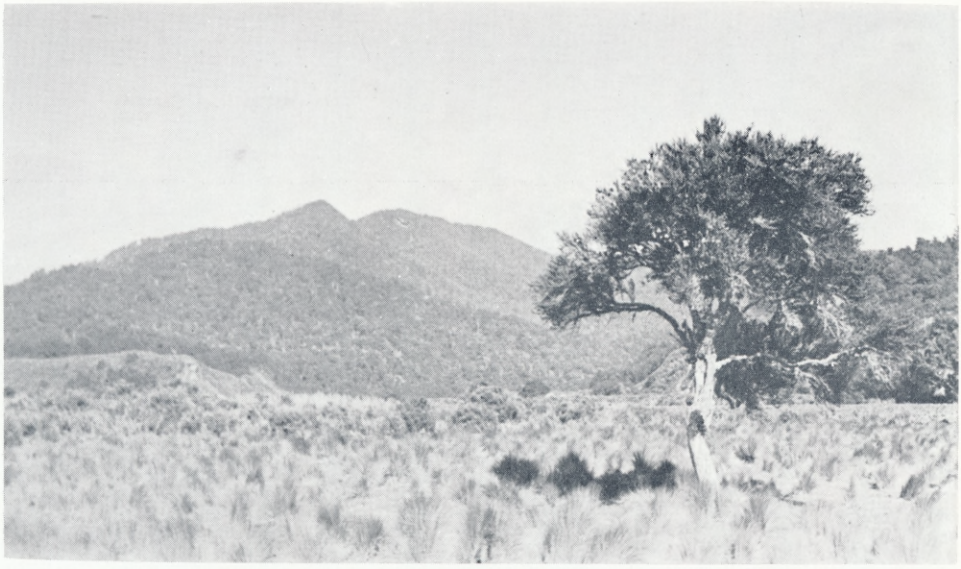


FIG. 1

Mohaka Head. Rouiti Peak (c. 4,250ft) in centre, red and silver beech with mountain beech cap. *Olearia virgata, Festuca, Clematis quadribracteolata* community in foreground.

FIG. 2

Waiotapuritia. Eastern face of valley, red and silver beech with mountain beech fringe above and below. *Dracophyllum subulatum* on dry terraces with *Phyllocladus alpinus* in gullies. Valley floor boggy with red tussock. Elements of riparian scrub-forest community in left foreground.

FIG. 3

Tikitiki Bush. Pole red and mountain beech, following fire and cutting. Introduced grassland indicates former margin. Rangitikei Valley lies beyond skyline. Boggy red tussock trough drains into Rangitikei tributary in foreground, but in the middle distance into Ngamatea Swamp.

FIG. 4

Ngamatea Swamp. The Tikitiki Bush lies behind peat auger; the Stowman Range beyond the Rangitikei forms the skyline on the right.

FIG. 5

Middle Range. Frost striations working down into snowgrass, main deer track on right. Peak (4,700ft) on Waiotaka-Waimarino divide in background.

(*C. C. Smith*)

FIG. 6

Middle Range. Frost striations.

(*C. C. Smith*)

FIG. 7

Ignimbrite Saddle, in right centre; Ngapuketurua (4,977ft) in centre background, with Lake Taupo behind.

FIG. 8

Mangoio. Dead mountain beech on lower slopes with regeneration dating from 1947.

FIG. 9

Hautapu. *Libocedrus* forest with narrow mountain beech margin.

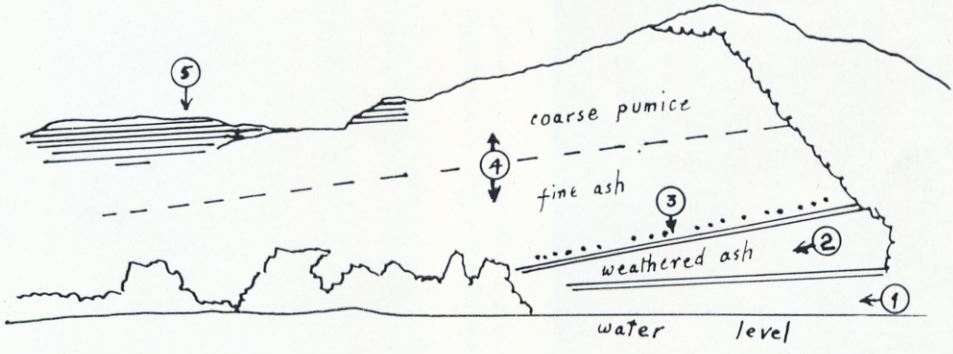


FIG. 10

Upper Ngaruroro. Pumice cliff near Te Matia confluence exposing from below (1) greywacke fragments; (2) weathered ash showers with a N.E. dip; (3) line of charred logs; (4) about 75ft of Taupo ash in two layers, fine below, coarser above; (5) at least 16 bands of narrow ash layers, visible on left hand side.

FIG. 11

Upper Ngaruroro. Tapui o Marua Hine (4,367ft) extreme left; Maungarahi (4,717ft) left skyline; Oamaru saddles in centre; Te Matia Stream in foreground. Typical forest capped hills with arid pumice terraces below and streams meandering through boggy flats.

FIG. 12

Moawhango. Kauaekeke scarp (limestone) in background, lower end of Kaikawaka Bush on extreme right. Islands of *Libocedrus* forest with *Podocarpus hallii* and some *Dacrydium colensoi*. A scrub margin with *Usnea* conspicuous here takes the place of a beech hedge.

cunninghamii is plentiful and *Weinmannia racemosa* common. The undergrowth has the general features of that of the Opawa Bush, previously described and calls for no additional comment.

Red beech forest here is distinguished by the comparative importance of *Weinmannia,* which is absent further south and sporadic to the north, and of *Podocarpus hallii,* thinly scattered elsewhere except in the *Libocedrus* association of the extreme south-west. Particularly in the Waiotaka and Whitikau Valleys *Weinmannia* occasionally dominates while large trees of both species with *Podocarpus hallii* sometimes approaching a diameter of 7ft are a feature. *P. ferrugineus* is frequent in the lower part of the belt. Undergrowth is generally sparse, though this may be due to deer. *Blechnum discolor* is plentiful in limited areas, but both it and the infrequent *Dicksonia lanata* appear to be restricted to drier situations as in the Northern Kaimanawa.

Mountain beech is the sole dominant in the upper forest belt. *Phyllocladus alpinus* is plentiful, also *Hebe corriganii, Coprosma pseudocuneata* and several other less palatable Coprosmas. The presence of *C. banksii* should be noted as this species in the Ruahine and Tararua Ranges has a distinct eastern-side distribution. A sprawling 8–10ft podocarp, intermediate in form between *Podocarpus hallii* and *P. nivalis* which is characteristic of the upper mountain beech forest becomes frequent. At the timberline *Phyllocladus alpinus* may form a narrow belt characteristically associated with *Dacrydium bidwillii* here either as a shrub or, more frequently, as a small tree.

(2) WAIPAKIHI FOREST. Silver beech reappears in the lower Waipakihi Valley largely replacing red beech, but its regeneration is confined to river terraces and it appears to be a relic forest in course of being replaced by mountain beech above 3,300ft and rather more doubtfully by red beech below this level. It is an isolated pocket, the nearest occurrence being across the Rangipo Desert on Pihanga and the slopes of Ruapehu.

Mountain beech is the sole dominant above 3,600ft, but a peculiarity of all types of forest here is the openness of the canopy and the density of an undergrowth of *Hebe corriganii* and enormous thickets of lawyer (*Rubus cissoides*). In consequence beech regeneration is sporadic and mainly on exposed spurs, appearing inadequate to perpetuate forest at the present day.

This unusual undergrowth suggests a succession following a widespread opening of the canopy, but it was already well developed as far back as 1933 and has shown no great development since, unless perhaps a progressive opening of the canopy. The cause is problematical on present evidence. There is some windthrow, but certainly not on a scale that would indicate damage due to an exceptional gale. Had the canopy been opened by gale, epidemic or drought, dense beech regeneration could have been expected. An early concentration of deer preventing beech regeneration until unpalatable undergrowth had taken charge is a possibility, but this would need to have occurred well before the peak population was reached in the range as a whole.

Podocarpus hallii is common but only below the mountain beech belt, in which the shrubby *Podocarpus* is frequent. *Phyllocladus alpinus* frequently dominates both the upper timberline and the margins of *Festuca*-dominated river terraces, as elsewhere associated with *Dacrydium bidwillii.* On these Waipakihi terrace margins *Pittosporum colensoi, Coprosma linariifolia* and *C. rugosa* and *Dracophyllum subulatum* are characteristic.

The precise boundary between the Waipakihi and Waikato forest has not been determined, but recent information from a Forest Survey field party is that the Waipakihi type of forest extends down the main Tongariro for at least two miles

below the confluence (2,900ft) without additional podocarps (which could be taken to mark the boundary) coming in.

The recent discovery of a *Libocedrus* log and the report by Druce of an isolated specimen of silver pine (*Dacrydium colensoi*) in the lower Waipakihi Valley introduces a new and unexpected element, a link with the *Libocedrus* forest of Rangataua and the south-west Kaimanawa, 15–20 miles distant.

(3) RANGITIKEI FOREST. Not only silver beech but red beech are completely absent, leaving mountain beech the sole dominant from as low as 2,800ft to 4,400ft and occasionally as high as 4,800ft. *Podocarpus hallii* is noticeably rare but the shrubby *Podocarpus* frequent. Subcanopy trees are infrequent and limited in variety, but there is a fairly dense growth of undershrubs (List 6).

The uniform composition of this type of forest and the complete absence of certain species, particularly of red beech, suggest that this area represents an early stage of forest succession.

CENTRAL KAIMANAWA, RIVER BANK

Pumice terraces are characteristic of almost the whole length of the Waipakihi Valley, and to a limited extent of the Rangitikei and Mangamaire Valleys. These terraces, particularly in the Waipakihi, are dominated by tussock, *Festuca novae-zelandiae* below 3,000ft, red tussock above this, and, as already stated, towards the valley-heads forest becomes discontinuous and red tussock becomes continuous with subalpine tussock. *Bulbinella hookeri* is common, and over the last 10–15 years there has been an invasion of the introduced *Senecio jacobeus*. *Gleichenia circinata* dominates on boggy ground. In the tussock scattered bushes of *Hebe venustula, Aristotelia fruticosa, Coprosma rugosa* and *Dracophyllum subulatum* are characteristic.

In these valleys there is not a great extent of exposed shingle, and what there is carries a considerable growth of mat-forming plants (List 7). In fact not only the shingle but the adjacent tussock terraces possess considerable stability, and descending the Waipakihi River in the midwinter of 1953, shortly after a flood which had covered the valley from side to side, the absence of any evidence of scour, either in tussock or shingle, was most striking. (Scouring caused by a big flood, presumably that of February 23, 1958, is recorded, but from recent information was only severe towards the lower end.)

CENTRAL KAIMANAWA, SUBALPINE VEGETATION

The general altitude of the Central Kaimanawa and the easy contours of most of its main ridges combine to give considerable areas above the timber line, but a lack of variety of land forms. Cliffs and screes are infrequent as compared with neighbouring North Island ranges.

Extensive areas of rock fragments carrying a sparse vegetation (List 8) are characteristic of the wide rolling crests particularly of the Middle and Umukarikari Ranges, and associated with these the development of frost striping on a large scale (Fig. 6).

Snowgrass (*Danthonia* sp.) is present throughout but only forms a closed association on the more sheltered slopes or in hollows. Elsewhere it is scattered except on pumice hummocks. This is the snowgrass tussock that occurs above the timber line of the central North Island ranges. It is recognizably distinct from either the broader or narrower-leaved forms that take its place in the Tararua Range. Over a considerable extent of the northern scarp on either side of the head of the Rangitikei River *Danthonia* is in the last stages of being replaced by large bluish-green tussocks of the sedge *Gahnia procera*, otherwise a forest species. As recently as 1945 a few tussock bases could still be identified here as *Danthonia* from occasional green shoots, apparently surviving intense browsing by deer.

As well as herbs (List 9) various woody species occur in *Danthonia* tussock, but there is no definite scrub belt. In fact lists 8, 9 and 10 overlap considerably and may be considered together. Scrub species (List 10) tend to become more frequent towards forest margins, and in some saddles at comparable altitudes, as for instance Ignimbrite Saddle, scrub is dominant, but this is not general. An unusual feature on the eastern slope of the Middle Range is the occurrence of *Olearia nummularifolia* projecting above the tussock as a 10ft tree at an altitude of over 4,800ft. The complete absence of *Celmisia incana* which occurs on the volcanoes and is also a prominent component of both tussock and open ground communities in the Kaweka and Ruahine Ranges is inexplicable.

CENTRAL KAIMANAWA, CLIFF AND SCREE

Neither situation is common. *Ranunculus insignis* and *Aciphylla colensoi* only flourish on sites inaccessible to deer and hence are mainly confined to cliffs, though small, close-browsed rosettes of the former persist as elsewhere on stable scree surfaces.

On screes *Myosotis australis* and *Parahebe spathulata* are local, *P. hookeriana* var. *olsenii* or more doubtfully *P. hookeriana* and *Epilobium glabellum* are common. *E. pychnostachyum* is rare but has been observed in a few localities from 1947 onwards. This species may be extending its range.

CENTRAL KAIMANAWA, BOG AND WATERCOURSE

There are no high altitude bogs of any significance, but on saturated ground bordering watercourses such species occur as *Caltha novae-zealandiae, Drosera arcturi, Gunnera dentata, Plantago uniflora, Hydrocotyle novae-zealandiae.*

SOUTHERN KAIMANAWA

To the south of the Central Kaimanawa Ranges lies open country known as the Inland Patea, and to the east the open country of the Taruarau and Ngaruroro, which is vegetationally a continuation of it.

It is convenient to take the line of the Inland Patea Road as the boundary of the Kaimanawa area since the southern boundary of the Inland Patea tussock with the podocarp forest of the lower Rangitikei has been obscured with the conversion of forest to farmland.

Within this boundary, as has already been explained, the south-western portion between Waiouru and Moawhango Village is being separately considered as the South-western Kaimanawa.

This leaves an arc of open country extending east from the Desert Road near Waiouru across the upper Moawhango basin and the Ngamatea Plateau north to the Oamaru Saddle in the upper Ngaruroro.

The whole of this area has been grazed from the earliest days of European occupation, though much of it is now abandoned, and practically the whole of it has been affected by fire from the 1870's onward, and some at least as early as the 1850's. Burning is still carried out in the stocked areas and deterioration of the cover over the past 25 years is widely apparent. Islands of beech forest occur throughout, many of which have been swept by fire and regenerated within the last 80 years.

SOUTHERN TUSSOCK AND GRASSLAND

Tussock grassland dominates the whole area, but as altitudes range from over 5,500ft on the Motumatai Range to 1,800ft where the Inland Patea Road crosses the main valley, *Festuca* or *Poa* may dominate the lower levels, while snowgrass occurs on the higher ground. Between these limits wide expanses of red tussock are characteristic.

Red tussock varies with the intensity of burning and grazing from a closed community almost shoulder high to stunted specimens scattered over barren open pumice, giving a wide range of habitats for the associated flora (List 11). Towards the 5,000ft mark a number of low-growing subalpine shrubs become prominent and over much of the Motumatai Range dominate, forming a close mat about a foot deep.

SOUTHERN SWAMP AND BOG

These fall into two categories, areas of standing water over-lying semi-liquid peat, such as Horotea Lake and the Ngamatea Swamp, and montane peat bogs.

There are also numerous small seepage bogs at the foot of pumice terraces which carry a similar vegetation to that of montane bogs and are, for that reason, not separately described.

Montane Bog. There are extensive areas approaching altitudes of 4,500ft in the twin heads of the Moawhango basin, also considerable areas around the Ngamatea Swamp proper, particularly on its western side, and smaller areas on the flatter parts of the Motumatai Range. Seepage bogs are frequent towards the head of the Ngarururo.

Gleichenia circinata frequently dominates over wide areas and *Hypolaena lateriflora* is abundant and locally dominant. A number of other species are characteristic (List 12).

Ngamatea Swamp. This consists of a series of waterways up to a quarter of a mile wide which were apparently meandering valleys, V-shaped in section, that became blocked and filled with peat to a considerable depth. No descriptive title seems fully adequate, perhaps fen or mere (Plate 4). A tall rush-like sedge, *Eleocharis sphacelata,* projects above the surface over a large proportion of the water surface with a submerged root system forming a mat on which it is possible to walk knee deep. *Epilobium chionanthum* is conspicuous and locally abundant, and *E. erectum* is also present. The large green and white flowered orchid *Prasophyllum suttonii* though rare has been collected here and at Horotea, a few miles north of the swamp, with similar vegetation. (*P. suttonii* has also been collected from a swamp at Hautu, near Tokaanu, on the margin of the Northern Kaimanawa.)

SOUTHERN CLIFF AND SCREE

Epilobium pubens var. *astonii* with showy pink flowers, some ½in across, occurs on cliffs at several points in the area. *Angelica montana* and *A. rosaefolia* are common in the same stations which presumably afford a refuge from browsing. Colonies of the entire-leaved form of *Hebe colensoi* are scattered but widespread from the upper Taruarau to the Moawhango, but the colony at the Taruarau bridge contains an element of the incised-leaved var. *hillii,* while a third form, a more robust plant, occurs on limestone at the Rangitikei Bridge. *Myosotis eximia* has been collected here and is also recorded by Druce from the Moawhango gorges downstream from Mt Azim. Although screes are negligible the occurrence of a small colony of *Epilobium pychnostachyum* on a small scree across the gorge from Mt Azim is worth mention.

SOUTHERN FOREST

Forest only occupies a small fraction of the total area in islands, few of any size and for the most part with mountain beech as the sole dominant, and in this respect links with the Rangitikei forest in the Central Kaimanawa. All forest margins have been affected by tussock fires, and many of the smaller clumps are pole stands regenerating after having been swept by fire.

The northern boundary at the Mangamingi confluence marks the limit of silver beech, but Druce reports some saplings in a forest clump at West Lawn

(Moawhango). This lies well outside the pattern of silver beech distribution and its relationship is obscure.

Red beech appears in several localities, but its distribution is irregular. Overmature trees dominate much of the Te Rei Bush on the limestone scarp north of Moawhango Village and red beech occurs again in the bush at West Lawn. There is also mature red beech in the Tikitiki Bush, together with 110 year old regeneration (Fig. 3). In addition there are a few trees beside the Inland Patea Road on the descent to the Taruarau, two or three trees are reported in forest on the eastern slopes of Tawaki Tohunga and a solitary hybrid of the *Nothofagus x blairii* form has been collected on the Stowman Range in regenerating forest. The tendency for mountain-beech forest to supplant former red-beech forest after fire probably applies to this case.

A feature of especial interest in the Tikitiki Bush is a small bog forest perhaps an acre in extent containing a few trees of *Libocedrus* and *Dacrydium colensoi,* with seedlings of both in evidence. This is an outlier of the South-western Kaimanawa forest, and with *Libocedrus* in a few stations south of the Inland Patea Road (Otupae and Pukeokahu) is evidence of a former link between the western Ruahine and South-western Kaimanawa forests.

In an east-west belt along the 60in isohyet across the whole of the area the death of a considerable proportion of trees in mountain-beech forest is conspicuous (Fig. 8). This was first noticed behind the Golden Hills Hut in December, 1946, and was then, in conjunction with the death of a variety of shrubs on the drier pumice terraces, taken to be a consequence of the drought in the beginning of that year. Recently-dead trees were abundant in the Tikitiki Bush early in 1949, and have been observed at West Lawn and off the Desert Road at the head of the Mangoio Stream. Examination of dense regeneration here where the canopy had been opened shows that it is even-aged from 1947. The dead trees are most abundant on easy slopes and flats, their death appearing to be connected with the depth of pumice. Identical patterns appear in the bush at West Lawn, with the exception that in one area at least the regeneration ante-dates the drought.

SOUTH-WESTERN KAIMANAWA

TUSSOCK AND SCRUBLAND

Red tussock is generally dominant as in the Southern Kaimanawa, but *Festuca* is abundant while *Celmisia spectabilis* is less prominent. On steeper faces a community dominated by *Phormium colensoi* with deciduous *Coriaria sarmentosa* and stunted *Leptospermum scoparium* is characteristic. This might be thought to be recently induced, but is frequently shown on early maps, and in fact the abundance of dead *Phormium* hummocks in what is now tussock show that its area has been reduced by burning and browsing.

Contiguous to it on more level ground upstanding isolated trees of *Griselinia littoralis, Hoheria sexstylosa, Pseudopanax crassifolium* and a *Pittosporum* (intermediate between *P. tenuifolium* and *P. colensoi*) indicate also a recent reduction of forest.

SOUTH-WESTERN KAIMANAWA FOREST (Fig. 12).

The pattern of open tussock country with scattered islands of forest continues from the Southern Kaimanawa across the tertiary scarps which lie between Moawhango Village and Waiouru. The forest composition, however, changes sharply, *Libocedrus* becoming the principal dominant, *Podocarpus hallii* dominant in limited areas and beech species playing a limited role on forest margins, but often absent.

The examination of *Libocedrus* patterns on the limestone outcrops of the Western Ruahine Range show that it is favoured by the presence of limestone. The tertiary formation between Waiouru and Moawhango is a likely factor in the occurrence of *Libocedrus*, though it should be pointed out that *Libocedrus* is absent from Te Rei Forest at the eastern end of the scarp. There are a few trees, living and dead, in its vicinity on the Paoneone Range but no trace has been found east of this till Pukeokahu.

The main forest area, known as the Kaikawaka Bush, lies on the slope south of the head of the Hautapu River, 3,000-3,600ft above sea level. At the present day it is an oblong some four miles by three, but continuous forest, probably podocarp forest, extending south of it down the slope has recently been burnt.

In the main forest *Libocedrus bidwillii* is dominant, frequently associated with *Podocarpus hallii*, which may dominate in limited areas, and occasional *Dacrydium colensoi*. There is a complete absence of beech species and of *Phyllocladus alpinus* from the margins. There is instead a dense marginal belt some two chains wide of small trees and shrubs. Where this belt has been breached by tussock fires the appearance of *Libocedrus* saplings is noticeable, but these are heavily browsed by sheep or deer. From a distant viewpoint it is likewise noticeable that a marginal belt of *Libocedrus* several chains wide has a denser canopy and fewer dead trees than the forest interior and is presumably younger.

As elsewhere the small conical heads form an open canopy so that subcanopy trees are abundant and undergrowth dense (List 13). The number of species rare on the ground but frequent as epiphytes indicates selective browsing.

A number of forest islands lie round the main forest, most of them to the north near Auahitotara trig. In most of these *Podocarpus hallii* becomes more prominent and may dominate, *Phyllocladus alpinus* appears as an important member of the community and beech makes its appearance as a narrow marginal hedge (Fig. 9), replacing a scrub margin in both northern and eastern directions. This hedge consists usually of mountain beech and occasionally of red beech, each island having its own species. The mountain-beech hedges are aged, in poor condition and smothered in *Usnea*. *Usnea* is also conspicuous on certain marginal shrubs.

PODOCARP FOREST

At the western end of the Kaikawaka Bush a promontory of podocarp forest projects to the edge of the scarp overlooking the Main Trunk Railway. This is dominated by *Podocarpus hallii* while *P. spicatus* and *Libocedrus* are frequent and *Dacrydium cupressinum*, *Podocarpus ferrugineus*, *P. dacrydioides* and *Gymnelaea cunninghamii* present. There is a corresponding variety of undergrowth, the whole community being somewhat unusual at an altitude approaching 3,300ft.

COMMENTARY

Since the publication in 1954 of Holloway's "Forest and Climate in the South Island of New Zealand" evidence of corresponding changes in the North Island has generally been accepted as bearing out his proof of the rapidity with which changes in climate are reflected in the vegetation. As he has pointed out these are less clearly defined further north; the influence of climate is not so crucial and the greater number of species and the corresponding variety of communities make the change more complex. In the central North Island such effects are furthed obscured by a succession of extensive showers of volcanic ash, and further still by the use of fire by a comparatively dense Maori population in the volcanic district.

In the central North Island the main factors may be summarized as follows:

(1) Secular changes.
(2) 1840 years. The latest (Taupo) ash shower.
(3) ? years. Climatic fluctuations since the Taupo shower.
(4) c. 350 years Maori burning of forest, scrub and fern.
(5) 90 years European burning and grazing of tussock.
(6) 60 years browsing of introduced wild animals.

While each of these can be recognized to some degree in the Kaimanawa Ranges it is not easy to separate, for example, successions due to climatic changes from those of recolonization of the ash surface, and the patterns due to volcanic destruction from those of Maori burning, while the absence of certain species may be due to accidents of recolonization or to the long period of undisturbed browsing by deer.

Considerable further evidence will be necessary as, for example, from pollen analyses and carbon dating, before many doubtful relationships can be cleared up, so this paper is necessarily in the nature of a preliminary survey.

The neighbouring ranges lie both within and without the area of the ash showers, and a brief comparison of these with the Kaimanawa Ranges is an essential preliminary to an attempt to disentangle the effect of eruptions.

Species Distribution

An examination of the vegetation in the neighbourhood of Taupo shows that other factors than volcanic action are involved in the distribution of species. Beech forest in particular is correlated largely with rainfall; the boundary of a number of northern species cuts across the area, while to further complicate analysis there is a group of endemics centred on the Inland Patea and associated with them a group of otherwise South Island species. On the other hand a number of species, some of physiognomic importance that might be expected to occur are absent, or almost completely so, from the surface of the Taupo ash.

This gives the picture of vegetation patterns which have been disrupted by volcanic eruptions, but are now largely, though not yet completely, re-established on a climatic basis; this, however, is superimposed on an older community, relics of which have survived the disturbance and are present as endemics or part endemics.

Patterns Determined by Rainfall

The fold mountain system of the North Island extends about 300 miles in a north-easterly direction from Cook Strait, and hence lies athwart the prevailing north-westerly winds. These are deflected by the central high land, which includes the main volcanic peaks, Ruapehu (9,175ft) and the outlying Egmont (8,260ft), so that either extremity of the system has a higher rainfall and a greater number of rain days.

This climatic pattern is reflected in the vegetation. On the Tararua Range above Cook Strait (and to some extent on the Raukumara Range towards East Cape, silver beech dominates the upper forest associated with, or in extreme cases replaced by, subalpine (*Olearia/Senecio*) scrub. Towards the centre silver beech is replaced by mountain beech, while *Olearia/Senecio* scrub dwindles and finally disappears from the driest and sunniest central part, the Kaweka Range, but as this also lies within the area of volcanic destruction the difficulty of separating climatic from volcanic effects is obvious.

Over most of the Kaimanawa Ranges the mountain beech upper forest matches that of the adjacent Kaweka Range except in the local area of high precipitation and humidity at the northern end, where, appropriately, there is an isolated silver beech forest. Red beech dominates the forest below both these

species, except in the belt of lowest rainfall where it becomes sporadic and is largely replaced by mountain beech or at lower elevations by a black-mountain beech swarm. (Unless a doubtful report of hard beech (*Nothofagus truncata*) in the adjacent Ahimanawa Range can be confirmed this species need not be considered. As far as is certainly known it does not occur at the present day between the Tararua Range and the East Coast north of Gisborne, though its type locality is given as "Ruahine Range, eastern side".)

There are certain features of beech forest within the shower which are peculiar to it, but these do not affect the distribution of species and lie outside the present argument. These have already been described; the high timberline, the belt of dead forest across the Inland Patea, and the tendency of beech forest to cling to crests and steeper slopes, leaving the valley bottoms and adjacent terraces in tussock.

DISTRIBUTION DEPENDENT ON LATITUDE

The 39th parallel, which passes across the Taupo area, is the approximate southern limit of a number of species which are typical of forests in the Auckland province. The most important of these are *Libocedrus plumosa* (*doniana*), *Phyllocladus glaucus, P. trichomanoides, Ixerba brexioides, Quintinia serrata* and *Dracophyllum latifolium.* All of these occur on part of the main ash shower, and one of them, *Phyllocladus glaucus,* has secured a footing in the Northern Kaimanawa. Though some of these, or related species, reappear in the South Island, all are absent between Taupo and Cook Strait. Their absence, whether due to temperature or some other factor, has no relation to volcanic action. (Cockayne's boundary between his Northern and Central Botanical Provinces, which lies further north and diagonally across the 38° parallel, is determined by the opposite aspect, the disappearance of southern species.)

LOCAL ENDEMICS

Perhaps the only strict endemic is *Logania depressa,* not collected since its original discovery by Colenso in 1847 in the Moawhango Valley, but there are a number of partial endemics which are centred on the Kaimanawa Ranges, most of them on the Inland Patea, and with these a number of South Island species not elsewhere recorded in the North Island.

A small glabrous subalpine Ourisia, *O. vulcanica,* is abundant throughout the range in a wide range of habitats and extends to the Tongariro National Park; two South Island species, an orchid, *Caladenia lyallii,* and a yellow forget-me-not, *Myosotis australis,* though not common, are distributed widely across both Kaimanawa and Kaweka Ranges.

The most important group are centred on the Inland Patea, and their distinctness and distribution are evidence that the vegetation toward the margin of the ash showers has a long history.

In this area Druce has identified a number of species hitherto only recorded from the South Island, most of them plants of boggy ground.

The nearest species to a true endemic, the glaucous *Hebe colensoi* (the entire leaved form) occurs sporadically on cliffs and extends to the Kaweka Range and the margin of the Ruahine Range. The large forget-me-not *Myosotis eximia* has the same xerophytic habitat and occurs with the *Hebe* in the Moawhango and Rangitikei Valleys as well as in several localities in the north-western Ruahine Range. With them in the Moawhango is the handsome large-flowered *Epilobium pubens* var. *astonii.* This also occurs on Hikurangi, the high peak towards East Cape.

It is significant that *Myosotis amabilis* related to *M. eximia* also occurs on Hikurangi, and a third closely allied species, *M. saxosa,* at a point between them, where the Napier-Taupo Road crosses the Titiokura Saddle, so that there are three isolated but closely related colonies round the southern and eastern margins

of the volcanic area with the *Epilobium* occurring at either extremity.

SPECIES UNRECORDED

While it is obviously impossible in an area of this extent to state categorically that any given species is completely absent, a number of species have never been recorded or are of such localized occurrence that various plant formations, particularly that of subalpine scrub, are considerably modified. Besides the probability that not enough time has elapsed since the last eruption for them to secure a foothold, the scarcity of suitable habitat is a possibility, as perhaps also the unsuitability of pumice soils; in a few instances limits appear to be set by diminishing rainfall.

Both *Libocedrus bidwillii* and *Dacrydium colensoi* are distributed round the western and southern margin of the Taupo shower and reappear to the north of it. The congruence between their boundary and the 6in isopach was so exact that some association was suspected, until the recent discovery of an individual of each species well within the shower near the mouth of the Waipakihi Valley. *Dacrydium biforme* has a less clearly defined pattern. It occurs to the north and south of the Taupo shower and also on the western slopes of Ruapehu, but there are a few colonies within the shower on the higher peaks of the Ahimanawa Range, and it has a foothold in a limited area of the Northern Kaimanawa Range. Elsewhere on the range it is replaced by *D. bidwillii.*

A number of subalpine species have not been recorded. The most important of these are the two main scrub species, *Olearia colensoi* and *Senecio elaeagnifolius.* As both become infrequent and disappear along the Ruahine Range outside the ash shower and reappear to the north in the Huiarau Range the cause appears to be climatic. (In cultivation *Olearia colensoi* shows a marked intolerance of low air humidities). The *Senecio*, however, appears unexpectedly near the summit of Tauhara, which lies in the low-rainfall area near Taupo township, and also occurs uncharacteristically as a river-cliff species in one or two localities in the Kaweka Range.

Both are absent from the Tongariro National Park, but a number of other scrub species which are absent from both the Kaimanawa and Kaweka Ranges are listed from there in Cockayne's report, *Pimelea buxifolia, Gaultheria subcorymbosa, Pittosporum rigidum* and *Dracophyllum filifolium.* Two other species unrecorded are *Astelia cockaynei* and *Celmisia incana,* the latter however occurring abundantly in the Kaweka Range. Its absence from the intervening Kaimanawa Ranges in view of its wind-distributed seed is inexplicable.

A few forest undergrowth species are unknown or have only rarely been recorded. The forest tussock (*Danthonia cunninghamii*) was listed as absent for 20 years, when a solitary plant perched out of reach of deer was discovered. *Libertia pulchella*, a small grass-like plant of beech-forest floor, but noteworthy on account of its distinct and narrow altitudinal range, has never been observed.

One conspicuous small tree, *Olearia rani,* has only been recorded once, and two lowland species, *Rhipogonum scandens* and *Hedycarya arborea*, which from their altitudinal range might be expected in forest near Lake Taupo, have not been seen.

CLIMATIC CHANGES

Outside the area of the ash showers a lowering of the timber line is evident in several of the North Island ranges. This is particularly conspicuous in mountain beech on account of its comparatively short-life-span, and is estimated to be of the order of 200ft within the last 200 years in the Ruahine Range. A similar pattern occurs 130 miles north of this on the Maungawaru Range.

Forest retreat is less obvious in the longer-lived (450–600 years) silver beech, but there is some evidence of deterioration in the Tararua forest line. Retreat

of silver beech is also recorded from Taratihi in the East Cape ranges (Cresswell).

In the Ruahine Range at a lower elevation the *Libocedrus/Dacrydium biforme* timberline is also retreating. At lower levels still there is some indication there of a retreat of red beech and of its replacement by mountain beech.

Corresponding evidence is generally lacking over the area of the Taupo ash shower. Not only is there no evidence of the retreat of the mountain-beech timberline, which is healthy with evidence of vigorous regeneration, but it frequently occurs at the exceptional altitude of 4,800ft in both the Kaimanawa and Kaweka Ranges, some 400ft above the average limit of the present-day retreating Ruahine timberline. Silver-beech forest also thrives at 4,600ft, an exceptional altitude for this species, on Whangatikitiki at the head of the Tauranga-Taupo River. As the Taupo ash is considered to be low in fertility, it appears necessary to call in some other factor, edaphic or climatic, to account for this.

There is, however, evidence of a succession in the ecotone between silver and mountain beech where the Kaimanawa and Kaweka forests meet near the head of the Ngarururo River. Above 4,000ft mountain beech is replacing relics of overmature silver beech though from this level down abundant silver beech regeneration is conspicuous. This has also been recorded on the southern slopes of Ruapehu at the same altitude above Rangataua. The general pattern appears to be a stage towards the development of the type of forest that occurs at the head of the Waimarino River and further afield on the southern Huiarau, with mountain beech dominant above, red below and silver occupying an intermediate zone as co-dominant, or more usually below the canopy as sub-dominant.

There is also a possibility that where mountain and silver beech are associated that their differing life spans, canopy densities and light requirements will result in an alternation of dominance.

Further south at a lower elevation and in a considerably drier climate in the lower Waipakihi Valley the status of the limited area of silver beech is different. It only occurs below 3,300ft and appears to be a relic, only maintaining itself on the river terraces and being replaced by red beech on the slopes.

Further south again between Waiouru and Moawhango with a rainfall approaching 50in the islands of *Libocedrus* forest frequently show traces of a narrow marginal hedge of mountain or red beech. Mountain beech in particular is in poor condition and usually infested with *Usnea*. Its previous status is obscure, but it does not now appear capable of maintaining itself. Red beech, which dominates the adjacent Te Rei forest, likewise appears to be in a state of decline.

Widespread death of mountain beech is conspicuous in a belt at 3,000–4,000ft from near the Desert Road at its highest point across the whole of the Southern Kaimanawa and beyond it to the head of the Manson Country (Kaweka), a distance of 30 miles. It follows the approximate 55in isohyet and is associated with easy slopes or level ground, so is probably related to the drying out of deep ash. This was first observed in 1947 when evidence of the 1945–46 drought was still evident in shrubland as well as forest, and was then assumed to be the result of it. Regeneration has since become typical in these areas, some, though not all of this, dating from 1947.

This appears to be a climatic boundary. Along it forest can occupy favourable sites forming a discontinuous pattern, and appears capable of expanding, if not checked by tussock burning, on to less favourable sites under average conditions. However, on such sites it remains vulnerable to an exceptional climatic fluctuation, which may occur once in a hundred years or so. There is no evidence of retreat of forest, but rather a tendency for it to advance. In fact the vigour

of regeneration indicates that there has only been a temporary setback.

VEGETATION PATTERNS ASSOCIATED WITH ASH SHOWERS

The paradox of the vegetation patterns of the Kaimanawa Ranges is that forests are most completely developed nearest the centre of the latest major eruption, while towards the south and south-east forest becomes discontinuous and of simpler structure, which suggests some degree of an outward colonisation towards the margin of the shower, but also from a wetter to a drier area.

This contrasts with the succession patterns on the western side of the shower beyond Lake Taupo in the Hauhangaroa Range. Here they show an inward recolonization from the unaffected forests of the King Country across the surface of the ash towards the centre of the eruption, and aided by the prevailing north-westerly wind.

From Fletcher's information it appears likely that podocarp forest was continuous round the whole perimeter of the lake 300–400 years ago, which would account for the podocarp remnants on the fringes of the Northern Kaimanawa forest. The problem is to account for the presence of well-developed beech forest well within the radius of buried charred timber and apparent total destruction with no adjacent seed source.

Extensive silver beech forest occupies the Northern Kaimanawa Range near the centre of eruption, with scattered colonies of clearly waterborne seed down the Ngarurоro and Mohaka Valleys. There are stands of silver beech in part of the Ahimanawa Range, but these appear to be invasions from the Mohaka colonies. The nearest extensive area lies 30 miles to the north-east across the inhospitable Kaingaroa Plain, and there is also silver beech on the western slopes of Ruapehu. Small pockets west of Lake Taupo, on Pihanga, in the Waipakihi and in the Moawhango suggest relics of more extensive silver-beech forest which have been isolated by the eruption and are barely maintaining themselves.

Red beech is also established near the centre of eruption, and mountain beech only a few miles further south. They present the same problems as silver beech, though in a less striking form. It is difficult to imagine that forest, particularly silver-beech forest, could have survived so close to the centre and equally difficult to visualize an outside seed source. Unless all three species survived within the area of charred forest remnants recolonization would have had to advance from the margin across the Kaingaroa Plains, the Inland Patea plateau or the Rangipo Desert. The most likely hypothesis seems to be that sufficient seed was deeply enough buried to escape immediate destruction by heat and then exposed by the deep gullying which is frequently characteristic of unconsolidated ash.

The transport of beech seed is the main problem. The speed with which associated species with wind- or bird-carried seed have established themselves over wide areas in the exotic plantations in the Atiamuri district is impressive evidence that the supply of such seed is ample to a considerable distance from possible sources.

There is evidence that the destruction of vegetation by volcanic eruptions is less complete and its recovery quicker than one would infer from the evidence of catastrophic forces at work. The Tarawera eruption (1886) was not comparable in scale nor in nature with the Taupo eruption, and is only referred to here as it gives some picture of the process of recovery under New Zealand conditions. A recent summary of its effects by Nicholls shows that the first accounts of the major destruction of vegetation by the deposit of mud and scoria were exaggerated. Not only was the reappearance of fern and other low-growing vegetation rapid, but recent Forest Survey plots in forest as close as three miles to the vent found no visible effects on the pre-eruption canopy trees.

Under tropical conditions rapid recovery of vegetation occurs even after its destruction by blast and hot ash. Taylor (1957) in comparing three recent eruptions in Papua, Mt Lamington (1951), Waiowa (1943) and Mt Victory (c. 1870), states that in the most recent of these a pelean type of eruption flattened all trees in the blast area and deposited up to 4½ feet of hot ash. Within a matter of months this surface was covered in vegetation, a number of species having survived the eruption. Two-and-a-half years later there was an almost continuous range of plant formations from bare ground to second growth forest. Examination of the two earlier eruptions showed a development towards climax forest. After 80 years climatic factors were dominant, but additional species were still entering the formation. He considered that it would take several centuries for the full range of species to become established. The same processes appear to be taking place at a slower rate on the Taupo ash, with a temperate climate and over a considerably wider area.

FIRE

The Maori use of fire for the piecemeal burning of fern land and forest clearings amounted over some hundreds of years to a considerable retreat of forest and the replacement of fern land by the invasion of tussock in areas of denser population as around Lake Taupo (Cruse illustrates the difficulty for this reason of finding suitable timber for spars near the Bay of Islands in 1820.) Occasional fires, such as those legendary fires named the fires of Tane, swept large areas, and some place names in the Southern Kaimanawa suggest such fires occurred there. These fires, however, occurred sporadically, and Maori burning was not intensive enough to take depletion beyond the replacement of forest by second growth and fern, and stunted fern by tussock, beyond which fire became no further use to them.

When Europeans introduced sheep this was followed by a new use of fire to replace fern by grassland and to open up tussock to improve grazing and stimulate new growth. This recurrent use of fire carried the depletion of the ground-cover a stage further and was quickly followed by the invasion of manuka scrub which various observers agree in dating from the 1870's.

It can now be observed that where abandoned scrubland is protected from burning near settlements and exotic plantations, that broadleaved species are invading scrubland on the more favourable sites, some of which are already reverting to light " second-growth " forest.

One apparently irreversible change has occurred in the Southern Kaimanawa area, where tussock fires have swept through most of the smaller beech islands. These have regenerated as pole stands of mountain beech with the frequent elimination of relics of red beech, whose charred logs can be recognized at the present day. Rare hybrids between red and mountain beech remain the only living evidence.

INTRODUCED ANIMALS

By 1931 red deer had reached or passed their peak. The previous forest composition was still recognizable, but browsing had reached the stage where canopy seedlings were inadequate for replacement and a major change seemed imminent.

The deer population then fell rapidly, but though mountain beech regeneration came away in the adjacent Kaweka Range and is now beyond the reach of deer browsing, for some reason which is not clear, this has not occurred on a comparable scale in the Kaimanawa forests.

Meantime the irruption of Japanese deer had led to a further cycle of intensive browsing at any rate in red- and silver-beech forest. There is some evidence that this in turn is changing its form. At the moment deer use is most frequently obvious near forest margins, while forest interiors show earlier though little recent

deer use, and canopy seedlings are not yet conspicuous except in light pools and such areas as the managed forest near Clement's Camp.

Where stock are run tussock burning is still carried out with the consequent weakening of ground cover, but considerable areas of the Inland Patea appear to have been abandoned or to be only intermittently stocked.

The effects on the vegetation of other introduced animals are not of major significance at the present day.

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PLANT LISTS

In the following lists I have indicated, where sufficient information is available, my estimate of the abundance of each species on the following numerical basis:—

5—Indicates dominant or co-dominant.
4—Indicates abundant or plentiful.
3—Indicates common.
2—To some extent this corresponds to the symbol o = occasional of overseas publications and to the f = frequent of Zotov's Tararua lists but *not* to f = c of some overseas lists. 2 may be considered as more definite than o, but less generous than f, and indicates a minor but recognizable component of its community.
1—Indicates rare.
loc.—Indicates local.

LIST 1.—*Taharua Valley, Characteristic Associated Species.*

Acaena microphylla
Pimelea prostrata
Pernettya macrostigma
Cyathodes fasciculata
(Also in damper hollows)
Euphrasia cuneata
Celmisia gracilenta
Raoulia australis
R. hookeri var. *albo-sericea*
Herpolirion novae-zealandiae

LIST 2.—*Northern Kaimanawa. River Shingle Colonizers.*

Muehlenbeckia axillaris
Epilobium melanocaulon
E. microphyllum
Vittadinia australis
Raoulia tenuicaulis

LIST 3.—*Opawa Bush.*

Subcanopy trees and undershrubs:

Melicytus ramiflorus	3	*Neopanax anomalum*	2
Aristotelia serrata	3	*Geniostoma ligustrifolium*	2
Brachyglottis repanda	3	*Pittosporum eugenioides*	2
Neomyrtus pedunculata	3	*P. tenuifolium* var.	2
Alseuosmia pusilla	3	*Pseudopanax crassifolium*	2
Coprosma tenuifolia	3	*Fuchsia excorticata*	2

C. rhamnoides	3	*Myrsine australis*	2
C. australis	2	*M. salicina*	1
C. lucida	2	*Schefflera digitata*	1
Griselinia littoralis	2		(but seedlings, 3)
Pseudowintera colorata	2	*Melicope simplex*	1

Tree ferns:

Dicksonia fibrosa	3	*Cyathea smithii*	1
D. squarrosa	2		

Other ferns:

Blechnum vulcanicum	4	*Hymenophyllum* spp. (on logs)	3
Todea hymenophylloides		*Trichomanes reniforme*	2
Gleichenia cunninghamii	loc. 4	*Leptolepia novae-zelandiae*	1
Blechnum discolor	loc. 3	*Blechnum filiforme*	1

Also a distinct fern community on the steep walls of dry gullies in the pumice:

Blechnum procerum	loc. 4	*Thelypteris pennigerus*	loc. 2
B. patersonii	loc. 4		

And on the floor of such gullies, *Todea superba* loc. 3

Epiphytes:

Collospermum hastatum	4	*Earina mucronata*	2
Astelia solandri (A. Cunn.)		*E. autumnalis*	2
Asplenium falcatum	4	*Tmesipteris tannensis*	1
Phymatodes diversifolium	3	*Trichomanes venosum*	1
Neopanax simplex	3		

(Not recorded, but probably present, *Phymatodes novae-zelandiae.*)

LIST 4.—*Northern Kaimanawa, Red Beech Associated Species.*

Subcanopy trees:

Carpodetus serratus	4	*Neopanax simplex*	3
Aristotelia serrata	4	*N. simplex* var. *sinclairii*	3
Griselinia littoralis	4	*N. arboreum*	2
Elaeocarpus hookerianus	3	*Weinmannia racemosa*	2
Fuchsia excorticata	3	*Podocarpus ferrugineus*	2
Cordyline indivisa	3	*P. hallii*	1
Phyllocladus alpinus	loc. 3	*Phyllocladus glaucus*	loc. 1

Undershrubs:

Myrsine divaricata	4	*Hebe corriganii*	loc. 3
Neomyrtus pedunculata	4	*Coprosma banksii*	2
Neopanax anomalum	4	*Coprosma colensoi*	2
Rubus cissoides	4	*C. foetidissima*	2
Coprosma microcarpa	3	*Cyathodes fasciculata*	2
C. tenuifolia	3	*C. juniperina*	2
Myrsine australis	loc. 3		

Ferns:

Gleichenia cunninghamii	4	*Dicksonia lanata*	loc. 3
Phymatodes diversifolium	4	*Polystichum vestitum*	2
Hymenophyllum demissum	3	*Phymatodes novae-zelandiae*	2
Blechnum discolor	loc. 3		

LIST 5.—*Northern Kaimanawa, Silver Beech Associated Species*

Myrsine divaricata	4	*Polystichum vestitum*	2
Coprosma colensoi	4	*Coprosma foetidissima*	2
C. banksii	3	*C. pseudocuneata*	2
Todea superba	3		

LIST 6.—*Rangitikei Forest*

Subcanopy trees:

Griselinia littoralis	2	*Neopanax simplex* var. *sinclairii*	2
Phyllocladus alpinus	2	*N. simplex*	2

Undershrubs:

Hebe corriganii	4	*Myrsine divaricata*	3
Coprosma pseudocuneata	4	*Cyathodes juniperina*	2
C. parviflora	4	*C. fasciculata*	2
C. microcarpa	3	*Rubus cissoides*	2
C. tenuifolia	3	*Gaultheria antipoda*	2
C. foetidissima	3	*Aristotelia serrata*	2

Ferns:

Gleichenia cunninghamii	*Blechnum fluviatile*

LIST 7.—*Central Kaimanawa, River Bank Species on Stable Shingle*

Pimelea prostrata	4	*Muehlenbeckia axillaris*	3
Raoulia tenuicaulis	4	*Epilobium melanocaulon*	3
Coprosma brunnea	loc. 4	(*E. microphyllum* not recorded)	
C. rugosa	loc. 4	*Claytonia australasica*	2
Raoulia glabra	4	*Hebe* sp.	2
Gunnera dentata	3	*Senecio glaucophyllus* var. *raoulii*	2

LIST 8.—*Central Kaimanawa, Open Community of Ridge Crests*

Danthonia sp.	4	*Dacrydium laxifolium*	3
Podocarpus nivalis	3	*Geranium microphyllum*	3
Muehlenbeckia axillaris	3	*Anisotome aromatica*	3
Dracophyllum recurvum	3	*Oreomyrrhis colensoi*	3
Gaultheria colensoi	3	*Phyllachne colensoi*	loc. 3
Raoulia grandiflora	3	*Drapetes dieffenbachii*	2
R. hookeri var. *albo-sericea*	3	*Cyathodes empetrifolia*	2
Pentachondra pumila	3	*C. colensoi*	2
Cyathodes fraseri	3	*Parahebe hookeriana* (?)	2

LIST 9.—*Central Kaimanawa, Species Associated with Snowgrass Tussock.*

Celmisia spectabilis	4	*Euphrasia cuneata*	3
Ourisia vulcanica	4	*Wahlenbergia pygmaea*	3
Coprosma cheesemanii var.	4	*Celmisia gracilenta*	3
C. cheesemanii var.	4	*Prasophyllum colensoi*	2
C. pumila	3	*Caladenia lyallii*	2
Lycopodium fastigiatum	3	*Forstera bidwillii*	2
Myrsine nummularia	3	*Pterostylis humilis*	loc. 2
Gentiana bellidifolia	3	*Ranunculus nivicola*	2

LIST 10.—*Central Kaimanawa, Scrub Species*

Senecio bidwillii	3	*Epacris alpina*	3
Cassinia vauvilliersii	3	*Olearia nummularifolia*	2
Hebe venustula	3	*Pimelea buxifolia*	2
H. odora	3	*Dacrydium bidwillii*	2
H. tetragona	3		

LIST 11.—*Southern Kaimanawa, Species Associated with Red Tussock*

Ophioglossum coriaceum		*Mentha cunninghamii*	
Chrysobactron hookeri		*Euphrasia cuneata*	
Ranunculus lappaceus		*E. zelandica*	
Carmichaelia orbiculata	loc. 2	*Ourisia vulcanica*	
Stackhousia minima		*Coprosma cheesemanii* var.	
Gentiana grisebachii		*C. cheesemanii* var.	
Aciphylla colensoi	1	*C. petriei*	loc. 3
A. squarrosa		*C. pumila*	
Pentachondra pumila		*Celmisia spectabilis*	
Pernettya macrostigma		*C. gracilenta*	
Cyathodes fraseri		*Microseris scapigera*	loc. 4
Cyathodes colensoi		*Senecio glaucophyllus* var. raoullii	loc. 3

LIST 12.—*Southern Kaimanawa, Bog Species*

Drosera spathulata	3	*Oreostylidium subulatum*	loc. 2
D. arcturi	3	*Utricularia novae-zelandiae*	loc. 3
D. binata	3	*Corybas macrantha*	loc. 2
Cyathodes empetrifolia	3	*Microseris scapigera*	loc. 3
Euphrasia cuneata	3	*Olearia virgata*	loc. 3
Selliera radicans	3	*Glossostigma elatinoides* (dry water channels)	loc 3
Craspedia minor	3		
Thelymitra uniflora	2	*Gunnera dentata* (dry water channels)	loc. 3
Herpolirion novae-zealandiae			
Drosera pygmaea	2	*Claytonia australasica*	loc. 3
Hypericum sp.	2	*Potamogeton cheesemanii* (standing water)	loc. 3
Cyathodes pumila	loc. 2		
Liparophyllum gunnii	loc. 2	*Myriophyllum* sp.	loc. 3

LIST 13.—*South-western Kaimanawa, Species Associated with Libocedrus Forest.*

Subcanopy trees:

Griselinia littoralis	4	*Carpodetus serratus*	3
Fuchsia excorticata	4	*Neopanax simplex* var. *sinclairii*	3
Hoheria sextylosa	3	*Dacrydium colensoi*	loc. 2
Podocarpus hallii	loc. 3	*Nothofagus* sp.	loc. marginal
Aristotelia serrata	3		

Undershrubs:

Pseudowintera colorata	4-5	*Myrsine divaricata*	3
Coprosma parviflora	4	*Melicytus lanceolatus*	2
C. tenuifolia	3	*Aristotelia fruticosa* (margins)	loc. 3

Lianes:

Rubus cissoides (narrow lvd)		*Muehlenbeckia australis*	3
R. schmidelioides (A. Cunn.)	4	*Parsonsia capsularis*	3

Epiphytes (all common):

Neopanax colensoi	*Griselinia littoralis*
N. simplex var. *sinclairii*	*Asplenium flaccidum*
Coprosma foetidissima	*Hymenophyllum malingii* (on *Libocedrus* only)
Gaultheria antipoda	
Myrsine divaricata	

Floor:

Polystichum vestitum	4	*Microlaena avenacea*	3
Hypolepis millefolium	4	*Todea superba*	2
Histiopteris incisa	3		

LIST 14.—*Forest Species Limited by Browsing*

Polystichum vestitum	*C. lucida*
Todea superba	*C. robusta*
Astelia nervosa var. *sylvestris*	*C. tenuifolia*
Neopanax colensoi	*C. foetidissima*
N. arboreum	*C. colensoi*
Gaultheria antipoda	*Olearia arborescens*
Coprosma australis	

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