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INFLUENCE OF INTRODUCED MAMMALS ON THE FOREST AND SHRUBLANDS OF THE GREY RIVER HEADWATERS

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ABSTRACT

The forests of the Grey River headwaters are ecotonal between the mixed podocarp and large-leaved hardwood forests which prevail further south in mid-Westland, and the **Nothofagus** forests which prevail further north. At low altitudes, in the south and west of the survey area, the dominant species are kamahi and **Quintinia acutifolius**, with some rimu, miro, kahikatea, Hall's totara, southern rata and mountain cedar. At high altitudes mountain cedar, pink pine, **Dracophyllum traversii**, **Olearia ilicifolia** and **O. lacunosa** dominate. In the north and east the dominant species are red beech, silver beech, and mountain beech. The sub-alpine shrublands are of more uniform composition and are dominated by **Dracophyllum longifolium**, **D. uniflorum**, **Phormium colensoi**, **Podocarpus nivalis**, and leatherwood in places.

The forests and shrublands were divided into 17 associations by using a numerical procedure. The composition, structure and habitat of each is described. The influence of ungulates (particularly red deer) and of opossums on each association and on sub-units of the survey area was determined by considering the susceptibility of the vegetation to browsing, the extent of modification in the vegetation resulting from past use, and the pattern of use at the time of the survey. It was found that in most cases the seral lacebark-broadleaf and kamahi-broadleaf associations were the most susceptible to the ungulates, were

the most modified from the original condition and were also receiving the greatest ungulate use at the time of the survey. The sub-alpine shrub associations were generally the least susceptible, the least modified and were receiving the least ungulate use. The kamahi-dominated associations were the most susceptible to opossum damage and were receiving the greatest opossum use at the time of the survey, while the **Nothofagus** forests were the least susceptible and were receiving the least use.

The areas most susceptible to ungulate damage were in the south where the forest was predominantly mixed podocarp and large-leaved hardwood and the least susceptible were in the north where **Nothofagus** species dominate. The areas where the vegetation was most modified by ungulates were the Crooked and Haupiri Catchments and the Elliot Range while the least modified were in the vicinity of Mt Te Kinga, around Bald Hill and in the Upper Grey. Ungulate use at the time of the survey was greatest in the Crooked, Haupiri and Upper Grey Catchments and least around Mt Te Kinga and Bald Hill. The most susceptible areas to damage by opossums were in the south and at the time of the survey opossum sign was most evident in the Crooked and Haupiri Catchments and in the vicinity of Mt Te Kinga.

INTRODUCTION

A reconnaissance survey of the headwaters of the Grey River was carried out during the summer of 1967-68 by staff of the Forest and Range Experiment Station, Rangiora. The purpose was to evaluate and describe the composition, structure, and habitat of the forest and shrub associations; and to determine the past and present influence of introduced browsing mammals.

The area studied includes the headwaters of the following major tributaries of the Grey River: the Crooked River from below the Evans confluence; the Ahaura River from below Granite Creek on the east bank and below the Haupiri River confluence on the west bank; and the Grey River from below Browns Creek on the north bank and below the Clarke confluence on the south bank. It also includes the slopes of Mt Te Kinga south-east of Lake Brunner (Fig. 1).

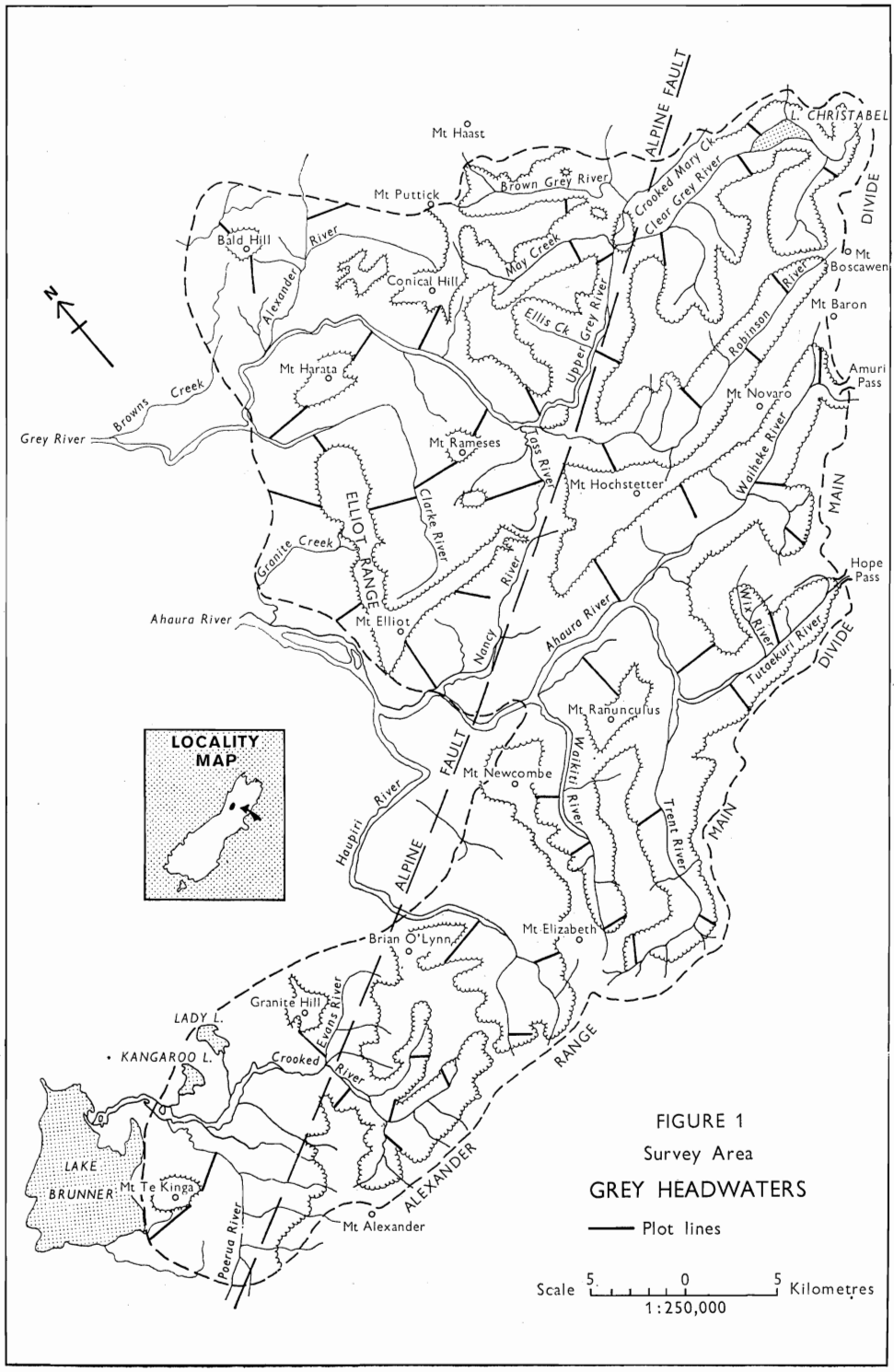
The total survey area is approximately 140,000 ha of which about two-thirds supports a forest or shrub cover.

TECHNIQUE

Six hundred and fifty-eight sociological descriptions of forest and shrub stands from throughout the survey area form the basis of this study. These descriptions were located at 60 m elevation intervals along 57 altitudinal transects.

The sampling procedure, the method of recording and the type of analysis for these sociological descriptions are, with several minor exceptions, identical to those used and described for the northern Fiordland survey (Wardle *et al.,* 1971). Thus the 658 sociological descriptions were classified into 17 associations using a numerical procedure. The survey area was divided into 7 geographic units and the composition of the forest and shrublands in each determined (Fig. 2). The susceptibility, the degree of modification, and the present use of the associations and geographic units by introduced mammals was determined from susceptibility ratings, indicator species and browse indices. The differences in the field techniques and method of analysis are outlined below.

1. Plot layout—the sociological descriptions were taken at elevation intervals of 60 m rather than at slope intervals of 135 m.


ALPINE FAULT
L. CHRISTABEL
Mt Haast
Brown Grey River
Crooked Mary Ck
Clear Grey River
DIVIDE
Mt Puttick
Bald Hill
Alexander River
Conical Hill
May Creek
Mt Boscawen
Robinson River
Mt Baron
Ellis Ck
Upper Grey River
Amuri Pass
Mt Harata
Browns Creek
Grey River
Mt Novaro
Mt Rameses
Waiheke River
MAIN
Mt Hochstetter
Clarke River
ELLIOT RANGE
Granite Creek
Hope Pass
Ahaura River
Mt Elliot
Nancy River
Ahaura River
Wilkin River
Tutaekuri River
DIVIDE
Mt Ranunculus
LOCALITY MAP
FAULT
Mt Newcombe
Haupiri River
ALPINE
Wilkin River
Trent River
MAIN
Mt Elizabeth
Brian O'Lynn
LADY L.
Granite Hill
Evans River
KANGAROO L.
Crooked River
RANGE
LAKE BRUNNER
Mt Te Kinga
ALEXANDER
Mt Alexander
Poerua River
FIGURE 1
Survey Area
GREY HEADWATERS
Plot lines
Scale 5 0 5 Kilometres
1:250,000

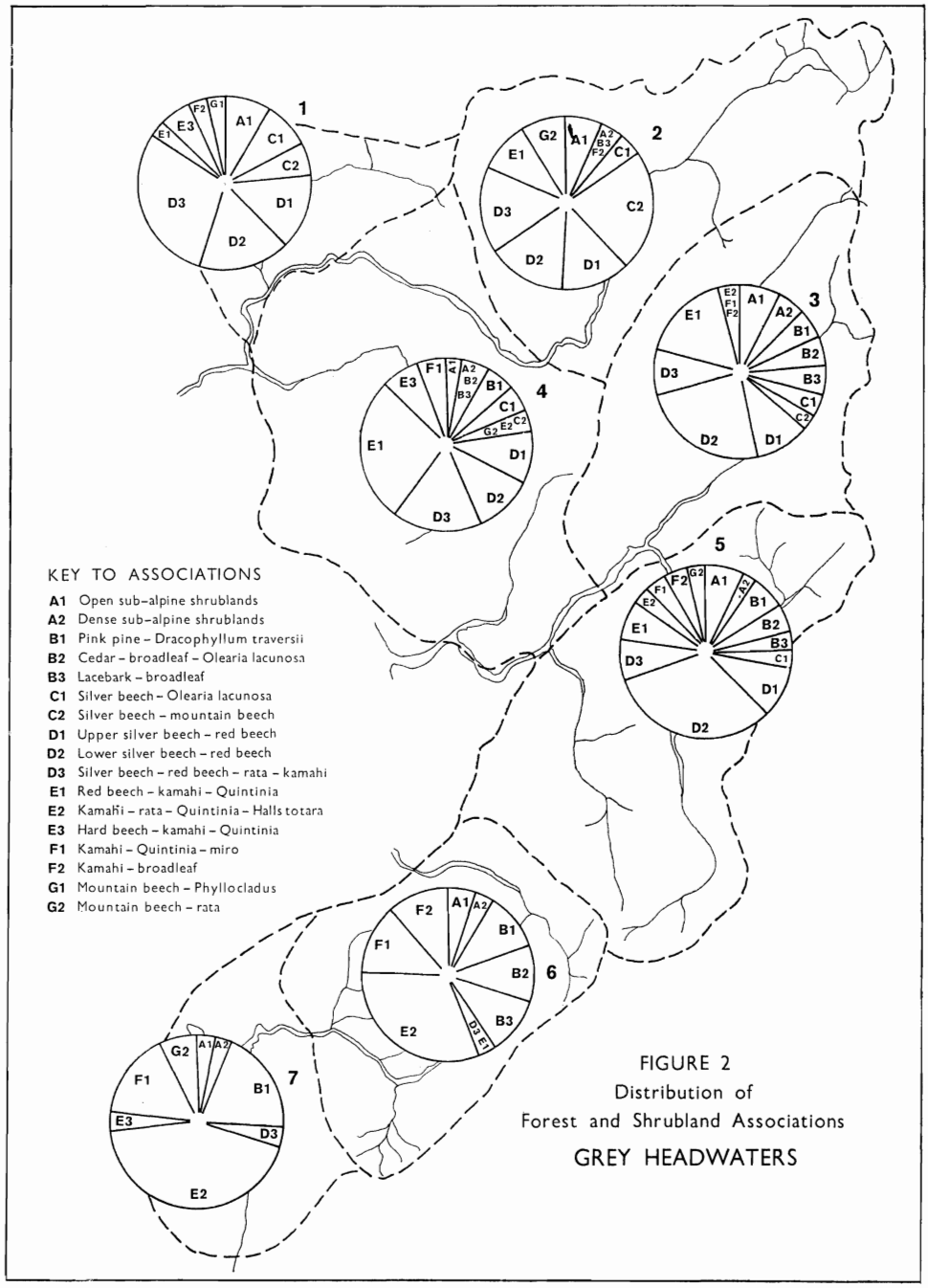


FIGURE 2
Distribution of
Forest and Shrubland Associations
GREY HEADWATERS

2. Soil measurements—systematic measurements of soil depth were not taken.
3. Susceptibility of associations—the modified method described by Wardle *et al.* (1973) and used in the analysis of the South Westland data replaces the method described in the 1971 paper.
4. Degree of modification (indicating history of utilisation)—ten tree and large shrub species, chosen to include those with high specific frequency and high susceptibility ratings, were used to indicate degree of vegetation modification.
5. Animal occupance—animal ecologists were not employed on this survey and there was no systematic estimation of pellet density. However tracking and abundance of pellets were visually estimated where sociological descriptions of the vegetation were taken and used to indicate the degree of animal occupancy. The type of analysis used on these data is described by Wardle, 1971.

DESCRIPTION OF THE SURVEY AREA

The survey area includes the tributary catchments of the Grey River which drain from the main divide in the south-east, the Alexander Range in the south, the Bald Hill-Mt Haast-Mt Puttick mountain complex in the north and the Elliot Range towards the west. The land is generally steep hill country with slopes averaging between 20 and 30 degrees but there are terraces close to most of the main rivers (Fig. 3). These terraces which become more extensive downstream, especially to the west, are often of glacial origin. Pleistocene glaciers occupied the upper reaches of the valleys of both the Grey and the Ahaura Rivers (Suggate, 1965), but there are now no glaciers of any extent.

FIG. 3—Grey Valley. General view to show wide river terraces and steep valley sides.

The highest peaks are Mt Alexander (1969 m) on the Alexander Range, and Mt Barron (1804 m) and Mt Boscawen (1774 m) along the main divide. The main divide which separates the headwaters of the Grey River and the Waiau River of North Canterbury generally lies between 1500 and 1850 m altitude but there are two low passes; Amuri Pass (1006 m) between the Waiheke tributary of the Grey and the Doubtful branch of the Waiau; and Hope Pass (1031 m) between the Tutaekuri tributary of the Grey and the Hope branch of the Waiau. The Elliot Range which is isolated from the main divide is between 1200 and 1500 m.

The main alpine fault runs in a NE-SW direction and bisects the survey area (Fig. 1). The rocks to the south-east of the fault are predominantly schists and greywackes. The rock in the vicinity of the main divide is of undifferentiated greywacke of the Torlesse group and is of Jurassic-Triassic age. Closer to the alpine fault, these greywackes give way first to a semi-schistose greywacke and then to a quartzo-feldspathic schist with no foliation, and finally, in the vicinity of the alpine fault, to biotite and garnet-bearing feldspathic schists of the Haast group. The ranges west of the Alpine fault are composed of granites, gneisses, granodiorites, and diorites of the Tuhua group, which are probably of Paleozoic age. The lower rolling country and terraces are more recent in origin and are composed of outwash gravels, mainly from the Otira glaciation (Gregg, 1964; Bowen, 1964).

Skeletal forest soils cover all the steep hill land. These are generally shallow and infertile, and consist mainly of freshly weathered soil and disintegrating rock fragments, overlain by peaty mor humus and litter. The soils are yellow-brown earths which are predominantly podzolic and belong to the Kanieri, Lewis, Haast, Hohonu, McKerrow, Whitcombe and Spenser series. The soils of the main valley terraces and lower rolling country are lowland podzolised yellow-brown earths and podzols, lowland yellow-brown earths, gley recent soils and recent soils and belong to the Okarito, Ikamatua, Blackball, Harihari and Hokitika series (N.Z. Soil Bureau, 1950, 1968).

The climate is humid and the rainfall heavy. The prevailing north-west winds bring most of the rain and change to southerly conditions usually brings fair weather. Both frost and snow are frequent in the high country in winter but may occur to some extent at all seasons. The rainfall is probably greatest in the south and west and lessens towards the main divide, especially in the north.

The seven geographic units of the survey were: 1, Bald Hill; 2, Upper Grey; 3, Waiheke-Robinson; 4, Elliot; 5, Waikiti-Tutaekuri; 6, Crooked-Haupiri; and 7, Te Kinga. The boundaries of each are shown in Fig. 2.

DESCRIPTION OF THE FORESTS AND SHRUBLANDS

The composition of the forests and shrublands varies considerably throughout the survey area. In the south and west the forests are mixed and are similar in composition to those further south in mid-Westland. To the north and east, however, *Nothofagus* species dominate.

In the south and west the low-altitude forests are dominated by *kamahi (*Weinmannia racemosa*) and *Quintinia acutifolius,* with some rimu (*Dacrydium*

* Botanical names used in this paper are according to Zotov (1963) for the grass sub-family **Arundinoideae,** Cheeseman (1925) for the remainder of the indigenous monocotyledons, Philipson (1965) for the genera of the **Araliaceae** and Allan (1961) for all remaining species.

cupressinum), miro (*Podocarpus ferrugineus*), kahikatea (*Podocarpus dacrydioides*), Hall's totara (*Podocarpus hallii*) and southern rata (*Metrosideros umbellata*), and with some mountain cedar (*Libocedrus bidwilii*) on low-lying swampy sites. On the higher slopes the podocarps, kamahi, *Quintinia acutifolius* and southern rata become less important until at timberline the forests are composed of mountain cedar, pink pine (*Dacrydium biforme*), *Dracophyllum traversii, Olearia ilicifolia* and *O. lacunosa.* In the north and east, red beech (*Nothofagus fusca*), silver beech (*Nothofagus menziesii*), and finally mountain beech. (*Nothofagus solandri* var. *cliffortioides*) become the dominant species. The podocarps, kamahi, *Quintinia acutifolius* and southern rata are present but the distribution is sporadic and the forest is predominantly one of silver beech, red beech, and occasionally hard beech (*Nothofagus truncata)* at low altitudes, and silver beech and mountain beech higher up. The timberline species are silver beech and mountain beech and rarely red beech.

The altitude of the timberline varies considerably. In the south and west it averages about 950 m but may be as low as 885 m. In the north and east where silver beech and mountain beech co-dominate it averages about 1220 m but may be as high as 1300 m.

Variation in the upper altitudinal limits of some species is of interest. The upper limits of the *Nothofagus* species are depressed towards the south and west. For instance the altitudinal limit of silver beech in the upper Grey which is in the north-east section of the survey area averages 1220 m but in the Trent catchment, near the southern limits of distribution for the species, only 970 m. Red beech reaches 1010 m in the upper Grey but only 880 m in the Trent. On the other hand, kamahi, *Quintinia acutifolius* and southern rata attain similar upper limits throughout. The upper limits of kamahi are nearly always between 790 and 820 m; of *Quintinia acutifolius,* nearly always between 780 and 840 m; and of rata, nearly always between 820 and 910 m.

The shrub belt varies in thickness dependent on the altitude that the timberline achieves. In the south and west, the belt is 150 to 180 m deep but where the timberline is high, as in the north and east, it is only 15 to 30 m deep. Where the timberlines are low, dense complex shrubland above the forest is dominated by *Dracophyllum longifolium,* pink pine, *Phormium colensoi,* leatherwood (*Olearia colensoi*), *Dracophyllum traversii* and *Olearia lacunosa.* Where the timberlines are high, the shrubland is open and dominated by *Chionochloa* species, *Dracophyllum uniflorum, Podocarpus nivalis* and *Phormium colensoi.*

The sociological descriptions collected on the survey were classified into 17 associations. Other minor associations do occur in the survey area, especially in the vicinity of the lowland swamps and terraces. These were largely ignored in sampling since the primary purpose of the study was to describe hill forest.

The 17 associations are listed below:

A1 Open sub-alpine shrublands
A2 Dense sub-alpine shrublands
B1 Pink pine-*Dracophyllum traversii*
B2 Cedar-broadleaf-*Olearia lacunosa*
B3 Lacebark-broadleaf
C1 Silver beech-*Olearia lacunosa*
C2 Silver beech-mountain beech

D1 High level silver beech-red beech
D2 Low level silver beech-red beech
D3 Silver beech-red beech-rata-kamahi
E1 Red beech-kamahi-*Quintinia*
E2 Kamahi-rata-*Quintinia*-Hall's totara
E3 Hard beech-kamahi-*Quintinia*
F1 Kamahi-*Quintinia*-miro
F2 Kamahi-broadleaf
G1 Mountain beech-*Phyllocladus*
G2 Rata-*Quintinia*-mountain beech

The composition, structure, and habitat of each association is described below, while the per cent frequency of the species of major importance is given in Appendix 1.

A1 — Open sub-alpine shrublands

Occurs on the gentler slopes, at high altitude, throughout the survey area, tending to be most important in the north (Fig. 2). It is the most complex association in the survey area (Fig. 4) with a mean of 32 vascular species per plot, most of which are herbaceous. There is an open shrub canopy dominated by *Dracophyllum uniflorum* and *Coprosma pseudocuneata* with some *Podocarpus nivalis, Hebe vernicosa, Phyllocladus alpinus, Coprosma colensoi* and *Dracophyllum longifolium.* There is a dense ground cover composed of *Celmisia discolor, Phormium colensoi, Celmisia armstrongii* and *Myrsine nummularifolia* with some *Senecio bellidioides, Anisotome aromatica, Chionochloa pallens* and *Gaultheria depressa.*

A2 — Dense sub-alpine shrublands (Fig. 5)

Again occurs throughout the survey area but tends to be more important in the south than in the north. It occupies similar altitudes, and the stands have similar mean top heights to those of A1 (Figs. 4, 6). However slopes are considerably steeper and the mean is around 35° as compared with 24° for A1 (Fig. 6). The shrub tier is denser and much more complex than in A1, but there is a reduction in the number of herbaceous species resulting in an overall lower complexity (Fig. 4). The shrub tier is dominated by *Coprosma pseudocuneata, Phormium colensoi* and *Phyllocladus alpinus* with *Podocarpus nivalis, Dracophyllum longifolium, Dracophyllum uniflorum,* leatherwood, *Olearia lacunosa, Senecio bennettii* and *Pseudopanax colensoi* also important. The ground cover is of scattered *Blechnum minus, Chionochloa flavescens* and *Ourisia macrocarpa.*

B1 — Pink pine-*Dracophyllum traversii*

Important in the south, and forms about one-fifth of the total woody vegetation in the Te Kinga unit but is rare to absent in the north. It occurs at high altitudes around 950 m either forming timberline stands, or a sub-alpine shrubland above the forest. The dominant canopy species are pink pine, *Dracophyllum traversii,* broadleaf (*Griselinia littoralis*) and *Pseudopanax lineare* and to a lesser extent *Dracophyllum longifolium,* mountain cedar, *Olearia lacunosa, Pseudopanax simplex,* and *Senecio bennettii.* The canopy is usually fairly open but there is a dense woody understorey formed by smaller plants of the above species and *Coprosma pseudocuneata, Phyllocladus alpinus, Coprosma foetidissima, Myrsine divaricata, Archeria traversii, Pittosporum divaricatum*

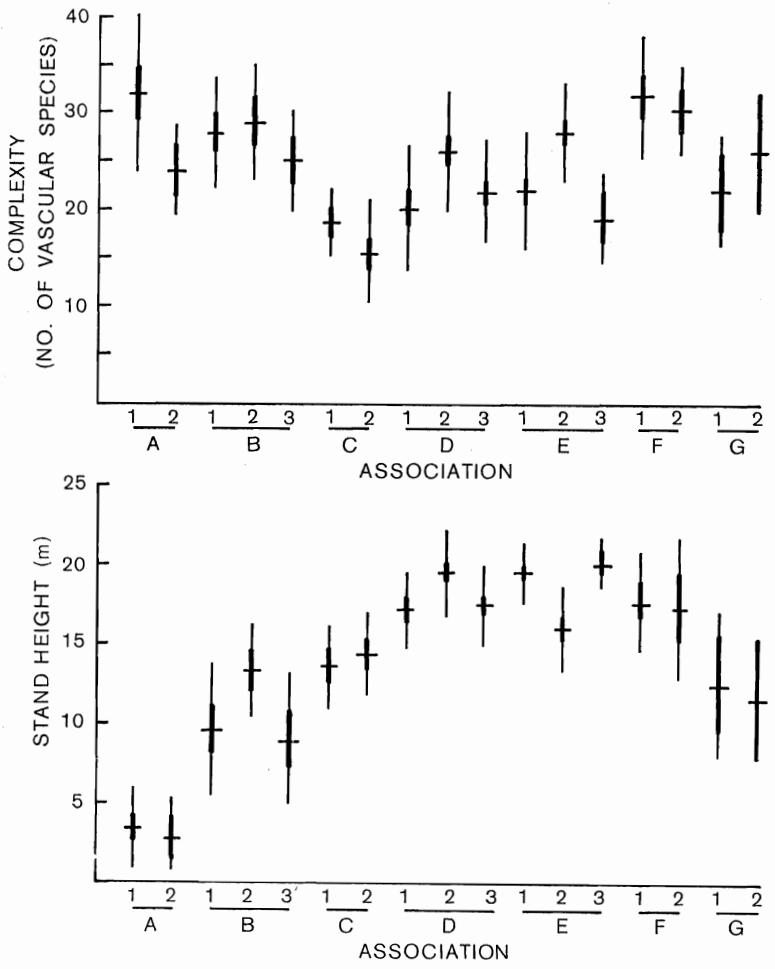


FIG. 4—Stand complexity (number of vascular plant species) and stand height for each association, the mean, standard error (P = 0.05) and standard deviation is shown in each case.

and *Pseudopanax colensoi.* The ground cover is fairly open and of *Blechnum minus, Phormium colensoi, Uncinia filiforme* and *Hymenophyllum* species.

B2 — Cedar-broadleaf-*Olearia lacunosa*

Reaches greatest importance in the Crooked-Haupiri and Waikiti-Tutaekuri catchments, but is rare in the *Nothofagus* areas further north (Fig. 2). It occurs at high altitudes (mean 885 m) and often forms the timberline forest, particularly on spurs (Fig. 6). The canopy which has a mean top height of 13 m (Fig. 4) is fairly open and is dominated by mountain cedar, broadleaf, and *Olearia lacunosa,* with some *Dracophyllum traversii* and *Pseudopanax simplex.* There is a moderately dense shrub tier of *Coprosma pseudocuneata, Myrsine divaricata* and *Archeria traversii* with some *Coprosma ciliata, Coprosma foetidissima,* pepperwood (*Pseudowintera colorata*) and *Pittosporum*

FIG. 5—Dense sub-alpine shrubland above timberline. This shrubland is dominated by **Dracophyllum longifolium, Phormium colensoi, Coprosma pseudocuneata** and **Olearia lacunosa.**

divaricatum. The ground cover is fairly open and dominated by *Polystichum vestitum* but *Cyathea colensoi, Uncinia filiforme, Blechnum capense, Blechnum fluviatile, Blechnum minus, Coprosma cheesemanii* and *Grammitis billardieri* occur frequently.

B3 — Lacebark-broadleaf (Fig. 7)

Occurs in gully heads and on high altitude eroding sites throughout (Fig. 6). The canopy is usually fairly open, has a mean top height of about 9 m (Fig. 4) and is dominated by lacebark (*Hoheria glabrata)* and broadleaf with some *Olearia lacunosa, Dracophyllum traversii* and *Olearia ilicifolia.* The shrub tier is invariably open and the main species is *Coprosma ciliata,* though there is often some *Myrsine divaricata* and *Coprosma pseudocuneata.* The density of the ground cover is variable, probably dependent on ungulate history. In some areas there is a dense 1 m-high sward of *Polystichum vestitum,* but in other areas only near-dead stumps of this species remain and the ground cover is now moss and *Hymenophyllum* ferns. Other frequent ground species are *Cardamine debilis, Luzula picta, Ourisia macrocarpa, Blechnum fluviatile, Coprosma cheesemanii, Epilobium* spp, *Ranunculus hirtus* and *Uncinia filiforme.*

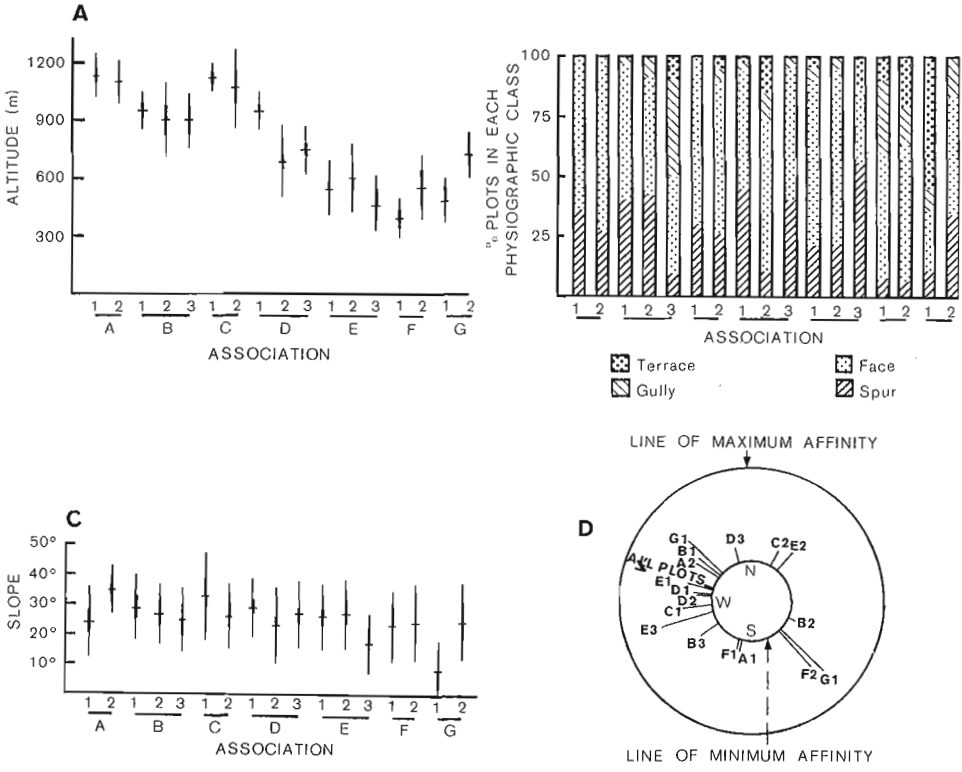


FIG. 6—Habitat of associations: A — altitude; B — Physiography; C — slope; and D — aspect. The mean, standard error ($P = 0.05$) and standard deviation is given for each association in A and C. The proportion of plants in each association occurring on terrace, gully, face and spur sites is given in B, and the mean aspect and degree of affinity calculated from components is given for each association in D.

FIG. 7—Lacebark-broadleaf forest in the Waiheke Catchment. The understorey has been modified by red deer to the extent that a former dense cover of **Polystichum vestitum** is now almost non-existent.

C1 — Silver beech-*Olearia lacunosa*

Occurs at higher levels than the other forest associations and the mean altitude is 1100 m (Fig. 6). It often forms the timberline forest on steep slopes in the northern and central areas (Fig. 2) but is absent from the south. The complexity is relatively low—the mean number of vascular species is only 18 (Fig. 4). The canopy is fairly open, has a mean top height of 13 m, and is dominated by silver beech. There is an open sub-canopy of *Olearia lacunosa* and *Dracophyllum traversii* and a moderately dense shrub tier of *Coprosma pseudocuneata* and *C. foetidissima* with some *Archeria traversii.* The ground cover is open and dominated by *Uncinia filiformis, Chionochloa conspicua* and *Coprosma cheesemanii* with some *Cyathea colensoi, Grammitis billardieri* and *Ourisia macrocarpa.*

C2 — Silver beech-mountain beech

Restricted to the northern areas and in the upper Grey forms nearly a quarter of the total woody vegetation (Fig. 2). It occurs at high altitudes around timberline, along with C1, but tends to be associated with the drier easterly slopes whereas C1 is more often found on western slopes. It is the least complex association in the survey area with a mean of only 15 species of vascular plants per plot. The canopy is moderately dense, has a mean top height of about 14 m (Fig. 4) and is dominated by silver beech and mountain beech. There are seldom any other tree species present. The shrub tier is also moderately dense and almost entirely composed of *Coprosma pseudocuneata.* There is an open ground cover of *Uncinia filiforme* and *Polystichum vestitum* with some *Coprosma cheesemanii* and *Nertera dichondraefolia.*

D1 — High level silver beech-red beech

Important at high altitudes in the northern and central areas but again it is absent from the south. The mean altitude is 920 m but this association seldom forms the timberline. The canopy is fairly dense, has a mean top height of 17 m and is dominated by red beech and silver beech. There is a moderately dense under-storey of broadleaf and *Pseudopanax simplex* with some *P. lineare* and an open shrub tier of *Coprosma foetidissima* and *C. pseudocuneata* with some *Pittosporum divaricatum, Myrsine divaricata* and *Archeria traversii.* The ground cover is open and the most frequent species are *Uncinia filiforme, Cyathea colensoi, Blechnum minus, Nertera dichondraefolia* and *Grammatis billardieri. Asplenium flaccidum* is a moderately common epiphyte.

D2 — Low level silver beech-red beech

This is one of the most important associations in the survey area though again it is absent from the south. It is most important in the Waiheke-Robinson catchment, where it forms a quarter, and in the Waikiti-Tutaekuri catchment, where it forms about one-third of the total woody vegetation. It occurs at mid altitudes, around 670 m, where it tends to occupy the gentler slopes and often terraces (Fig. 6). It is one of the tallest associations, and the canopy, which has a mean top height of 20m, is usually dense and dominated by red beech and silver beech. There is a moderately dense small tree tier of broadleaf, lancewood (*Pseudopanax crassifolium*) and *Pseudopanax simplex* and an open shrub tier of *Coprosma foetidissima,* pepperwood and *Myrsine divaricata.* The ground tier is fairly open and dominated by *Nertera dichondraefolia, Grammitis*

billardieri, Blechnum minus, Microlaena avenacea and *Uncinia filiforme* though *Blechnum discolor, Blechnum fluviatile* and *Cyathea colensoi* are also frequent. *Asplenium flaccidum* is a moderately common epiphyte.

D3 — Silver beech-red beech-rata-kamahi

A relatively minor association except in the north-west where in the Bald Hill and Elliot areas (Fig. 2) it forms stands, often on ridges, around 730 m. It is a tall community with a mean top height of 17 m. The canopy is dense and composed of silver beech, red beech, southern rata and kamahi, with some *Quintinia acutifolius* and Hall's totara. There is a fairly dense small tree layer of broadleaf and *Pseudopanax simplex* with some *Pseudopanax lineare* and a moderately dense shrub tier of *Coprosma foetidissima* and *Phyllocladus alpinus* with some *Coprosma pseudocuneata.* The ground vegetation is very open and the most common species are the small ferns—*Grammitis billardieri* and *Blechnum minus.*

E1 — Red beech-kamahi-*Quintinia*

Is of minor importance in the south but in the Elliot and Waiheke-Robinson areas it forms respectively about one-quarter and one-sixth of the total woody vegetation. It usually occurs on the lower slopes around 540 m altitude and is one of the tallest forest associations with a mean top height of about 19 m. The canopy is dense and dominated by red beech, kamahi, *Quintinia acutifolius* and occasional southern rata and there is a dense sub-canopy formed by poles of these species and also broadleaf, lancewood and *Pseudopanax simplex.* The shrub tier is open and almost entirely of *Coprosma foetidissima.* The ground cover is also fairly open and dominated by *Blechnum discolor,* though the small fern species—*Grammitis billardieri, Hymenophyllum* spp. and *Blechnum minus* are also common.

E2 — Kamahi-rata-*Quintinia*-Hall's totara

Important in the south, particularly in the Crooked-Haupiri and Te Kinga areas where it forms respectively one-third and almost one-half of the total woody vegetation. It is of minor importance elsewhere (Fig. 2). It occupies the mid slopes around 580 m. The canopy is dense, has a mean top height of 16 m and is dominated by kamahi, rata, *Quintinia acutifolius* and Hall's totara with occasional miro. There is a moderately dense sub-canopy of broadleaf and *Pseudopanax simplex* and a fairly open shrub tier of *Coprosma foetidissima* and pepperwood with some *Myrsine divaricata* and *Coprosma banksii.* The ground cover is of fairly dense *Blechnum minus* and *B. discolor* with frequent *Grammitis billardieri, Hymenophyllum* spp and *Cyathea colensoi.*

E3 — Hard beech-kamahi-*Quintinia*

A minor association, represented only in the western areas. It occurs on western aspects at low altitudes particularly on spurs and terraces (Fig. 6). It is the tallest and also one of the simplest associations with a mean top height of about 20 m and a mean number of vascular plant species per plot of around 19 (Fig. 4). The canopy is dense and dominated by hard beech, kamahi, and *Quintinia acutifolius* with some southern rata, rimu, miro and red beech. There is a fairly open sub-canopy of the small tree species, lancewood and *Pseudopanax simplex* and a moderately dense shrub tier of *Coprosma foetidissima.* The ground cover is open *Blechnum discolor, Grammitis billardieri* and *Hymenophyllum* spp.

F1 — Kamahi-*Quintinia*-miro

Occurs in the southern and central areas often as a seral community in gullies and terraces (Fig. 6) around 400 m altitude, but it is only moderately important. It is the most complex forest association with a mean of about 31 species of vascular plants per plot. The canopy is moderately dense and dominated by kamahi, *Quintinia acutifolius* and miro. There is a fairly dense small tree tier of broadleaf, putaputaweta (*Carpodetus serratus*), mahoe (*Melicytus ramiflorus*), wineberry (*Aristotelia serrata*), pate (*Schefflera digitata*) and the tree ferns *Cyathea smithii* and *Dicksonia squarrosa.* The shrub tier is again fairly dense and dominated by pepperwood and *Coprosma foetidissima* with some *C. rhamnoides,* and there is a dense ground cover dominated by *Metrosideros diffusa, Blechnum discolor, Asplenium bulbiferum* and *Blechnum fluviatile* with some *Nertera dichondraefolia, Microlaena avenacea, Phymatodes diversifolium,* and *Grammitis billardieri. Asplenium flaccidum* is a common epiphyte.

F2 — Kamahi-broadleaf

A minor association which occurs on seral gully and terrace sites throughout but is never very extensive. It occupies a fairly wide altitudinal belt around a mean of 550 m and is most common on south and east aspects (Fig. 6). The association is fairly complex with a mean of 30 species of vascular plants per plot. The canopy is moderately dense, has a mean top height of about 17 m and is dominated by broadleaf and kamahi with some southern rata and *Quintinia acutifolius.* There is a fairly open sub-canopy of *Pseudopanax simplex,* wineberry, and putaputaweta and an open shrub tier dominated by pepperwood and *Coprosma foetidissima.* The ground cover is fairly open and dominated by *Polystichum vestitum, Blechnum fluviatile* and *Nertera dichondraefolia,* with some *Cardamine debilis,* waterfern (*Histiopteris incisa*), *Todea superba, Cyathea colensoi, Microlaena avenacea* and *Phymatodes diversifolium. Rubus cissiodes* is an important liane and *Asplenium flaccidum* a common epiphyte.

G1 — Mountain beech-*Phyllocladus*

This minor forest association occurs at low altitudes, on gentle poorly drained slopes and terraces, in the north-west of the survey area. The canopy is fairly open, has a mean top height of about 12 m and is dominated by mountain beech, with some pokaka (*Elaeocarpus hookerianus*). There is an open sub-canopy of scattered broadleaf and *Pseudopanax simplex* and a dense shrub tier of *Phyllocladus alpinus, Coprosma parviflora, Myrsine divaricata, Coprosma pseudocuneata* and *Neomyrtus pedunculata,* with some *Coprosma colensoi* and *C. foetidissima.* The ground cover is dense regeneration of the above species with *Uncinia filiforme, Hymenophyllum* sp. and *Libertia pulchella.*

This association becomes more widespread on the poorly drained terrace country west of the survey area.

G2 — Rata-*Quintinia*-mountain beech

Again a minor association which occurs on slopes and spurs with thin, infertile soil overlying hard, slow-weathering parent material. The canopy is fairly open, has a mean top height of about 11 m and is dominated by southern rata and *Quintinia acutifolius* with some kamahi, Hall's totara, pokaka and mountain beech. There is a fairly open sub-canopy tier of broadleaf, *Pseudopanax lineare* and *Pseudopanax simplex* and a dense

shrub tier of *Phyllocladus alpinus, Coprosma foetidissima* and *C. pseudocuneata* with some *Archeria traversii, Coprosma colensoi, Cyathodes fasciculata* and *Dracophyllum longifolium.* The ground cover is dense *Gahnia procera, Blechnum minus* and *B. capense* with some *Grammitis billardieri, Libertia pulchella* and *Hymenophyllum* spp.

ANIMAL DISTRIBUTION

Red deer, chamois, goats, hares, pigs and opossums all occur in the forests and shrublands of the Grey survey area. The distribution of these mammals throughout the seventeen associations at the time of the survey is shown in Table 1. Pigs, hares and goats were of limited distribution and these animals are not further discussed. Chamois sign was reasonably common at high altitudes, particularly in the denser sub-alpine shrublands and around timberline. The main mammals influencing the vegetation are red deer and opossums. Red deer sign was most frequent in the seral forest and at high altitudes, with the exception of the "dense sub-alpine shrublands". It was least frequent at low altitude and in the special site mountain beech associations.

TABLE 1—Weighted mean percent occupancy for red deer and mean percent occupancy for other mammals in the forest and shrubland associations in the Grey River headwaters

Association	Red Deer	Chamois	Goat	Hare	Pig	Opossum
A1 — Open sub-alpine shrublands	57	14	3	6		14
A2 — Dense sub-alpine shrublands	42	40				13
B1 — Pink pine-Dracophyllum traversii	53	6	8			56
B2 — Cedar-broadleaf-Olearia lacunosa	65	4				63
B3 — Lacebark-broadleaf	70					45
C1 — Silver beech-Olearia lacunosa	53	18				4
C2 — Silver beech-mountain beech	61					3
D1 — High level silver beech-red beech	53					25
D2 — Low level silver beech-red beech	49					41
D3 — Silver beech-red beech-rata-kamahi	54		1		1	38
E1 — Red beech-kamahi-Quintinia	52					30
E2 — Kamahi-rata-Quintinia-Hall's totara	54		23			79
E3 — Hard beech-kamahi-Quintinia	34					31
F1 — Kamahi-Quintinia-miro	53					60
F2 — Kamahi-broadleaf	59					95
G1 — Mountain beech-Phyllocladus	45			9		64
G2 — Rata-Quintinia-mountain beech	44	17	33			33

Opossum sign was generally most frequent in the kamahi associations, i.e., the 'kamahi-broadleaf', 'kamahi-rata-*Quintinia*-Hall's totara', and 'kamahi-*Quintinia*-miro' forest, and least in the high altitude beech associations — i.e. 'silver beech-mountain beech', 'silver beech-*Olearia lacunosa*' and 'high level silver beech-red beech forest'. It was also low in the sub-alpine shrubland association.

The geographic distribution of ungulate (grouped) and opossum sign is given in Table 2.

TABLE 2—Weighted mean percent occupancy for ungulates and mean percent occupancy for opossums in each of the 7 geographic units of the survey area

Unit	Ungulates	Opossums
Bald Hill	49	21
Upper Grey	77	38
Waiheke-Robinson	56	19
Elliot	56	24
Waikiti-Tutaekuri	60	51
Crooked-Haupiri	74	85
Te Kinga	47	60

ANIMAL-PLANT INTER-RELATIONSHIPS

Ungulate-plant inter-relationships

(a) *Susceptibility and trend in vegetation*

The relative susceptibility of the more important tree, shrub and large herb species to the ungulates (especially to red deer since this mammal is the greatest user of the forests and shrublands) is shown in Table 3. Those plant species with susceptibility ratings of greater than one have a reduced frequency in the 0.3-1.8 m tier which may be related to browsing by ungulates. This reduced frequency is more pronounced in the tree species than in the shrubs and herbs which implies that regeneration of tree species is in most cases more susceptible to browsing pressure. There are exceptions and the most pronounced of these are *Asplenium bulbiferum, Polystichum vestitum, Todea superba* and *Cyathea colensoi.* These ferns have high susceptibility ratings, comparable with some of the most susceptible tree species. The most susceptible tree species are fuchsia, broadleaf, lacebark and wineberry.

The associations which are the most susceptible to browsing by ungulates are those containing the highest proportion of susceptible species. These are the associations in which browsing by ungulates is expected to cause the greatest change in composition and structure. The relative susceptibility of both overstorey and understorey has been calculated separately for all the associations other than the open and dense sub-alpine

TABLE 3—Susceptibility ratings and frequencies of the more important species

SHRUBS AND HERBS			TREES		
Species	S.R.	*Freq.	Species	S.R.	*Freq.
Asplenium bulbiferum	40.00	41	Fuchsia excorticata	13.00	27
Polystichum vestitum	13.13	212	Griselinia littoralis	9.07	708
Todea superba	9.28	113	Hoheria glabrata	4.21	66
Cyathea colensoi	3.25	310	Aristotelia serrata	4.17	56
Coprosma foetidissima	1.72	674	Podocarpus ferrugineus	3.75	102
Olearia ilicifolia	1.70	27	Senecio bennettii	3.38	62
Coprosma ciliata	1.62	144	Melicytus ramiflorus	3.00	28
Coprosma colensoi	1.43	165	Schefflera digitata	2.69	51
Astelia cockaynei	1.26	163	Pseudopanax colensoi	2.60	180
Olearia lacunosa	1.13	134	Pseudopanax crassifolium	2.19	242
Cyathodes fasciculata	1.13	32	Carpodetus serratus	2.06	92
Podocarpus nivalis	1.07	64	Pseudopanax lineare	1.93	248
Blechnum discolor	1.05	433	Pseudopanax simplex	1.92	552
Coprosma banksii	1.05	156	Weinmannia racemosa	1.81	527
Coprosma parviflora	0.87	125	Nothofagus fusca	1.39	661
Coprosma pseudocuneata	0.80	453	Nothofagus truncata	1.35	63
Neomyrtus pedunculata	0.78	153	Quintinia acutifolius	1.25	575
Olearia colensoi	0.75	84	Nothofagus solandri var. cliffortioides	1.20	187
Myrsine divaricata	0.69	362	Nothofagus menziesii	0.98	832
Phyllocladus alpinus	0.67	320	Metrosideros umbellata	0.98	369
Chionochloa flavescens	0.65	51	Dicksonia squarrosa	0.96	102
Pseudowintera colorata	0.64	420	Dracophyllum traversii	0.89	172
Archeria traversii	0.54	193	Elaeocarpus dentatus	0.87	63
Coprosma rhamnoides	0.52	163	Libocedrus bidwillii	0.87	71
Chionochloa pallens	0.50	39	Cyathea smithii	0.79	150
Dracophyllum uniflorum	0.49	73	Podocarpus hallii	0.75	312
Phormium colensoi	0.47	157	Dacrydium biforme	0.69	100
Ghania procera	0.43	43	Dacrydium cupressinum	0.60	53
Dracophyllum longifolium	0.39	78			
Chionochloa conspicua	0.36	45			
Pittosporum divaricatum	0.29	222			

* The frequency records represent the sum of observations used in the calculations of S.R. This includes the sum of frequencies in the < 0.3, 0.3-1.8, and 1.8-4.6 m tiers for tree species and the sum in the < 0.3 and 0.3-1.8 m tiers for shrub and herb species.

shrublands where overstorey susceptibility alone is considered (Fig. 8). The associations where the overstorey species are most susceptible to browsing by ungulates are the seral associations B3 and F2 and the lowland kamahi association F1.

The least susceptible are the sub-alpine shrubland associations, A1 and A2; and the mountain beech associations which occur on poorly drained and infertile soils, G1 and G2.

The susceptibility of the understorey more or less follows the susceptibility of the overstorey. The associations with the most susceptible understoreys are again F2, F1 and B3. However, the silver beech-mountain beech forest of the Upper Grey (C2) shows

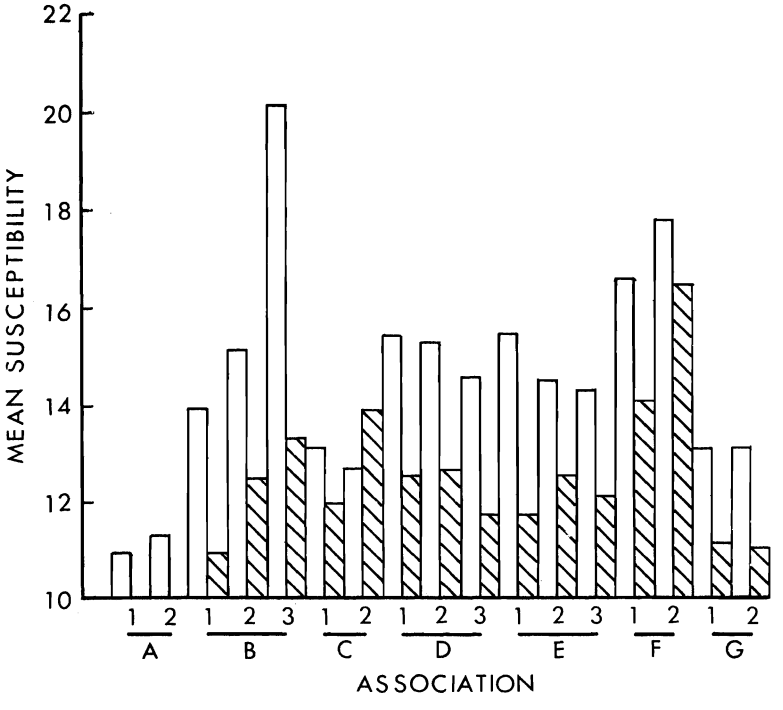


FIG. 8—Relative susceptibility of the associations to browsing by red deer. Understorey susceptibilities are shown hatched and overstorey open.

relatively high susceptibility in the understorey while that of the overstorey is relatively low.

The geographic units of the survey area which are the most susceptible to browsing ungulates are those with the highest proportion of susceptible forest and shrub associations. The order of susceptibility of these is as follows:

Unit 6 Crooked-Haupiri
5 Waikiti-Tutaekuri
4 Elliot
3 Waiheke-Robinson
7 Te Kinga
1 Bald Hill
2 Upper Grey

It is apparent from the above that the most susceptible areas are those in the south, where the forest is mixed and has a high kamahi component, while the least susceptible are in the north where the forests are mostly composed of *Nothofagus* species. The one exception is around Mt Te Kinga which is in the south and yet is of relatively low susceptibility. This is because of the lower proportion of seral associations in this area (Fig. 2).

(b) *Recent utilisation of the vegetation*

Even though almost all tree, shrub and herb species show evidence of having been browsed to some extent by ungulates, it is relatively few which provide most of the fodder. This follows the same pattern as for South Westland (Wardle *et al.,* 1973) and Northern Fiordland (Wardle *et al.,* 1971). The 22 species listed in Table 4 between them provide almost 80% of the fodder, with the first eight accounting for about 50%. The seven *Coprosma* species listed provide about 30% of the total fodder.

TABLE 4—The browse index and approximate percentage of total browse for the major fodder species. The order of preference is given. Species which produce less than 1% of the total fodder are not shown. (The percentages shown are indicative only. They rely on a fairly loose relationship between the records of browsing and the bulk of fodder taken)

Species	Browse Index	% Total Browse
Griselinia littoralis	430	8.9
Coprosma foetidissima	416	8.6
Coprosma pseudocuneata	411	8.5
Weinmannia racemosa	346	7.2
Polystichum vestitum	213	4.4
Myrsine divaricata	205	4.2
Cyathea colensoi	197	4.1
Pseudopanax simplex	183	3.8
Quintinia acutifolius	163	3.4
Pittosporum divaricatum	145	3.0
Blechnum minus	133	2.8
Nothofagus menziesii	133	2.8
Coprosma rhamnoides	129	2.7
Coprosma ciliata	126	2.6
Microlaena avenacea	117	2.4
Coprosma banksii	97	2.0
Metrosideros umbellata	98	2.0
Archeria traversii	94	1.9
Coprosma parviflora	75	1.6
Coprosma colensoi	74	1.5
Olearia lacunosa	66	1.4
Pseudowintera colorata	50	1.0

The order of recent utilisation of the 17 associations has been calculated by determining the weighted per cent browse frequency for each of ten indicator species for each association (Table 5) and then calculating a mean ranking order for these species. The decreasing order of recent utilisation is given below:—

B3 Lacebark-broadleaf
F2 Kamahi-broadleaf
B2 Cedar-broadleaf-*Olearia* lacunosa
D1 High level silver beech-red beech
E2 Kamahi-rata-*Quintinia*-Hall's totara
D2 Low level silver beech-red beech
E1 Red beech-kamahi-*Quintinia*
F1 Kamahi-*Quintinia*-miro
E3 Hard beech-kamahi-*Quintinia*
G1 Mountain beech-*Phyllocladus*
D3 Silver beech-red beech-rata-kamahi
B1 Pink pine-*Dracophyllum traversii*
C1 Silver beech-*Olearia lacunosa*
C2 Silver beech-mountain beech
A2 Dense sub-alpine shrubland
G2 Rata-*Quintinia*-mountain beech
A1 Open sub-alpine shrubland

TABLE 5—Weighted percent browse frequencies for the ten major fodder species in each of the 17 associations. Nil browse records are given. The index has not been calculated where there is a low frequency of a species in an association. Weighted browse frequencies of more than 300% reflect a high utilisation of epicormic shoots and small seedlings

Indicator species	ASSOCIATION															
	A1	A2	B1	B2	B3	C1	C2	D1	D2	D3	E1	E2	E3	F1	F2	G1	G2
Griselinia littoralis			150	∞	∞		∞	2350	775	686	700	2750		900	∞		
Coprosma foetidissima			175	150		111	140	233	134	195	186	158	80	50	200	100	60
Coprosma pseudocuneata	63	69	107	219	236	179	176	231	220	148		167				183	67
Weinmannia racemosa			150						220	274	455	375	140	175	500		
Polystichum vestitum	400			∞	920	∞	∞	850	720			∞			1100		
Myrsine divaricata			80	112	289	100	50	77	104	61	77	138			133	0	
Cyathea colensoi			175	600		500	340	245	250	238	156	380			800		
Pseudopanax simplex			140	167				289	210	133	155	163	133	0		300	25
Quintinia acutifolius									42	59	192	97	54	125	50		8
Pittosporum divaricatum			59	69	100	0	0	113	141	0		25				167	4

It is apparent that the two associations at present receiving the heaviest use by the ungulates are the seral ones, B3 and F2. Since these are also the most susceptible to damage by browsing (Fig. 8) it must be concluded that the ungulates are at present favouring the associations where they can do most harm.

The order of recent utilisation, determined from browsing, differs, in many cases, from the order determined from animal sign such as tracking and pellets (Table 1). This suggests that tracking and pellet sign does not necessarily indicate browsing intensity. Association A1, the open sub-alpine shrubland, provides an example. This association, as a result of being well tracked, shows a high per cent occupancy in Table 1. However browsing sign is minimal and it is ranked last in order of recent utilisation. The probable explanation is that though the animals frequently pass through the shrublands while moving between the alpine grassland and timberline forests, they do not favour this association to feed in.

The order of recent utilisation of the seven geographic units of the survey area has also been calculated by determining a mean ranking order of per cent browse frequencies for ten indicator species (Table 6).

TABLE 6—Weighted per cent browse frequencies for the ten major fodder species in each of the seven sub-units of the survey area. Weighted browse frequencies of greater than 300% reflect a high utilisation of epicormic shoots and small seedlings

Indicator species	Area						
	Bald Hill	Upper Grey	Waiheke Robinson	Elliot Range	Waikiti Tutaekuri	Crooked Haupiri	Te Kinga
Griselinia littoralis		700	554	1817	667	5150	800
Coprosma foetidissima	172	193	174	169	115	217	94
Coprosma pseudocuneata	260	159	118	188	141	153	33
Weinmannia racemosa	113	410	657	269	295	642	81
Polystichum vestitum		4600	2600	1100	436	1733	
Myrsine divaricata	33	38	104	95	78	177	13
Cyathea colensoi	200	227	330	195	173	440	350
Pseudopanax simplex	100	281	105	177	153	233	107
Quintinia acutifolius	14	83	175	82	241	183	9
Pittosporum divaricatum	25	66	132	123	115	106	20

The decreasing order of recent utilisation of the seven geographic units is given below:—

Unit 6 Crooked-Haupiri
2 Upper Grey
3 Waiheke-Robinson
4 Elliot
5 Waikiti-Tutaekuri
1 Bald Hill
7 Te Kinga.

This order more or less coincides with the order of ungulate occupancy determined from animal sign (Table 2). The Crooked-Haupiri and Upper Grey show both the highest browsing intensity and highest animal sign, while Bald Hill and Te Kinga have lowest browsing intensity and lowest animal sign.

(c) *Extent of modification of the vegetation*

Ten indicator species were chosen to represent the extent of modification of both the associations and geographic units of the survey area. The indicator species are listed

in Tables 7 and 8. The indices shown in these tables for each of the indicator species were calculated from tier frequencies in the manner described by Wardle *et al.* (1971). These indices portray the frequency of the species inside the ungulate-accessible 0.3-1.8 m tier of the forest or shrub association relative to the frequencies in the tiers below 0.3 m and above 1.8 m, thus indicating the extent to which the forest understorey has been removed by ungulates. High indices indicate associations or areas where the vegetation has been heavily utilised and has not had a chance to recover, while low indices indicate associations or areas where utilisation has always been low, or perhaps where there has been initial high utilisation but subsequent reduction in ungulates has allowed the vegetation to recover.

The relative extent to which the associations have been modified by ungulates has been determined by calculating a mean ranking order for the indices in Table 7. The decreasing order of modification for the associations is given below:—

B3 Lacebark-broadleaf
F2 Kamahi-broadleaf
E2 Kamahi-rata-*Quintinia*-Hall's totara
D3 Silver beech-red beech-rata-kamahi
D1 High level silver beech-red beech
E1 Red beech-kamahi-*Quintinia*
E3 Hard beech-kamahi-*Quintinia*
B2 Cedar-broadleaf-*Olearia lacunosa*
F1 Kamahi-*Quintinia*-miro
C1 Silver beech-*Olearia* lacunosa
D2 Low level silver beech-red beech
G1 Mountain beech-*Phyllocladus*
C2 Silver beech-mountain beech
B1 Pink pine-*Dracophyllum traversii*
A2 Dense sub-alpine shrublands
A1 Open sub-alpine shrublands
G2 Rata-*Quintinia*-mountain beech

The above ranking is similar to the ranking for recent utilisation and this suggests that the pattern of browsing between associations has remained fairly constant. The ungulates are at present using the seral associations most and these are the ones which have been the most modified in the past. They are using the sub-alpine shrublands and rata-*Quintinia*-mountain beech forest the least and these are also the ones which have been least modified in the past.

The relative extent to which the geographic units of the survey area have been modified by ungulates has been determined by calculating a mean ranking order for the indices in Table 8. The decreasing order of modification for these is given below:—

Unit 6 Crooked Haupiri
4 Elliot
3 Waiheke-Robinson
5 Waikiti-Tutaekuri
2 Upper Grey
1 Bald Hill
7 Te Kinga

TABLE 7 - Degree of modification for 10 indicator species in each of the 17 associations. The index has not been calculated where there is a low frequency of a species in an association. High indices indicate high modification

Indicator species	ASSOCIATION																
	A1	A2	B1	B2	B3	C1	C2	D1	D2	D3	E1	E2	E3	F1	F2	G1	G2
Griselinia littoralis			4.5	>38.0	>20.0	>13.0	>12.0	18.3	5.8	6.7	8.3	16.5	>8.0	14.5	>17.0	>11.0	>6.0
Pseudopanax colensoi	1.3	>8.0	2.5			2.8	>11.0	1.4	2.5	2.8	1.5	2.8					1.5
Pseudopanax simplex	>6.0		1.5	2.3			1.5	2.4	2.5	1.3	2.4	1.6	1.8	1.2	4.5	2.0	0.5
Weinmannia racemosa			1.3						1.9	1.6	2.2	2.0	1.3	1.9	3.3		0.4
Nothofagus fusca				0.8			1.3	1.2	1.3	1.5	1.6		1.5	0.9	4.0	1.5	
Coprosma foetidissima			1.1	1.2		1.2	1.2	1.2	1.2	1.6	1.2	1.5	1.9	1.3	4.3	0.8	0.8
Nothofagus menziesii	0.5		1.4	0.8	1.3	0.9	1.0	1.0	1.1	1.0	0.8					0.7	
Metrosideros umbellata			0.9	0.1				1.1	0.8	1.0	0.9	1.5	0.6	1.5	>4.0		1.2
Coprosma pseudocuneata	0.4	0.2	0.9	0.9	0.8	0.8	0.6	0.8	1.0	0.8		0.7				0.8	0.8
Myrsine divaricata			0.6	0.9	0.8	0.5	0.3	0.6	0.7	1.0	0.8	1.2			0.5	0.9	0.8

TABLE 8—Degree of modification calculated for 10 indicator species in each of seven sub-units of the survey area. The index has not been calculated where there is a low frequency of a species in a sub-unit. High indices indicate high modification

Indicator species	Area						
	Bald Hill	Upper Grey	Waiheke Robinson	Elliot Range	Waikiti Tutaekuri	Crooked Haupiri	Te Kinga
Griselinia littoralis	> 21.0	7.3	5.4	14.2	5.1	28.3	8.3
Pseudopanax colensoi	3.0	3.3	2.0	1.7	2.1	9.5	0.9
Pseudopanax simplex	0.7	1.9	1.7	2.1	2.7	2.5	1.1
Weinmannia racemosa	1.0	1.7	3.2	1.9	1.5	2.6	1.3
Nothofagus fusca	1.1	1.4	1.6	1.3	1.8	—	—
Coprosma foetidissima	1.4	1.6	2.0	1.7	1.5	2.4	1.3
Nothofagus menziesii	1.0	0.9	1.0	1.0	1.1	—	—
Metrosideros umbellata	1.1	0.6	1.1	0.9	0.7	1.5	1.3
Coprosma pseudocuneata	0.5	0.5	0.8	1.0	0.9	0.8	0.8
Myrsine divaricata	0.8	0.5	0.5	0.8	0.5	1.0	1.9

The forests and shrublands of the Crooked-Haupiri area have been the most modified from browsing by ungulates. This area is also the most susceptible to ungulates and it is currently receiving the greatest use. The Te Kinga and Bald Hill areas have been least modified and are currently receiving the least use. On the other hand the Upper Grey is little modified from past use but is currently receiving the second highest use by ungulates. This difference could result from a relatively recent build-up of animal numbers in the area. However the Upper Grey has probably carried red deer populations for a longer period than the rest of the survey area (Clarke, 1971) and it is more likely that the difference results from differences in forest composition. The Upper Grey forests are predominantly *Nothofagus* and are probably less likely to show severe modification as a result of ungulate use than are the mixed forests which predominate in the south.

Opossum-plant inter-relationships

The survey of the Grey Catchment headwaters was primarily designed to determine the influence of ungulates in the forests and shrublands. No objective assessment of opossum-plant inter-relations was made and conclusions relating to the influence of opossums on the vegetation were based on purely visual evidence.

Opossums are widespread throughout the survey area. They are most prevalent in the kamahi forests which dominate in the south and least prevalent in the *Nothofagus* forests, which dominate in the north. Opossum sign was most in evidence in the kamahi-broadleaf and kamahi-rata-*Quintinia*-Hall's totara associations especially (Table 1) in the vicinity of the Crooked-Haupiri catchments (Table 2). Sign was also relatively high in the mountain beech-*Phyllocladus* and cedar-broadleaf-*Olearia lacunosa* associations, and in the vicinity of Mt Te Kinga and the Waikiti-Tutaekuri catchments.

In the north, in the *Nothofagus* associations, the opossums feed predominantly on the foliage of fuchsia and *Pseudopanax* species, particularly *Pseudopanax simplex.* These species are highly susceptible to defoliation and frequent tree death is directly attributable to opossums. However fuchsia and the *Pseudopanax* species at most form an understorey

in the *Nothofagus* forests and the ultimate health of these forests is unlikely to be grossly affected by the removal of them. Damage to the *Nothofagus* species, on which the ultimate health of these forests depends, is minimal and limited to occasional bark chewing in the crown and some minor defoliation.

In the south, in the kamahi-dominated and mixed associations, fuchsia and the *Pseudopanax* species are again preferred fodder species. However kamahi, rata, ribbonwood and *Olearia ilicifolia* are also severely attacked, especially as the food resources offered by the former species start to diminish. *Olearia ilicifolia* is reasonably tolerant to opossum damage, but the others, and particularly rata, are all susceptible to defoliation and frequently death of these species results from damage caused by opossums feeding on the foliage. These species are important dominants, especially in the south and especially in associations B3, E2, F1 and F2 and therefore opossums form a real threat to the stability of the southern forests. The extent of the opossum damage is at present greatest in the Crooked-Haupiri catchments but the Te Kinga area is potentially equally susceptible.

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REFERENCES

ALLAN, H. H. 1961: "Flora of New Zealand." Vol. 1, Govt. Printer, Wellington. 1,085 pp.

BOWEN, F. E. 1964: Sheet 15 Buller. "Geological map of New Zealand, 1 : 250,000." Dept. Sci. Indust. Res., Wellington.

CHEESEMAN, T. F. 1925: "Manual of the New Zealand Flora." 2nd ed., Govt. Printer, Wellington. 1,199 pp.

CLARKE, C. M. 1970: Liberations and Dispersal of Red Deer in Northern South Island Districts. **N.Z. J .For. Sci. 1 (2):** 194-207.

GREGG, D. R. 1964: Sheet 18 Hurunui. "Geological map of New Zealand, 1 : 250,000." Dept. Sci. Indust. Res., Wellington.

NEW ZEALAND METEOROLOGICAL SERVICE 1969: "Rainfall observations for 1967". **N.Z. Met. Serv. Misc. Publ. 110:** 53 pp.

NEW ZEALAND SOIL BUREAU 1950: Soils and Agriculture of Westland. **N.Z. Soil Bur. Bull. 2.** 24 pp.

NEW ZEALAND SOIL BUREAU 1968: General survey of the soils of South Island, New Zealand. **N.Z. Soil Bur. Bull. 27.** 404 pp. and maps.

PHILIPSON, W. R. 1965: The New Zealand genera of the **Araliaceae. N.Z. J. Bot. 3:** 333-41.

SUGGATE, R. P. 1965: Late Pleistocene Geology of the northern part of the South Island, New Zealand. **N.Z. Geol. Surv. Bull. n.s. 77.** 91 pp.

WARDLE, J. 1971: The forests and shrublands of the Seaward Kaikoura Range. **N.Z. J. Bot. 9:** 269-92.

WARDLE, J.; HAYWARD, J. AND HERBERT, J. 1971: Forests and scrublands of Northern Fiordland. **N.Z. J. For. Sci. 1 (1):** 80-115.

WARDLE, J.; HAYWARD, J. AND HERBERT, J. 1973: Influence of ungulates on the forests and scrublands of South Westland. **N.Z. J. For. Sci. 3 (1):** 3-36.

ZOTOV, V. D. 1963: Synopsis of the grass sub-family **Arundinoideae** in New Zealand. **N.Z. J. Bot. 1:** 78-136.

APPENDIX 1 — The per cent frequency of the major species for each association

	A1	A2	B1	B2	B3	C1	C2	D1	D2	D3	E1	E2	E3	F1	F2	G1	G2
Anisotome aromatica	62	20			9												
Archeria traversii	8	47	78	88	23	58	3	54	15	29	3	27				9	67
Aristotelia serrata				4				2	10	1	6	4		57	53		
Asplenium bulbiferum											1	15	6	73	42		
Asplenium flaccidum			11	13	36	21	11	54	63	46	36	35	31	87	84		
Astelia cockaynei	5	33	25			17	40	17	1	4	7	8		3	16	27	17
Blechnum capense	30	20	33	50	5		3	3	14	13	18	31		20	16	18	50
Blechnum discolor			3					3	68	41	100	73	56	80	21	45	
Blechnum fluviatile			6	58	50		17	31	64	14	28	19		70	100		
Blechnum minus	41	73	86	54	23	25	14	53	77	58	56	83	19	13	21	45	83
Cardamine debilis	11		3	21	86		3		7		1	2		17	68		
Carpodetus serratus									25	3	33	23		70	58		
Celmisia armstrongii	76	27			5	4											
Celmisia discolor	95	7	3	8			3										
Chionochloa australis	59	20	3			4	3										
Chionochloa conspicua	8	7	25	4	23	67		2			1						
Chionochloa flavescens	32	67	14	21	18			2				4					17
Chionochloa pallens	68	7		4		13											
Coprosma banksii			22	8		4	3	15	26	32	28	52	6				33
Coprosma ciliata	22	7	19	79	77	21	17	12	22	5	1	15	6	10	47	9	
Coprosma cheesmanii	41	40	19	54	59	67	69	29	14			4			11		
Coprosma colensoi	57	27	42	13	9	13		22	25	11	15	42	6		5	55	50
Coprosma foetidissima	3	7	89	75	5	75	40	88	82	94	91	94	88	63	63	55	83
Coprosma parviflora	14		6	21	18	13	14	17	34	16	15	8	6	10	21	73	
Coprosma pseudocuneata	92	100	97	100	68	96	80	83	43	52	10	19			16	64	83
Coprosma rhamnoides	5			21		4		7	38	5	48	2	6	50	26	18	
Cyathea colensoi	5		31	88	18	58	34	66	64	32	37	54	6	13	53	36	
Cyathea smithii									3		24	23		97	47		
Cyathodes fasciculata									2	8	8		31	7			50
Dacrydium biforme	35	40	81	29						4						27	33
Dacrydium cupressinum									4	1	15	29	63	47		9	
Dicksonia squarrosa				4				5	18	5	15	23	25	67	11		
Dracophyllum longifolium	54	60	64	13	18	4		7				2					50
Dracophyllum traversii	19	40	89	67	55	63	6	19	4	9		10					
Dracophyllum uniflorum	92	60	14		5	13											17

	A1	A2	B1	B2	B3	C1	C2	D1	D2	D3	E1	E2	E3	F1	F2	G1	G2
Elaeocarpus hookerianus			3					2	13	20	3	19	13		11	64	50
Enargea parviflora	19		19	17	5		8	12	12	20	2	25	13		5	45	33
Epilobium spp.	38	13	3	13	55		3								5		
Gahnia procera	3	7	25						1	9		17			5		83
Gaultheria depressa	62	40	36	4		38	20	17	1	5							17
Grammitis billardieri	3	20	42	58	45	50	43	97	83	75	99	96	94	57	68	45	100
Griselinia littoralis	3	7	83	100	77	42	23	88	96	90	84	88	44	90	89	55	83
Hebe vernicosa?	73	40	31		5	8	14										
Histiopteris incisa			11	46	23	8	3	7	20		7	21	6	40	63	18	
Hoheria glabrata	3	13	3	42	100	4	6		5						37		
Hymenophyllum demissum	3		8	21	18	8		8	16	29	69	71	38	47	16		
Hymenophyllum flabellifolium			3					7	8	30	49	71	50	43	32		17
Hymenophyllum multifidum	30	40	53	38	64	42	6	22	20	23	21	17	31	17	16		50
Hymenophyllum sp	3		3	4		8	46	8	19	22			13	3	11	55	50
Libertia pulchella			14	8				12	3	37	4	40	25	7		27	67
Libocedrus bidwillii	5		67	71	41			15	5	24	2	38		3	26	36	33
Luzula picta	41	27	14	46	64	42	17	10	3								
Melicytus ramiflorus											3	2		60			
Metrosideros diffusa									2	1	29	33	19	100	16		17
Metrosideros umbellata			44	29				14	28	89	55	98	81	37	58		100
Microlaena avenacea			11	33		4	3	15	74	15	25	44		50	53	27	
Myrsine divaricata	5	20	81	100	77	29	34	66	65	37	22	62	6	10	47	73	33
Myrsine nummularifolia	78	40	14			21	20										
Neomyrtus pedunculata									13	8	40	37	44	27		64	
Nertera dichondraefolia		13	6	25	5	29	51	56	86	6	45	44	25	63	89	18	
Nothofagus fusca			6	21	9	4	26	92	100	91	97	10	63	37	37	27	
Nothofagus menziesii	14		17	38	23	96	100	98	90	92	48	2	6		16	45	33
Nothofagus solandri var. cliff.		7	11	4		21	91	15	8	39	1		19			100	50
Nothofagus truncata										1	13	2	94	3	5		
Olearia colensoi	43	67	44	8	18	13						2					
Olearia ilicifolia	8	7	6	29	50				3			2			5		
Olearia lacunosa	68	67	56	71	68	96	26	24	1	3		2					
Ourisia macrocarpa	38	67	14	42	64	58	3	2	9					3			
Phormium colensoi	95	93	86	42	27	25	14		1	1		8					17
Phyllocladus alpinus	65	87	92	29	23	8	9	24	15	75	8	40	44		5	91	100
Phymatodes diversifolium					9				5	3	9	17		50	53		

APPENDIX 1 - Continued

	A1	A2	B1	B2	B3	C1	C2	D1	D2	D3	E1	E2	E3	F1	F2	G1	G2
Pittosporum divaricatum	11	7	67	63	9	29		73	38	27	2	13			5	9	
Podocarpus ferrugineus			3						8	5	27	56	69	73	11	18	
Podocarpus hallii	5		44	33	9	4	3	14	23	51	21	98	25	23	42	18	67
Podocarpus nivalis	70	73	14		5	8											
Polystichum vestitum	24	33	6	92	95	38	63	37	40	3	9	12	6	27	100		
Pseudopanax colensoi	46	53	58	11	9	46	31	19	20	30	15	25	6	10	11	18	33
Pseudopanax crassifolium			11				3	5	69	41	67	33	62	23	16	27	17
Pseudopanax lineare	3		72	42	5	8	17	54	28	61	2	13		3			83
Pseudopanax simplex	14	13	69	54		13	9	66	77	92	52	87	69	27	63	55	67
Pseudowintera colorata		7	17	71	14		3	25	86	34	45	85		80	100		
Quintinia acutifolius			14					3	23	73	91	100	100	80	58		100
Ranunculus hirtus	5			29	50		9		5		1			3	11		
Rubus cissoides				21	9		9	10	48	6	17	19		40	79		
Schefflera digitata									6		6	10		57	42		
Senecio bellidioides	65	33	3				3										17
Senecio bennettii	16	60	50	29	9	29		7	1			2					17
Todea superba			8	21	5	4		15	36	5	7	33		33	63		
Uncinia filiforme	8	13	75	88	59	96	86	83	77	29	10	35	13	7	42	64	17
Weinmannia racemosa			17		5				41	75	98	100	100	93	84	9	83