FORESTS OF THE WAITAKI AND LAKE HAWEA CATCHMENTS

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ABSTRACT

The forests of the Waitaki and Lake Hawea catchments have been divided into 12 associations using a combination of Sorensen's 'k' index of similarity and a group average clustering procedure. Four associations are dominated by mountain beech, three by silver beech and five by mountain beech and silver beech together. The composition, structure and habitat of each association is described.

Forest health was determined by using the stand parameters of basal area, stem density, mean stem size, diameter size class distribution and regeneration frequency. It was concluded that with the exception of the Tasman catchment the forests are approaching a state of overmaturity, especially in the Dingle and Timaru River catchments where mean stem size is larger and stem density smaller than elsewhere. Further, in these catchments, the basal area is much lower than in the remainder of the survey area, suggesting that deterioration of the stands is occurring. As yet this is not being compensated for by an increase in regeneration.

INTRODUCTION

The forests of the Waitaki and Lake Hawea catchments were examined during the summer of 1973/74. The purpose was to describe the composition, structure and habitat of the various associations, to examine forest health and to establish a number of permanent reference points in order to follow future trends in forest health.

The study area includes all the catchments draining into Lake Hawea, Lake Ohau, Lake Pukaki and Lake Tekapo and also includes the headwaters of the Ahuriri River catchment. The total area is *c.* 470 000 ha of which 32 000 ha (7%) supports forest (Figs. 1 & 2).

Description of the Survey Area

The geology, climate and soils, and the fire and animal history of the survey area have been summarised by Guest (1974).

The area is mountainous, peaks of 2500 m are common, the highest being Mt Cook at 3765 m. There are many glaciers and the influence of previous glacial advances is apparent in many places.

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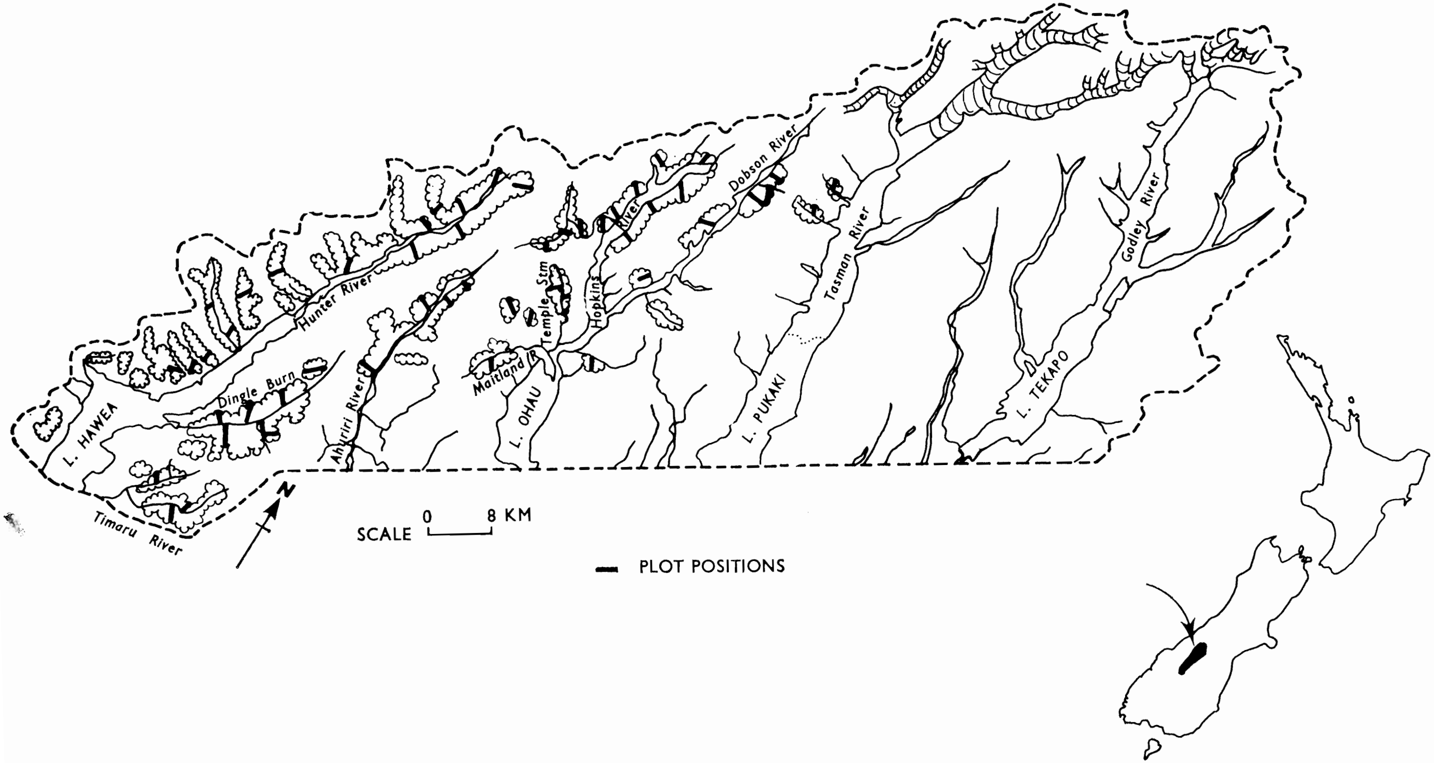

FIG. 1—Waitaki-Lake Hawea Survey area.

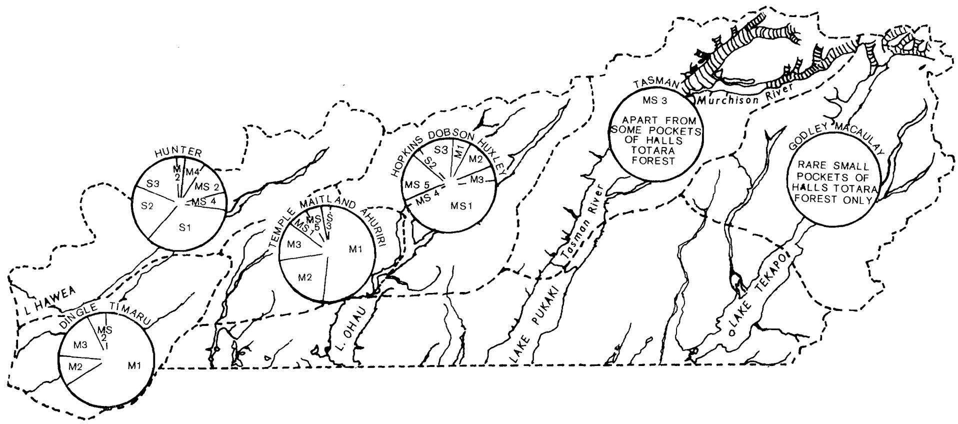

FIG. 2—Distribution of forest associations. Symbols are defined in the text.

The climate is harsh. The predominant north-westerly wind usually brings precipitation. As most of this falls on meeting the barrier of the alps, there is a marked reduction in precipitation towards the east, estimated to range from 7500 mm in the alps, to 1500 mm at the heads of the lakes. Throughout the year at high altitudes, and during the winter elsewhere, most falls as snow, so that spring avalanches are common. Frosts may occur at any time during the year.

Most of the area is composed of greywacke and argillite of low to medium induration. However, down the eastern flank of the Ben Ohau Range, and through the Hopkins, Huxley, and parts of the Hunter catchments, there is a band of weakly schistose, non-foliated greywacke and argillite. Also throughout the west bank of the Hunter, there is a band of finely foliated quartzo-feldspathic schist.

The soils of the area are predominantly high country yellow brown earths. These are moderately acid with a dark brown loose loamy topsoil and a yellow friable subsoil.

There are probably few areas which have been totally excluded from the influence of forest fires. Much of the land has, in the past been managed for sheep grazing, but this land use is diminishing as unsuitable areas are being retired. There is a long history of introduced game animals. Red deer (*Cervus elaphus* L.) were first released near Lake Hawea in 1868, and spread into surrounding areas quite rapidly. Effective control by the use of helicopters has been achieved in recent years but numbers were probably already diminishing when helicopters were first used. European chamois (*Rupicapra rupicapra* L.) and Himalayan thar (*Hermitragus jemlahicus* Smith) were both released in the vicinity of Mt Cook in 1904-09. Although chamois dispersed much more rapidly than thar, both are now common throughout the survey area. European hares (*Lepus europaeus* Pallas are ubiquitous whilst rabbits (*Oryctolagus cuniculus* L.) are locally common.

METHODS

Sampling Procedure

A total of 208 permanent plots were located at 180 m intervals along 56 randomly chosen altitudinal transects running from valley floor to treeline (Fig. 1). At each, a description of the forest composition and structure was made, and the habitat defined.

All vascular plant species were recorded within each of 5 forest tiers delineated by the following heights: stand top height, 15.6 m, 4.6 m, 1.8 m, 0.3 m, and ground level. The physiognomic species in each tier were identified and the altitude, aspect, slope, physiography and soil drainage at each plot recorded. At each plot site an area of 20 m × 20 m was demarcated by tapes and the corners were permanently marked by aluminium pegs. Within this the diameter at breast height over bark (d.b.h.o.b.) of all trees greater than 1 cm diameter at 1.35 m above ground level were measured and recorded, and permanently tagged 1 cm below the level of measurement. Stems of less than 1 cm d.b.h.o.b. but taller than 1.35 m were counted only. Within each plot 24 systematically located circular subplots, each with a radius of 0.49 m, were established, and the centre point of each was permanently marked with a numbered aluminium peg. Within each of these subplots the number of stems of woody species, and the presence of all other vascular plant species were recorded within each of 5 tiers delineated by the following heights: ground level, 15 cm, 45 cm, 75 cm, 1.05 m and 1.35 m.

Analyses

The 208 sociological descriptions were classified into 12 associations using the numerical procedure of Sorensen's 'k' index of similarity and a group average cluster analysis similar to that described by Wardle (1971). The mean composition, structure and habitat of each of the associations was then calculated. The survey area was divided into major catchments or groups of catchments and the distribution of each association throughout these derived (Fig. 2).

Stem diameter data were used to calculate basal area, mean stem diameter, stand density, mean stem girth and stand diameter distribution for individual plots, for associations and for catchments, while data from the 0.49-m radius subplots were used to determine density and frequency values for regeneration of tree species, and density values for woody understorey species.

DESCRIPTION OF THE FORESTS

Little has been published on the composition and structure of the forests of the Waitaki and Lake Hawea catchments. Other than a brief description of Governor's Bush near Mt Cook, Cockayne (1928) provides little of specific nature. Holloway (1954) provides a brief description but this is partly in error in stating that "in the Hunter Valley and other valleys draining to Lake Hawea, mountain beech (*Nothofagus solandri* var. *cliffortioides*)* is everywhere dominant and may be the only beech species present". In fact silver beech (*Nothofagus menziesii*) is the major species in the Hunter Valley and in the headwaters is the only species. Wardle (1970a) briefly describes the composition of the forests of both the Hawea and Waitaki catchments and gives information on both the relative distribution of the beech species and on the nature of the treelines.

The three beech species; red beech (*Nothofagus fusca*), silver beech, and mountain beech, are all present in the survey area though red beech occurs only in the vicinity of

* Botanical names used in this paper are according to Cheeseman (1925) for the grasses, Moore and Edgar (1970) for the remainder of the indigenous monocotyledons, Philipson (1965) for the genera of the Araliaceae, Healy (1970) for the introduced weed species and Allan (1961) for all remaining species.

Kidd's Bush at the head of Lake Hawea, and again as a small stand half way up the Hunter Valley at Ferguson Creek. There is another record from Huxley Forks (Anon. 1958) which the present survey was unable to confirm even though some time was spent examining the described locality. Silver beech and mountain beech dominate the forest either singly or in combination throughout most of the region and for this reason the associations which were determined by a combination of Sorensen's 'k' similarity coefficient and group average cluster, have been grouped under the headings of mountain beech forest, mountain/silver beech forest and silver beech forest. Silver beech dominates most of the forest in the Hunter Valley. It is also present in the upper catchments of the Dingle, Ahuriri, Huxley, Hopkins and Dobson and it also occurs in the Tasman. Mountain beech takes over dominance downstream and, in fact, the relative proportion of mountain beech to silver beech in the forest increases directly with increasing distance from the Main Divide, the percentage of forest dominated by each being as follows:

Distance from Main Divide (km)	0-6.5	6.5-13	13-26	26+
Mountain beech associations	0	18	53	96
Mountain/silver beech associations	23	56	36	4
Silver beech associations	77	26	11	0

Beyond 50 km from the Main Divide, and also in the northern tributaries of the Waitaki, i.e., the Godley, Macaulay and most of the Tasman, beech forest gives way at all altitudes to a predominantly tussock grassland with some scrub. The only forest consists of small, widely separated stands of Hall's totara (*Podocarpus hallii*) usually occurring around the 900 m contour and often associated with *Phyllocladus alpinus*, broadleaf (*Griselinia littoralis*), and *Hoheria glabrata.* These stands are probably remnants of what was once a much more extensive forest of Hall's totara (Holloway, pers, comm.). These stands are not discussed further in this report as they are minimal in extent and mostly occur outside the region of the survey proper.

The altitudinal limits of forest show a marked variation from catchment to catchment (Wardle, 1970a). In the Dobson the treelines are at their lowest (around 1100 m) while in the Hopkins, which lies immediately to the south, they are nearly always around 1200 m. Further south, in the Ahuriri and upper Dingle they may reach 1200 m while in the lower Dingle they reach a maximum for the survey area of around 1250 m. The treeline in the Hunter Valley is between 1125 and 1150 m. Silver beech forms most of the upper valley treelines even where mountain beech is present, and mountain beech is usually limited to valley floors, spurs and alongside steep gradient tributaries. Downstream, mountain beech replaces silver beech forest at low altitudes and ultimately at treeline as well. Silver beech then becomes restricted to the lower and middle slopes and ultimately, from the Dingle northwards, disappears altogether with the forest becoming pure mountain beech.

Mountain Beech Forests

The four associations which have been grouped under this heading have a canopy dominated by mountain beech, and though silver beech may be present it is usually an insignificant component. Each of the four associations is characterised by some feature of the understorey composition and structure. Thus M1 is a very simple forest with very few associated vascular species (Table 1). M2 has an understorey characterised by the presence of **Phyllocladus alpinus** and **Podocarpus nivalis**, M3 lacks a sub-canopy of small trees but has a shrubby tier in which the **Coprosma** species are very important and M4 has a sub-canopy of small tree shrub-hardwood species such as lancewood (**Pseudopanax crassifolium**) and broadleaf.

The site occupied by each of these four associations may be differentiated largely in terms of altitude and moisture availability. M2 usually occurs close to the upper limits of forest and is the characteristic association where mature beech forms a natural treeline. M1 and M3 occur on the mid slopes and M4, which is a minor association, usually occurs at low altitudes. Thus the mean altitude for M2 is 1032 m; for M1, 886 m; for M3, 723 m and for M4, 462 m (Fig. 3). M1 is most important towards the east, on the drier faces and spurs and on the steeper slopes (Fig. 3) while M3 usually occupies moister and more sheltered sites.

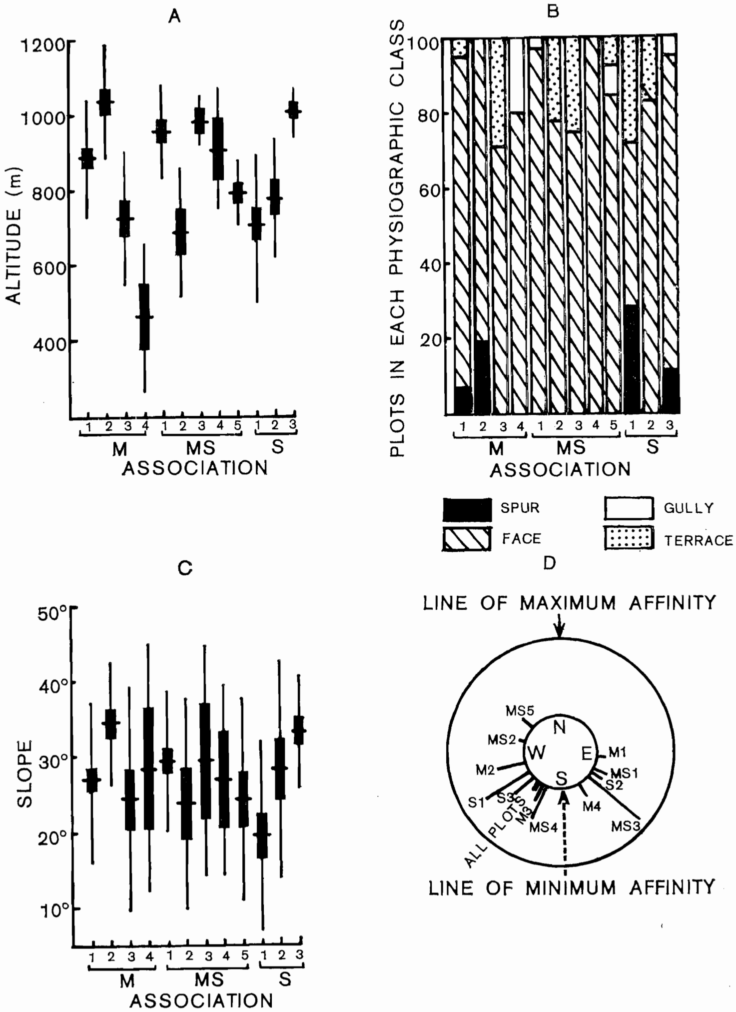

FIG. 3—Habitat of associations: A — Altitude; B — Physiography; C — Slope; and D — Aspect. The mean, standard error (P = 0.05) and standard deviation is given for each association in A and C. The proportion of plots in each association occurring on terrace, gully, face and spur sites is given in B, and the mean aspect and degree of affinity calculated from components is given for each association in D.

TABLE 1—Percent frequency for major vascular species in each association, and for the the total area

Species	M1	M2	M3	M4	MS1	MS2	MS3	MS4	MS5	S1	S2	S3	Total
Acaena novae-zelandiae	2		47		3	33			62		8		10
Anisotome sp.	2	5	7		3				15			11	4
A. hastii							75					6	2
Archeria traversii											23	22	3
Aristotelia fruticosa	4	5	20		9		50	50	46			11	10
A. serrata				25	6	11					8		2
Asplenium flaccidum	2		7	25		11				11	46	6	6
A. colensoi			20						8				2
A. richardii									15				2
A. hookerianum	2		20						23				3
Blechnum capense						11	25				31	6	3
B. minus			7		9			25	38		46	6	8
B. penna-marina	4		60		35	56	75	50	85	39	92	39	34
Cardamine debilis			33		3		25		23			17	6
Carpodetus serratus			7	75		56					23		6
Celmisia petiolata								25	8			11	2
Chiloglottis cornuta			7		3	33	25	25	8	17	38	6	8
Coprosma cheesemanii		5					75				8	6	3
C. ciliata	13	19	33	100	24	11		25	62	28	77	50	30
C. depressa	5		33		38				77	22	69	44	25
C. foetidissima						11					54		4
C. linariifolia	2		13		3	67		25			38		8
C. lucida				100		22					23		4
C. parviflora	2	29	47	50	15	78	100	100	77	22	62	22	30
C. propinqua			27			22	25		23		15		6
C. pseudocuneata	7	33	7		44	22	75	75	15	6	62	94	30
C. rhamnoides	2	5		100		56		75		28	23		11
Corybas triloba	4		20	25	6	78	75		31	17	69	11	17
C. macranthus					6				38		8	6	4
Cyathodes juniperina				75									1
Dracophyllum longifolium		29					25	100			23	44	11
D. uniflorum		14					25					6	2
Elaeocarpus hookerianus					6							6	1
Elytranthe flavida	4	24	13		88	11			38		8	6	23
Elytranthe sp.						44				28			4
E. tetrapetala	84	90	80	75	91	33	50		62	89	54	50	75
Epilobium sp.	2		33				25		15		8	6	5
Exocarpus bidwillii		5											1
Fuchsia excorticata				25	3				15		23		3
Gastrodia cunninghamii	2		7	25									2
Gaultheria antipoda	7	43		25	15	22		25	23	6	31	22	16
G. depressa		5			9				8				2
G. crassa	2	29			3	11	25	75		6		50	11
Grammitis billardieri	4	24	13	75	29	67	50	50	54	78	85	28	33
Griselinia littoralis	2	14	13	50	3	89	75		15	33	92	33	22
Hebe subalpina					3		100				8	17	4
H. salicifolia				25	3	11	25				8		2
Helichrysum bellidioides	2	5	33		3	11		100	31		8		9
Histiopteris incisa			7		3								1
Hoheria glabrata	2				6		50		31		46	6	8
Hymenanthera alpina	5						50		46		8	6	6
Hymenophyllum sp.	4				56	11	50	50	31	67	62	33	27
Hypochaeris radicata	7	5	40	50	3	22	50		8				9
Hypolepis millefolium	5	24	67		15	11		25	62	44	62	22	20
Lagenophora petiolata	4		7	25	3	67	100		31	39	69	28	19
Leptospermum scoparium				75								6	2
Luzula picta	2								8			17	2
Luzula sp.			7				50		8		15	6	3
Lycopodium fastigiatum		5					25						1
Lycopodium sp.		5			3							17	2
L. australianum					6		50		8				2
Myrsine divaricata		10			9	67		50	15	39	92	11	17

TABLE 1—Continued

Species	M1	M2	M3	M4	MS1	MS2	MS3	MS4	MS5	S1	S2	S3	Total
M. nummularifolia		5					25				8		1
Muehlenbeckia axillaris	2		7			11		25			8		2
Nertera dichondraefolia										33	23		4
Nothofagus cliffortioides	100	100	100	100	100	56	100	50	100	11	38	28	79
N. menziesii	9	29	7		88	67	50	100	69	100	92	100	52
Olearia nummularifolia							75				8		2
Phyllocladus alpinus	7	86	7		15	22	75	25	15	6	62	100	30
Pittosporum divaricatum	2	5	7										1
P. eugenioides				25									1
P. patulum	4	5			3							11	3
Poa colensoi	4	5	27			11	25	75					6
Podocarpus hallii	18	38		50	29	78	50		69	22	38	22	29
P. nivalis	7	81			26		25	25	38			67	23
Polystichum vestitum	4	10	73	25	59	11	75	25	85	44	92	61	39
Pseudopanax colensoi							100				23	17	5
P. crassifolius	2			100		78				11	46	11	11
P. simplex		5			3	56			38	28	85	61	17
Pterostylis sp.	18		7	25		22				56	15		13
Ranunculus hirtus	4	10	80		26	33	25		38		23	44	22
Rubus cissoides			33	50		67				11	23		9
R. schmidelioides			7		3				54		15		5
Senecio bennettii							100					11	3
S. haastii	4	5	33		9		25	25	8		15	11	9
S. cassinioides							25					6	1
Trifolium sp.			20						23				3
Uncinia uncinata	2		33	25			50	25	8		15	17	8
U. gracilenta	2	5	47		24	11		25	46		31	11	15
U. filiformis			33	25		22	50	25		67	46	33	17
Urtica incisa			27		3				15				3
Weinmannia racemosa		5											1

Composition and Structure

M1 — Simple mountain beech forest.

By area this is the most important mountain beech association. It is a simple community, averaging only 4.2 vascular species per plot. There is a fairly dense canopy which includes rare silver beech and has a mean top height of 18.4 m (Fig. 4). The understorey small tree and shrub tiers are poorly represented and apart from mountain beech seedlings, there are only rare Hall's totara and **Coprosma ciliata**. The ground cover is largely litter and rock and the only vegetation is scattered patches of moss and rare **Pterostylis** orchids. **Elytranthe tetrapetala** is an important parasite present in 84% of all plots.

M2 — Mountain beech/**Phyllocladus alpinus/Podocarpus nivalis** forest.

Again a fairly simple association with a mean of 8.6 species of vascular plants per plot. The canopy is usually more open than M1 and not as high. The mean top height is 14.5 m. Mountain beech is by far the most important tree species but there is an increase over M1 in the frequency of both silver beech and Hall's totara. Characteristic of this type is the moderately well developed two-tier shrub understorey of **Phyllocladus alpinus** over **Podocarpus nivalis**. Other shrubby species which may be present include **Coprosma parviflora**, **C. pseudocuneata**, **Gaultheria antipoda** and **Dracophyllum longifolium** with a little **Gaulthera crassa** and **Coprosma ciliata**. Generally the ground cover is better developed than in 'M1' with more vegetation and less litter. The most frequent herbaceous species are **Grammitis billardieri** and **Hypolepis millefolium**. **Elytranthe tetrapetala** is again an important parasite and is present in 90% of all plots.

M3 — Mountain beech/**Coprosma** forest.

This association is more complex than either the previous two but the canopy is simple with mountain beech the only tree species apart from rare silver beech. The canopy, which is moderately dense, is taller than for the previous two associations with a mean top height of 21.2 m. The characteristic of this type is the lack of a definite sub-canopy but the presence of a moderately well developed shrubby understorey dominated by **Coprosma** species. The main species in the shrub tiers are **Coprosma ciliata** and **C. parviflora** but there is some **Coprosma propinqua** and wineberry (**Aristotelia serrata**). There is a well developed ground cover of the shield fern (**Polystichum vestitum**) as well as **Ranunculus hirtus**, **Hypolepis millaefolium** and **Blechnum penna-marina**. Other herbaceous species include **Acaena novae-zelandiae**, **Cardamine debilis**, **Epilobium** spp., **Helichrysum bellidioides**, **Hypochaeris radicata** and **Uncinia** spp. **Elytranthe** spp. are moderately important parasites.

M4 — Mountain beech/shrub hardwood forest.

This minor association is only represented by 4 plots, all from the Hunter Valley. It is the tallest of the mountain beech associations with a mean top height of 21.4 m. The canopy is exclusively of mountain beech but there is a well developed sub-canopy of shrub hardwood species. The most important of these is lancewood but broadleaf **Carpodetus serratus**, manuka (**Leptospermum scoparium**), **Fuchsia excorticata**, wineberry and Hall's totara are also present. The shrub tiers are moderately dense and dominated by **Coprosma lucida**, **C. ciliata**, **Cyathodes juniperina** with some **Coprosma parviflora**. The ground cover is fairly open, with a scattering of small herbs such as **Grammitis billardieri**, **Hypochaeris radicata** and some **Uncinia** spp.

Mountain/Silver Beech Forests

Five associations are recognised here, all of which are ecotonal between pure mountain beech and pure silver beech forest. Mountain beech and silver beech are usually both present and frequently co-dominant. MS1 is relatively simple with few understorey species other than some minor herbs; MS2 is again simple but has a sub-canopy of small-tree shrub hardwood species such as broadleaf and lancewood; MS3 is a very complex but minor type which is characterised by **Senecio bennettii** and **Pseudopanax colensoi** in the understorey; MS4 is again minor but has **Dracophyllum longifolium** as the characteristic understorey species; and MS5 has a well developed and complex ground cover of herbaceous species dominated by the fern **Polystichum vestitum**.

The site occupied by each of the five associations may be differentiated in terms of altitude, locality and physiography. MS1 is usually restricted to high altitudes (Fig. 3) and only occurs in the Waitaki catchment (Fig. 2); MS2 occurs at low altitudes and on gentle slopes and terraces only in the Lake Hawea drainage system; MS3 is a minor association restricted to the Tasman catchment; MS4 is again a minor association occupying the mid altitudes on fairly dry rocky areas, mainly in the Hunter; and MS5 occurs at low altitudes and is restricted to the Waitaki catchment.

Composition and Structure

MS1 — Simple mountain/silver beech forest.

This is by area the second most important association particularly in the Hopkins, Dobson and Huxley catchments. It is the most simple of the mountain/silver beech associations with an average of only 9.8 vascular plant species per plot. The canopy is moderately dense mountain and silver beech with mountain beech often being the more important species. The subcanopy small-tree tier consists of poles of the two beech species and little else other than the occasional Hall's totara. There is an open shrub tier dominated by scattered **Coprosma pseudocuneata** with some **C. ciliata** and **Podocarpus nivalis** and a ground cover of minor herbaceous species of which **Polystichum vestitum** and **Hymenophyllum** fern occur most frequently. Other less frequent ground cover species include **Blechnum penna-marina**, **Coprosma depressa**, **Grammitis billardieri** and **Ranunculus hirtus**. **Elytranthe tetrapetala** and **E. flavida** are both important vascular parasites.

MS2 — Mountain beech/silver beech/shrub hardwood forest.

This association is similar to M4 in that there is a sub-canopy of shrub-hardwood species. However whereas the canopy is solely made up of mountain beech in 'M4', silver beech is equally abundant here. The canopy has a mean top height of 23.2 m — making this the tallest association in the survey area. The sub-canopy of small trees is well developed and is composed of Hall's totara, lancewood, broadleaf and **Coprosma linariifolia** with some **Pseudopanax simplex** and **Carpodetus serratus**. There is also a moderately dense shrub tier of **Coprosma parviflora**, **Myrsine divaricata**, and **Coprosma rhamnoides** with some **C. lucida**, **C. propinqua**, **C. pseudocuneata**, **Gaultheria antipoda** and **Phyllocladus alpinus**. The most frequent herbaceous forest floor species are **Blechnum penna-marina**, **Corybas triloba**, **Grammitis billardieri** and **Lagenphora petiolata** but **Acaena anserinifolia**, **Chiloglottis cornuta**, **Ranunculus hirtus**, **Uncinia** spp. and **Hypochaeris radicata** are also often present. **Rubus cissiodes** is a moderately important liane and **Elytranthe** spp. are moderately common parasites.

MS3 — Mountain beech/silver beech/**Senecio bennettii** forest.

This minor association, though important in the Tasman catchment, was not observed elsewhere. It is the most complex of all associations in the survey area and the mean number of vascular plant species per plot is 29.5. Mountain and silver beech both occur in the canopy but there is a preponderance of mountain beech. There is an open sub-canopy of the small trees, broadleaf, **Hoheria glabrata** and Hall's totara, and a dense shrub tier dominated by **Pseudopanax colensoi**, **Senecio bennettii**, **Coprosma parviflora**, **C. pseudocuneata**, and **Phyllocladus alpinus** with some **Aristotelia fruticosa.** There is a mat of vegetation on the forest floor dominated by **Hebe sub-alpina**, **Lagenophora petiolata**, **Anisotome haastii**, **Blechnum penna-marina**, **Coprosma cheesemanii**, **Corybas triloba**, **Olearia nummularifolia** and **Polystichum vestitum**.

MS4 — Mountain beech/silver beech/**Dracophyllum longifolium** forest.

Again a minor association, characterised in this case by the presence of **Dracophyllum longifolium**. The canopy, which is fairly open, has a mean top height of only 16 m and is dominated by mountain and silver beech with silver beech usually being the more important species. The shrub tier is moderately dense and dominated by **Dracophyllum longifolium**, **Coprosma parviflora**, **C. pseudocuneata**, **C. rhamnoides** and **Gaultheria crassa**, with some **Aristotelia fruticosa** and **Myrsine divaricata**. The ground cover is fairly complete and the major species are **Helichrysum bellidioides** and **Poa colensoi**. Other ground cover species include **Hymenophyllum** spp., **Blechnum penna-marina** and **Grammitis billardieri**.

MS5 — Mountain beech/silver beech/**Polystichum** turf forest.

Mountain and silver beech are the canopy species with mountain beech usually the more plentiful. There is an open sub-canopy of beech and Hall's totara, and sometimes **Hoheria glabrata** and **Pseudopanax simplex** but the shrub tier is moderately dense and dominated by **Coprosma parviflora** and **C. ciliata** with some **Aristotelia fruticosa**, **Podocarpus nivalis** and **Hymenanthera alpina**. There is a dense turfy ground cover in which the main species are the ferns **Polystichum vestitum**, **Hypolepis millaefolium** and **Blechnum penna-marina**; the creeping woody **Coprosma depressa**, and the herb **Acaena anserinifolia**. Other less important ground species include **Grammitis billardieri**, **Uncinia gracilenta**, **Ranunculus hirtus**, **Blechnum minus**, **Corybas** spp., **Helichrysum bellidioides**, **Hymenophyllum** spp. and **Lagenophora petiolata**. **Elytranthe** spp. are common parasites and **Rubus schmidelioides** an important liane.

Silver Beech Forests

The silver beech forests have been divided into three associations, each covering about the same total area. In each, silver beech is the dominant canopy species but there may be a little mountain beech. The main characteristic of S1 is the simple composition; S2 on the other hand is very complex and has a well developed subcanopy of small tree species of which broadleaf, **Pseudopanax simplex** and lancewood are the most important;

while the third association, S3, is characterised by a dense shrub tier of **Phyllocladus alpinus** and **Coprosma pseudocuneata**.

The site occupied by each can be differentiated largely in terms of altitude and slope; S1 occupying gentle slopes at low altitude; S2 moderate slopes at mid altitudes, and S3 steep slopes at high altitudes (Fig. 3). S3 is the characteristic association where silver beech forms a natural treeline.

Composition and Structure

S1 — Simple silver beech forest.

This association has a dense high canopy dominated by silver beech and it is only rarely that mountain beech is present. The mean top height is 22.2 m, making it one of the tallest associations in the survey area, and the mean number of vascular plant species per plot is 10.1. The understorey is sparse, though there may be occasional broadleaf, **Pseudopanax simplex** and Hall's totara in the small tree tier and scattered **Myrsine divaricata**, **Coprosma ciliata** and **C. rhamnoides** in the shrub tier. The ground cover is fairly open. The species which occur most frequently are **Uncinia filiformis Hymenophyllum** spp., **Grammitis billardieri** and **Polystichum vestitum**. The parasite **Elytranthe tetrapetala** is quite common.

S2 — Silver beech/shrub hardwood forest.

Silver beech dominates the canopy but there is often a little mountain beech present. It is a tall complex association with a mean top height of 21.3 m and a mean number of vascular species per plot of 25.1. Next to MS3, it is the most complex association in the survey area. There is a well developed sub-canopy of shrub-hardwood species dominated by broadleaf, **Pseudopanax simplex** and lancewood but also with **Hoheria glabrata**, **Coprosma linariifolia,** Hall's totara, **Pseudopanax colensoi**, **Carpodetus serratus**, **Dracophyllum longifolium** and **Fuchsia excorticata**. The shrub tiers are also well developed and dominated by **Myrsine divaricata** and **Coprosma ciliata** with **C. parviflora**, **C. pseudocuneata**, **Phyllocladus alpinus** and some **Coprosma foetidissima**, **Gaultheria antipoda**, **Archeria traversii** and **Coprosma linariifolia**. There is a dense ground cover of herbs, ferns and creeping woody plants, in which the most frequent species are **Polystichum vestitum**, **Blechnum penna-marina** and **Grammitis billardieri**. Other important ground species include **Lagenophora petiolata**, **Corybas triloba**, **Coprosma depressa**, **Hymenophyllum** spp., **Hypolepis millefolium**, **Uncinia** spp., **Blechnum minus** and **Blechnum capense**. **Elytranthe tetrapetala** is moderately important as a parasite and **Asplenium flaccidum** as an epiphyte.

S3 — Silver beech/**Phyllocladus/Coprosma pseudocuneata** forest.

This low growing forest has a mean top height of only 15.9 m. The canopy is dominated by silver beech, though there may be a little mountain beech as well. There is sometimes a sparse sub-canopy of scattered **Pseudopanax simplex**, and more rarely, broadleaf, Hall's totara, and **Pittosporum patulum**. The shrub tier is dense **Phyllocladus alpinus,** and **Coprosma pseudocuneata** with some **Podocarpus nivalis**,**Coprosma ciliata**,**Gaultheria crassa** and less frequently **Dracophyllum longifolium** and **Archeria traversii**. The ground vegetation is dominated by **Polystichum vestitum**, **Coprosma cheesemanii**, **Ranunculus hirtus** and **Unicinia** spp. with some **Blechnum penna-marina**, **Hymenophyllum** spp., **Lagenophora petiolata**, **Grammitis billardieri** and **Hypolepis millaefolium**. **Elytranthe tetrapetala** is a moderately important parasite.

STAND STRUCTURE AND HEALTH

The Forests in General

The forests of the Waitaki and Lake Hawea catchments are of relatively simple composition. Mountain beech, silver beech, or an admixture of both nearly always dominate the canopy. The only other species which occasionally reaches large-tree proportions is Hall's totara. It may do this in the relict pure stands mentioned previously, or it may occur sporadically as isolated trees within an otherwise pure *Nothofagus* forest. The shrubby and small-tree understorey is likewise of low density and with few species (*see* preceding section).

The health of such a simple forest can really only be described in terms of the pattern of mortality and replacement of the dominant *Nothofagus* species. This pattern will be discerned in future, as the plots established in this, the first survey of the area to date, are remeasured. Only indications of the present health of the stand can be determined now, and this by consideration of the present structure of the forest, and by comparison of it with other forests where measurements have been taken. The various parameters of forest structure which will be described are: stand basal area as measured at 1.35 m above ground level, mean stem size, stand density, stand diameter size class distribution, and regeneration densities and frequencies.

The overall total mean basal area of the Waitaki and Lake Hawea catchment stands is 52.66 m^2/ha. This is composed predominantly of mountain beech with 35.96 m^2/ha or 68.3% of the total, and silver beech which provides 16.09 m^2/ha or 30.6%. Hall's totara provides 0.7% and all other species together a mere 0.4%. These other species are all in the small tree and shrub categories and include *Dracophyllum longifolium*, *Coprosma pseudocuneata*, *Phyllocladus alpinus*, *Myrsine divaricata*, broadleaf, *Pseudopanax simplex, Archeria traversii, Hoheria glabrata,* and lancewood.

The mean stem size as measured at 1.35 m above ground level is 17.37 cm for mountain beech, 17.28 cm for silver beech and 5.80 cm for Hall's totara, calculated from all stems which are 1.35 m or greater in height.

The mean density of the three main tree species; mountain beech, silver beech, and Hall's totara, is 913.6, 363.2 and 58.5 respectively, giving a total of 1335.3 stems per hectare. This is roughly in proportion to the basal area, with mountain beech making up 68.4% of the total and silver beech 27.2%.

The stand diameter size class distribution of the *Nothofagus* species combined is shown in Fig. 5. The density of stems per hectare for each 5 cm diameter class is given. The smallest class includes those stems 1.35 m or greater in height which have breast height diameters between 0 and 5 cm. The largest class includes all those stems of 50 cm or greater diameter. Some 14.6% of the total mountain beech stems and 20.3% of the total silver beech stems fall into the 0-5 cm 'ingrowth' class. The distribution of Hall's totara stems is not included in the diagram; even though the occasional stem may reach diameters greater than 30 cm, some 65% are in the 0-5 cm class.

The size class distribution of the smaller trees, and shrub species has been calculated for 2 cm diameter intervals (Table 2). It is interesting to note the complete absence of some of the more palatable species, such as broadleaf, *Pseudopanax simplex*, *Carpodetus serratus* and lancewood from the smaller size classes. This is undoubtedly the results of prolonged browsing by red deer. However, even if these species are completely prevented from regenerating the effect on the general health of the stand will be minimal since they make up such a minor proportion of it.

The total density of stems of all woody species in the 15-135 cm height category is given in Table 3. This category includes most of the shrub tier and also established seedlings of the tree species. Ephemeral tree seedlings are considered as mostly being less than 5 cm in height. There are 32 species represented in the 15-135 cm height

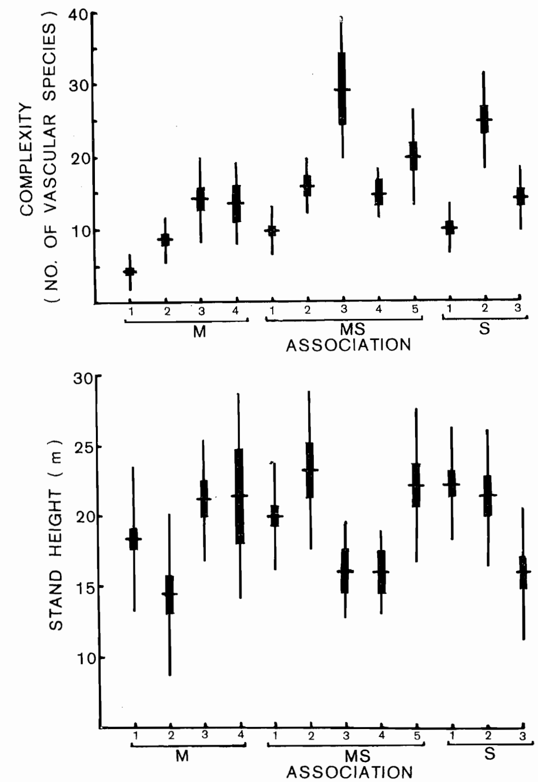

FIG. 4—Stand complexity (number of vascular plant species) and stand height for each association. The mean, standard error (P = 0.05) and standard deviation is shown in each case.

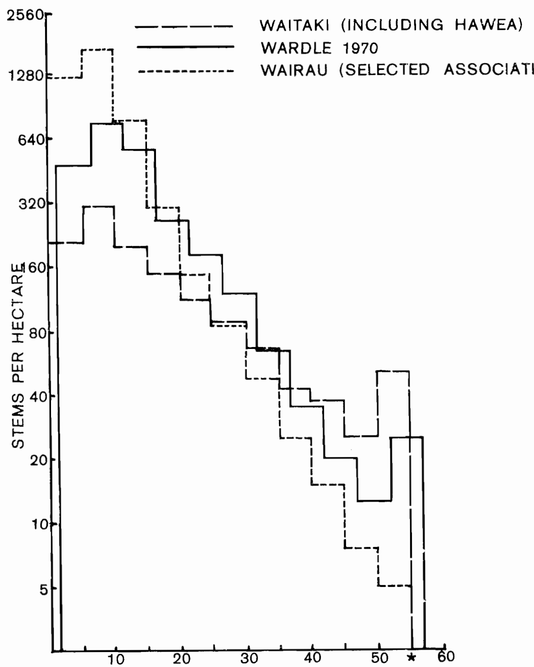

FIG. 5—Diameter class distribution for the survey area, for the Wairau Catchment (selected associations), and for the mean mountain beech stand (Wardle 1970b).

TABLE 2—Mean size class distribution for small trees and shrubs (density values in stems per hectare for 2-cm size classes)

Species	Upper points of 2-cm diameter classes										
	2	4	6	8	10	12	14	16	18	20	20+
Griselinia littoralis	0	0	0	0.1	0.7	0.6	0.7	0.2	0.2	0.2	0.2
Phyllocladus alpinus	21.5	8.9	7.5	3.1	2.1	1.5	0.2	0.4	0.2	0	0.2
Pseudopanax crassifolium	0	0.1	0.1	0.2	0	0	0.1	0	0.2		
Archeria traversii	0	0.4	2.1	1.8	1.0	0.5	0	0.4	0.4		
Dracophyllum longifolium	0.8	3.6	2.5	1.5	1.0	0	0.2	0	0.1		
Hoheria glabrata	2.9	1.6	0.6	0.4	0.2	0	0.1				
Pseudopanax simplex	0	0	0.6	0.4	0.2	0.4					
Carpodetus serratus	0	0	0.4	0	0.1	0.1					
Leptospermum scoparium	0	0.2	0.1	0.1	0.1	0.1					
Coprosma linariifolia	0.2	0.2	0	0.2	0.2						
Myrsine divaricata	1.1	6.0	1.2	0.1							
Coprosma pseudocuneata	37.4	8.9	2.3	0.4							
C. parviflora	2.7	1.1	0.4								
Podocarpus nivalis	2.8	1.8	0.4								

category, and these provide between them, a total density of 7783 stems/ha. Of these 25 species are of minor importance only and contribute a mere 8% of the total. The seven species which make up the remaining 92% are mountain beech, *Podocarpus nivalis, Phyllocladus alpinus, Coprosma pseudocuneata,* Hall's totara, *Coprosma parviflora* and silver beech. Mountain beech provides almost 50% of the total.

It is to be expected that the presence of regeneration in *Nothofagus* forest may be related to the density of the overstorey, and that as the overstorey becomes more open, the regeneration becomes more frequent. Such a relationship has been calculated for the plots established in the forests of the survey area. The best relationship was provided by comparison of the frequency of regeneration in the 15-135 cm height category as taken from the 0.49-m radius subplots within the permanent plots, and total stem girth, as a measure of overstorey density (total stem girth gave a better relationship to regeneration frequency than did basal area). Even so a pattern was only apparent with mountain beech regeneration within mountain beech-dominated stands and silver beech showed no recognisable pattern at all. Even with mountain beech frequent strong exceptions to this relationship occur and the reason appears to be related to stand history. For instance, it may be some time after canopy becomes open that regeneration appears, especially if the opening up process has been rapid. Where this happens there is a situation of

TABLE 3—Density (stems/ha) of woody species in the 15-135 cm height category (density values in stems per hectare)

Tree species (seedlings) Species	Density	Shrub species (stems) Species	Density
Nothofagus solandri	3798	**Podocarpus nivalis**	1516
Podocarpus hallii	381	**Phyllocladus alpinus**	416
Nothofagus menziesii	279	**Coprosma pseudocuneata**	386
Griselinia littoralis	67	**C. parviflora**	362
Pseudopanax colensoi	32	**C. ciliata**	132
P. simplex	30	**Coprosma rhamoides**	113
P. crassifolium	16	**Myrsine divaricata**	56
Hoheria glabrata	13	**Gaultheria crassa**	27
Pittosporum patulum	8	**G. antipoda**	21
Carpodetus serratus	5	**Coprosma foetidissima**	19
Aristotelia serrata	3	**Dracophyllum longifolium**	19
Fuchsia excorticata	3	**Coprosma propinqua**	19
		C. linariifolia	19
		Aristotelia fruticosa	13
		Hymenanthera alpina	8
		Hebe subalpina	8
		Dracophyllum uniflorum	5
		Coprosma lucida	3
		Senecio cassinioides	3
		Coprosma crassifolia	3

low total stem girth related to low seedling frequency. Conversely a situation may arise where there has been partial canopy opening which has induced high regeneration. Subsequently the parent canopy may extend to fill the gaps but the seedlings, which in the beech species are persistent under shade conditions, will remain alive leading to a high total stem girth related to high regeneration frequency.

Treating plots dominated by mountain beech and silver beech separately, the percentage frequency of seedlings (F) calculated from 0.49 m radius plots for stands of various total stem girth (t.s.g.) categories is as follows:

T.s.g. category (m/ha)	Mountain beech stands mean t.s.g.	F	Silver beech stands mean t.s.g.	F
< 500	380	24.7	376	6.0
500-600	552	22.9	540	2.1
600-700	652	6.1	652	3.8
700-800	748	7.2	748	7.0
800-900	848	4.2	844	3.1
900+	1096	2.7	1004	7.7

Thus the seedling frequency for mountain beech is dependent on the overstorey density, but that of silver beech varies in a haphazard manner. The reason for this difference in pattern is not known. It is also apparent that in all the total stem girth categories except one, F for silver beech is less, and in some cases considerably less, than for mountain beech, although it is generally accepted that the former is more shade tolerant in the regenerative phase.

Relating Forest Structure to Forest Health

This can best be done by comparison of the structure of this forest with other forests of similar composition. Two models only are available for this purpose. One of these is the mean mountain beech stand described by Wardle (1970b) which was derived from measurements taken in the Kaweka Range and the Buller, Waimakariri and Rakaia catchments. The other is derived from a survey of the Wairau catchment by Manson and Guest (1975), using 7 of the 13 Wairau forest associations which most resemble the Waitaki-Lake Hawea forests in composition and habitat (all Manson and Guests' 'A' associations plus B1 and B2). Both model stands used in the comparison have a lower proportion of silver beech. Wardle's model is derived from pure mountain beech forest, while the selected Wairau associations have 2% of the stems silver beech, and the remaining 98% mountain beech. In the Waitaki-Lake Hawea survey area, 28% of the stems are silver beech and 72% mountain beech. The differences are probably not sufficient to affect the conclusions formed below.

The mean basal area of the Waitaki-Lake Hawea stands is considerably higher than the mean for the selected Wairau associations, i.e., 52.7 m^2/ha (c.f. 45.5), but not quite as high as for Wardle's stand with 57 m^2/ha. The mean diameter of *Nothofagus* stems is higher than for either of the areas used in the comparison but stand density is much lower. The survey area has a mean of only 1277 stems/ha whereas that for the selected Wairau associations is 4213 and Wardle's mean stand has approximately 2500 stems/ha.

Wardle (1970b) concluded that a stand of mountain beech which has a basal area of approximately 57 m^2/ha (250 sq ft/ac) will be quite healthy even if no regeneration is present. As the value for the survey area approaches this figure it may be concluded that, on average the forests are in quite good condition and that at this stage the presence or absence of regeneration is quite incidental. It must be emphasised (see later) that even though the mean stand is in a relatively healthy state, some stands will be better than average, and some worse. Also the relatively large mean stem size and the low stem density indicate that the Waitaki-Lake Hawea forests are generally old and possibly approaching overmaturity. There is further evidence to support this conclusion from the diameter size class distribution within the stand. It is apparent from comparison with Wardle's mean stand and Manson and Guests' Wairau forests (Fig. 5) that the Waitaki-Lake Hawea stands have a considerably lower proportion of stems in the smaller size classes but a higher proportion in the larger size classes (the 2 in. interval used by Wardle is approximately equivalent to the 5 cm interval used in the other two areas).

The number of stems in the 0-15 cm classes (i.e., 0.5 to 6.5 in. for Wardle) is respectively 3645, 1800 and 711 for the Wairau, Wardle (1970b) and Waitaki-Lake Hawea, whereas for 40 cm + classes (16.5 in. for Wardle) the numbers are respectively 27, 56 and 110. Thus there are only 1/5 the number of stems in the smaller size classes in the Waitaki as in the Wairau but 5 times the number in the large size classes. The smallest category (0-0.5 cm), in the Waitaki-Lake Hawea stands contains only 14.6% of the total mountain beech and 20.3% of the total silver beech stems. The corresponding percentages for the selected Wairau associations are 28 and 39.4%.

In each of the three areas the frequencies of stems in the successive diameter classes fit well a logarithmic relationship of the form:

$\log Y = a + b\,x$ where Y represents frequency and x the diameter class,

if the smallest ingrowth class of 0-5 cm (0.5-2.5 in.) is ignored. The frequency of stems in this smallest ingrowth class, however, is considerably depressed from the general relationship (Fig. 5), and Wardle (1970b) explains this in terms of browsing mammal influence. However there are probably other factors related to stand competition as well.

The mean regeneration density (15-135 cm height category) of mountain beech and silver beech combined, for the survey area, is 4077 seedlings/ha. This is considerably lower than for the selected Wairau associations where the range is between 4295 and 26 823, with a mean of 9037 seedlings/ha. However, this is to be expected as the basal area in the Waitaki-Lake Hawea is much higher than in the Wairau and it certainly does not necessarily signify that the forests in the former area are in poorer health.

In summary, the Waitaki-Lake Hawea forests have a high basal area, a low density of stems in the regeneration and ingrowth categories but a relatively high density in the larger tree categories. In general, these stands are at present in fair health, but are old and perhaps approaching overmaturity, and in consequence they must start to degenerate in the near future. If this degeneration of the parent stands is associated with adequate seedling establishment and growth then the forest will retain a reasonably healthy condition. If on the other hand regeneration is in any way impeded a particularly critical condition will develop.

Variation in Structure and Health

Stands will be compared in two ways. Firstly in terms of the various forest associations defined here and secondly by comparison of the various catchments within the survey area. In each case three groups of parameters will be used: firstly the basic parameters of mean stem diameter, stand density and basal area; secondly the size class distribution of the stands; and thirdly the relationship between total stem girth as an indicator of overstorey density, and regeneration frequency of the *Nothofagus* species in the 15-135 cm height category.

A. *The Associations*

From mean basal area, stem density and stem size for each association (Table 4) it is apparent that those associations that deviate most from the overall means can be placed into two groups.

The first group is characterised by large mean stem diameters and low densities and includes associations M3, MS2 and MS5.

The second group, characterised by small mean stem diameters and higher than average stem densities, includes associations M2, M4 and MS3.

Of these groups it is the first which is potentially the most susceptible to deterioration in health. Large stem sizes and low densities indicate that the stands are either approaching or have reached overmaturity. Further evidence for this is provided from

TABLE 4—Mean basal area, stem density, and stem size (d.b.h.o.b.) for mountain beech and silver beech for the 12 associations, and for all forests in the study area

Type	Basal area (m²/ha)			Density (stems/ha)			Stem size (cm)	
	*Total	Mountain	Silver	*Total	Mountain	Silver	Mountain	Silver
M1	53.12	52.48	0.49	1264.55	1227.38	7.71	18.92	24.61
M2	55.62	49.74	4.30	1883.87	1615.59	113.96	16.09	16.69
M3	41.58	40.48	1.10	686.36	668.08	18.28	23.13	24.52
M4	41.16	40.89	0.00	1439.61	1364.83	0.00	14.59	NIL
All Mountain Beech	51.37	49.52	1.40	1316.98	1230.64	32.28	18.26	18.47
MS1	58.29	48.00	9.84	1421.65	1035.26	273.61	18.69	15.53
MS2	49.51	25.84	22.22	983.29	490.26	371.16	21.84	22.07
MS3	49.83	36.13	12.63	4044.63	3016.33	361.46	8.66	15.59
MS4	55.36	12.83	41.95	1439.61	199.43	947.28	22.59	18.92
MS5	47.07	38.86	7.55	995.22	613.62	210.93	23.67	17.17
All Mountain/Silver Beech	54.06	40.09	13.30	1438.48	944.55	324.85	17.63	17.44
S1	54.83	5.49	49.24	1118.66	79.46	1032.97	21.78	18.43
S2	52.88	4.33	45.52	1015.83	81.02	646.06	20.57	23.37
S3	54.79	0.00	49.16	1857.90	0.00	1281.61	NIL	16.41
All Silver Beech	54.32	3.14	48.28	1370.17	50.05	1029.48	21.26	18.31
All Forests	52.66	35.96	16.09	1366.74	913.6	363.2	13.37	17.28

* The total figures for basal area and stem density refer to all **Nothofagus** stems plus associated trees and shrubs greater than 1 cm diameter at 135 cm above ground level.

the size class distribution (Table 5). These are the four associations with the lowest proportion of stems in the smaller ingrowth size classes and the highest proportion in the larger size classes. In M3, MS2, and MS5, the basal area is well below the overall average (Table 6) and this would suggest that these stands have already begun to deteriorate. This deterioration should be associated with the establishment and release of regeneration, at least in mountain beech, and in fact the percent frequency of mountain beech seedlings in M3 is certainly well above an expected value determined by relating the percent frequency of mountain beech seedlings from all plots dominated by mountain beech in the survey area, with the sum of stem girth of those plots (Fig. 6). On the other hand MS5 has the expected value for mountain beech regeneration, and MS2 considerably less. The lowest percent frequency of silver beech regeneration for any association is also found in MS2 (Table 7). Association S2 on the other hand has probably not yet begun to deteriorate as the basal area remains fairly high.

The second group can probably be regarded as being healthy. The smaller-than-average mean stem size and higher-than-average density indicates that these stands are younger. Further evidence for this is provided by Table 5 from which it is apparent that these three associations have the highest proportion of stems in the smaller ingrowth categories and the smallest proportion in the larger tree categories. In association MS3, which is restricted to the Tasman catchment, this is particularly evident. It has a density of 3377.79 *Nothofagus* stems/ha compared with an overall mean for the survey area of 1276.8 and 85% of these are in the 0-15 cm diameter ingrowth class. The mean diameter for mountain beech, which is the main tree species, is 8.66 cm compared with an overall survey mean of 17.37 cm.

TABLE 5—Size class (diameter breast height outside bark) distribution of **Nothofagus** stems expressed as a percentage of total, for each association and related groups of catchments

Association	Ingrowth category (0.15 cm)	Mid size category (15-40 cm)	Large tree category (40 cm+)
M1	50	41	9
M2	60	35	5
M3	42	46	12
M4	63	33	4
MS1	58	32	10
MS2	41	47	12
MS3	85	13	2
MS4	48	43	9
MS5	42	47	11
S1	58	30	12
S2	45	39	16
S3	62	30	8
Catchments			
Hunter	55	34	11
Dingle-Timaru	49	42	9
Temple-Maitland-Ahuriri	52	41	7
Hopkins-Dobson-Huxley	57	34	9
Tasman	85	13	2

TABLE 6—Percent regeneration frequency (F) and mean total stem girth (breast height) for plots dominated by silver beech in each association and related groups of catchments

Association	Mean total stem girth (m)	F (%)
MS1	679.2	2.78
MS2	603.2	0.00
MS4	799.2	15.28
S1	665.6	3.24
S2	596.4	3.47
S3	780.8	6.13
Overall mean	687.2	4.50
Catchment		
Hunter	778.4	3.18
Hopkins-Dobson-Huxley	653.6	8.13
Overall mean	688.0	4.60

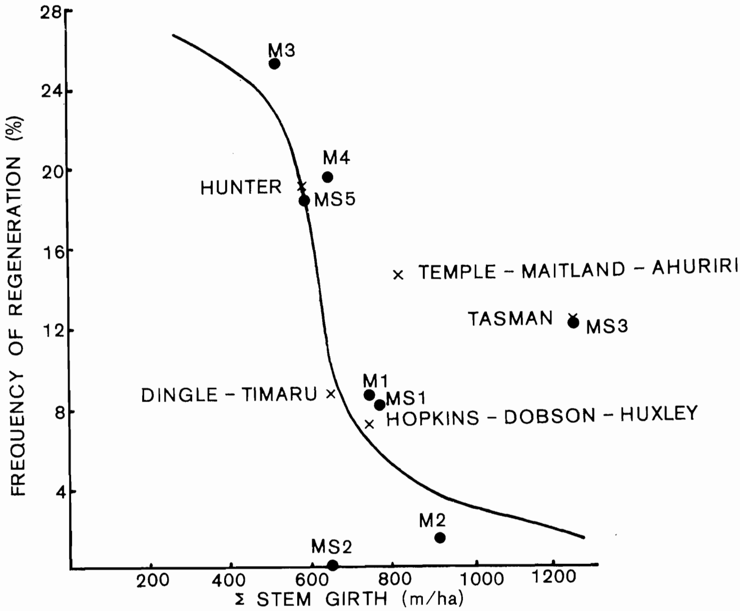

FIG. 6—The relationship between percent frequency of regeneration of mountain beech, and the sum of stem girth as an indicator of overstorey competition. The position of each association and major catchments relative to the mean is shown. The relationship has been calculated only from plots dominated by mountain beech.

TABLE 7—Mean basal area, stem density, and stem size (d.b.h.o.b.) for mountain beech for the five sub-units of the survey area

Catchment	Basal Area (m/ha)			Stem Density (Stems/ha)			Stem Size (cm)	
	*Total	Mountain	Silver	*Total	Mountain	Silver	Mountain	Silver
Hunter	51.46	8.77	41.39	1173.13	195.44	809.17	17.86	19.44
Dingle-Timaru	46.88	46.42	0.25	1083.34	1051.85	4.26	19.43	21.13
Temple-Maitland-Ahuriri	54.59	51.80	2.72	1510.04	1415.93	56.71	17.38	20.63
Hopkins-Dobson-Huxley	56.25	39.73	15.78	1470.05	848.29	425.59	19.09	16.06
Tasman	49.83	36.13	12.63	4044.63	3016.33	361.46	8.66	15.59

* The total figures for basal area and stem density refer to all **Nothofagus** stems plus associated trees and shrubs with d.b.h.o.b. greater than 1 cm.

Particular attention should be paid to the status of the three high altitude associations: M2 (mountain beech-*Phyllocladus alpinus-Podocarpus nivalis*); MS1 (simple mountain beech-silver beech); and S3 (silver beech-*Phyllocladus alpinus-Coprosma pseudocuneata* forest). These are the types which most typically form the treeline stands and as such they occupy sites which are ecologically marginal for *Nothofagus* survival.

The first of these, M2, has already been discussed to some extent, and it has been concluded, as a consequence of the high stem density and smaller-than-average stem size, that it is in a reasonably healthy state. There is further evidence to support this from stand basal area and stem size class distribution. The mean basal area of 55.62 m^2/ha is higher than for the other mountain beech associations (Table 4) and it has a higher proportion of stems (i.e. 60%) in the smaller, 0-15 cm diameter ingrowth categories. On the other hand the percent regeneration frequency is lower than might be expected (Fig. 6).

In MS1 the stand density is marginally above the average for the total survey area, and the mean diameter, at least for the dominant species mountain beech, is well above. Further, the proportion of stems in the large-tree diameter category tends to be high. This suggests that the stands in this type are approaching old age. On the other hand, the basal area, which is the highest of all the associations, indicates a closed stand, and the frequency of regeneration is somewhat above that expected (Fig. 6).

The third association, S3, has an average stem density, slightly below average stem size, and slightly above average basal area (Table 4). The diameter size class distribution is weighted towards the smaller size classes (Table 5) and the percent frequency of regeneration is above average. It can be concluded therefore that this association is at present in a reasonably healthy state.

B. *Catchments*

It is not possible from the information gathered and sampling intensity on this survey to determine the relative health of each small catchment, or to determine the best and the worst areas within a catchment. The survey area has therefore been divided into five units, by pooling some adjacent catchments, as follows:

(i) The Hunter catchment, including the forests at the head of Lake Hawea.
(ii) The Dingle and Timaru catchments.
(iii) The Temple, Maitland and Ahuriri catchments.
(iv) The Hopkins, Dobson and Huxley catchments.
(v) The Tasman catchment.

There are 41-69 permanent plots in each of these areas, except for the Tasman catchment (4 only). It was decided to keep the Tasman catchment as a separate entity, regardless of the small sample size and minimal area, since forest in the catchment differs markedly from that elsewhere.

The forest structure and health in each of the five units will be discussed separately below, again using the three groups of parameters which were used to compare the associations. These are: mean stem diameter, stand density and basal area (Table 7); diameter size class distribution (Table 5); and the relationship between total stem girth and frequency of regeneration (Fig. 6, Table 6).

Hunter

In the Hunter catchment, the forests are predominantly silver beech, though there is some mountain beech and a little red beech in the lower reaches. The basal area of 51.46 m^2/ha is slightly below average for the survey area. Mean stem diameter is a little larger than average but stem density for **Nothofagus** is lower than for any of the other sub-units of the survey area. The diameter size class distribution is weighted towards the large tree categories, and the frequency of regeneration is very low. It can be concluded therefore that this catchment tends towards overmaturity more than most of the others, and that even though there are some signs of the stands beginning to degenerate, there is as yet little response in regeneration.

Dingle-Timaru

The forests of these catchments are almost entirely composed of mountain beech; silver beech being restricted to scattered trees bordering the main stream of the Dingle and at the heads of small side creeks. The basal area is much lower than for any of the other sub-units, mean diameter of both mountain beech and silver beech is larger, and the density of **Nothofagus** stems is low (Table 7). The diameter size class distribution again tends to be weighted towards the larger size classes (Table 5) and there is a considerably lower proportion of stems in the ingrowth category than elsewhere. Further, the frequency of regeneration is slightly below the expected (Fig. 6). All in all, these stands can be regarded as being the most overmature in the survey area. The canopy has deteriorated to a greater extent than elsewhere, and regeneration frequencies are still low.

Temple-Maitland-Ahuriri

Again mountain beech is the dominant species, with silver beech restricted to the valley heads. The basal area and stem density are both high, while mean stem size is about average (Table 7). The diameter size class distribution is about average (Table 5), while the percent frequency of regeneration is well above the expected value (Fig. 6). The stands must therefore be regarded as generally being in good health, and though disintegration of the canopy is to be expected, it is not yet apparent.

Hopkins-Dobson-Huxley

Mountain beech is again the dominant species but there are quite large areas of mixed mountain/silver beech, and pure silver beech towards the headwaters. Basal area is higher than for any of the other sub-units. Stem diameter of the dominant species is fairly large, but there is a reasonable proportion of stems in the smaller-diameter ingrowth categories. The stands are similar but probably slightly older than those of the Temple-Maitland-Ahuriri, but, on the other hand, the frequency of regeneration is down.

Tasman

The Tasman stands are variously composed of mountain beech and silver beech, with either species locally dominant. These stands are unusual for the survey area in that they appear to be relatively young. The mean stem diameter is 8.66 cm for mountain beech and 15.59 cm for silver beech (Table 7). This compares with an overall survey average of 17.37 and 17.28 cm. The density of both beech species is 3377.8 stems/ha, compared with an overall mean of 1276.8, and 85% of these stems are in the smaller ingrowth categories (Table 5). Further the frequency of regeneration is much greater than would be expected (Fig. 6). These stands give the impression of being vigorous and there is a suggestion that mountain beech may be in the process of replacing silver beech in them.

DISCUSSION AND CONCLUSIONS

There is some evidence (Wardle, 1974b) that the drier monotypic mountain beech forests are composed of mosaics of single, two, or sometimes three age classes and are seldom truly mixed-aged. The same probably applies for the drier eastern silver beech forests. It is probable that these uniform stands result from catastrophe, either windthrow, extreme snow break, fire, insect attack such as pinhole borer, or in some cases by combinations of these factors.

It is likely that most of the Waitaki and Lake Hawea forests originated in such a manner some time ago, and now most are beginning to reach overmaturity. These forests would have maintained a high and constant basal area, with stem mortality, resulting mainly from competition, being balanced by growth of the remaining trees. In the absence of further catastrophe this process would have continued with high basal areas being maintained, until mortality related to tree overmaturity started to develop. As the stands are relatively even-aged over large areas, the trees forming the canopy would tend to reach a state of overmaturity together, and growth of the remaining stems is now no longer capable of balancing the basal area deficit caused by mortality. The basal area must decrease, and reduced competition from the adult trees should permit regeneration to occur. If adequate regeneration does occur the stand will be rejuvenated, and a canopy reformed. If regeneration is inhibited the stand must deteriorate rather rapidly and a critical situation will develop.

Evidence from basal area, stem size and density, and diameter size class distribution suggests that most of the Waitaki and Lake Hawea stands are probably approaching such a state of overmaturity. The forests of the Dingle Burn and Timaru River have probably reached this state and are now starting to deteriorate, regeneration is not proceeding at the anticipated rate, and therefore a critical situation may well be developing. The forests of the Hunter are likewise overmature but deterioration has not proceeded as far, while those of the Hopkins-Dobson-Huxley and Temple-Maitland-Ahuriri, though old, have not yet begun to deteriorate. The Tasman forests on the other hand represent an early stage of the process. They are composed of young, vigorous and high density stands where mortality related to competition is high and mean stem diameter small.

It has been mentioned that if normal regeneration proceeds following canopy deterioration then the stand will remain in a healthy state but that if regeneration is inhibited, a critical situation will develop. Consequently the Lake Hawea and Waitaki forests, with the exception of those of the Tasman, must be kept under constant surveillance at this stage. This would best be done by repeat photography of the forest canopy from the air, and methods should be developed for determining from sequential photographs, the onset and rate of canopy deterioration. Following such deterioration regeneration assessments should be made. If and where regeneration is found wanting, as in parts of the Dingle and Timaru catchments, the cause must be determined. If the lack is related in any way to browsing ungulates, efficient control measures must be rapidly enforced.

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