NZ ISSN 0048-0134

NEW ZEALAND
JOURNAL OF FORESTRY SCIENCE

New Zealand Forest Service,
Forest Research Institute, Rotorua

Editor: J. B. Lowry

VOLUME 5 AUGUST 1975 NUMBER 2

PROTECTION FORESTS OF THE WAIRAU CATCHMENT

B. R. Manson† and R. Guest*
Forest Research Institute, New Zealand Forest Service, Rangiora

(Received for publication 31 May 1974)

ABSTRACT

The structure and composition of the forests of the Wairau were determined from information collected at 365 permanently marked plots.

The forests were classified into associations using a multi-linkage cluster analysis and Sorensen's "k" index of similarity. The structure and habitat of each of these associations were described, and their condition in relation to the influences of animals was evaluated.

Forest condition was found to be poorest in the forests close to timberline, and those to the east of the catchment.

INTRODUCTION

A survey of the forests of the Wairau catchment (Marlborough) was carried out during the summer of 1972-73 by staff of the Protection Forestry Division of the Forest Research Institute. The purpose was to describe the structure and composition of the forests; to establish a large number of permanent reference points to detect future change; and to determine which forest associations and which areas are in need of further animal control measures.

The area studied includes all of the Wairau catchment west of the Blenheim-to-

† Mr B. R. Manson was killed in a mountaineering accident in April 1974.
* Present address: New Zealand Forest Service, P.O. Box 513, Christchurch.

Nelson highway on the north bank, and west of the Avon River on the south bank; covering approximately 346 620 ha with an estimated 77 060 ha of indigenous forest.

The catchment is fed by a number of large tributaries which are separated by high, steep, and in many cases badly eroded, mountain peaks and ranges. The highest peaks in the catchment are to the south-west where Mt McKay (2298 m) and numerous other peaks over 1900 m are found. The height of the ranges decreases to the east and north of here and averages about 1500 m on the north bank and in the south-eastern parts of the catchment.

The area is divisible into two geologically distinct regions separated by the Wairau fault which extends along the valley floor from near Tophouse to the sea. This fault separates the northern region of moderately erosion-resistant Marlborough schist from the southern region of alpine greywacke which has high erosion potential because of its intensely shattered and faulted nature.

The soils of the catchment are all yellow-brown earths which separate into two basic types according to the nature of the parent material. Schist is the major parent material of the Patriarch and Onamalutu types found north of the Wairau fault, while the southern Hurunui, Tekoa and Kaikoura types are derived from greywacke.

South of the Wairau fault, Hurunui stony and silt loams are developed under low to moderate rainfalls at altitudes from 150 m to 913 m in the lower foothill regions of all tributaries. The Tekoa stony loams occupy the mid to lower reaches of these tributaries on steeper slopes with higher rainfall, at altitudes from 300 m to 1070 m, while the low fertility Kaikoura loams develop on very steep slopes between 760 m and 1520 m in the tributary heads.

The foothill areas of the northern region carry the Onamalutu silt loams which give way to the Patriarch stony and silt loams on the steeper slopes between 760 m and 1220 m. Rainfall is moderate in the northern region.

Although the climate of the mountain regions of the catchment is poorly recorded, it is known that there is a rainfall gradient from west to east in the main valley. Annual rainfall decreases from 1549 mm at Lake Rotoiti to 1262 mm at the mouth of the Branch River, 1041 mm at the Leatham Homestead, 853 mm in the lower Waihopai and 655 mm at Blenheim. Records from major tributaries indicate that their annual rainfall is higher than in the main valley, and that on the average the forested hill areas of the catchment receive from 2030 mm in the west to 1270 mm in the east. Distribution of the rain is reasonably even throughout the year except for a dry period from mid-summer to early autumn.

Summer temperatures are high and strong dry winds are common, making conditions for plant establishment and growth quite severe. Snow normally falls on the higher ranges during the winter months.

The survey area has been divided into six blocks (Fig. 1) so that comparisons of forest composition and condition can be made between different areas of the catchment.

A total of 365 sociological descriptions were located at 90 m altitudinal intervals along 66 randomly chosen altitudinal transects running from valley floor to timberline.

Each description, which covered an area of approximately 0.04 ha, involved listing all vascular plants which occurred within each of the five 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 dominant species, and the density of each tier were recorded together

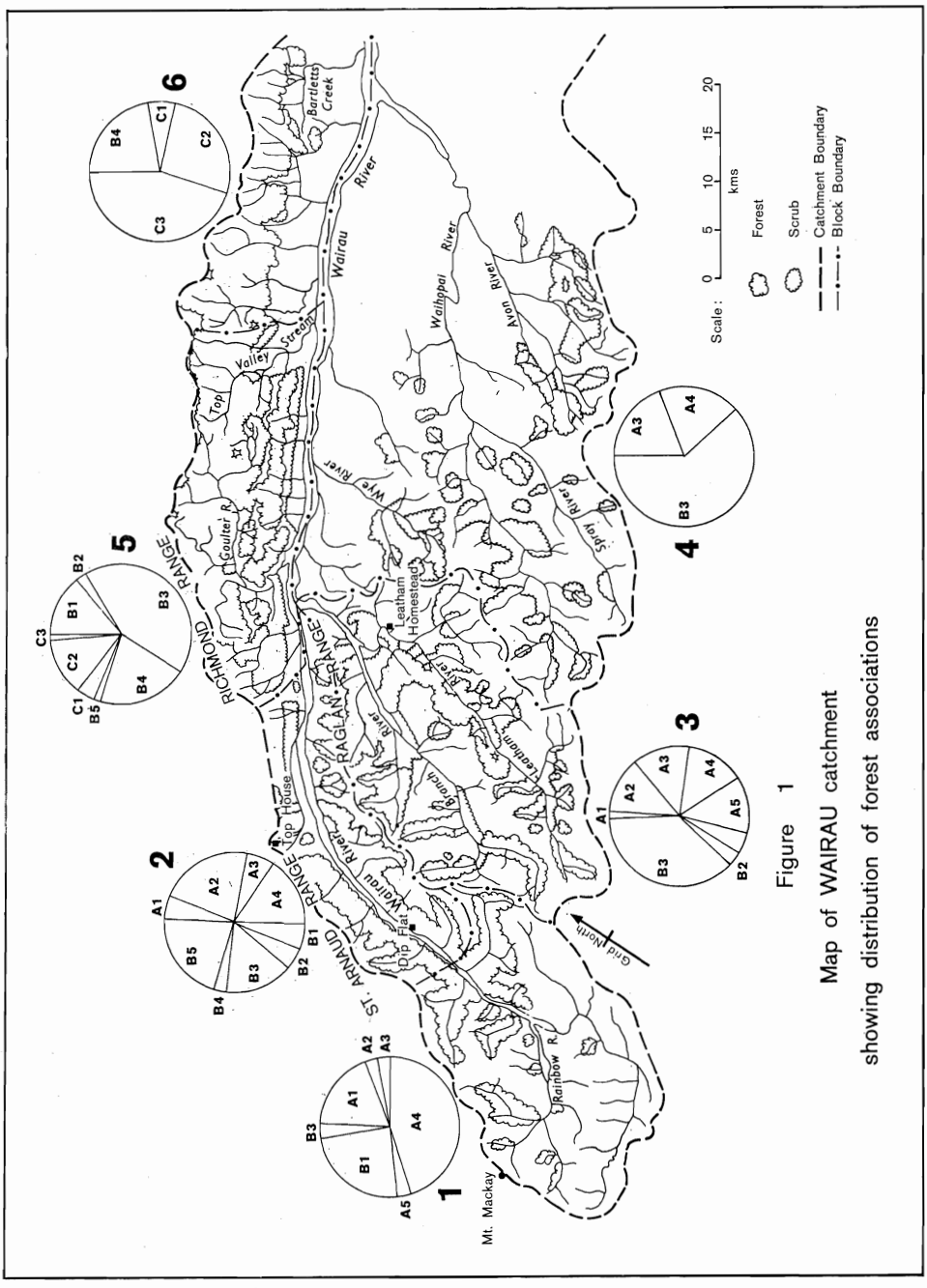

Figure 1

Map of WAIRAU catchment showing distribution of forest associations

with the altitude, aspect, slope, physiography, soil depth and soil drainage. The percentage of the soil surface covered by moss, litter, living vascular plant material, bare soil and rock was also recorded.

At the site of each sociological description a permanent plot 20 m^2 was also established. Within each plot 24 circular subplots, each with a radius of 0.49 m, were established at fixed points which were marked by a numbered aluminium peg.

Within each of these subplots the frequency of regeneration of each tree species was recorded in six size classes between ground level and 1.35 m tall. All stems of tree species on the plot greater than 1 cm diameter at breast height (d.b.h.) were permanently tagged and the diameter measured 1 cm above the point of tag attachment.

ANALYSIS

The 365 sociological descriptions were divided into 13 associations using a numerical procedure similar to that outlined by Wardle *et al.* (1971).

The mean structure and habitat of the 13 associations were calculated using information from both the sociological descriptions and the permanent plot measurements.

The simple nature of the bulk of the forests has made it impossible to estimate the relative susceptibility (Wardle *et al.,* 1971) of each of the associations to ungulate damage. Estimation of current ungulate utilisation of the forests using browse indices (Wardle *et al.,* 1971) has also proved impossible because of the very low incidence of highly and moderately palatable species.

THE ASSOCIATIONS

The 13 recognised associations have been divided into three classes as follows:

Class A — Associations found only south of the Wairau fault.
- A1 — Mountain beech-*Phyllocladus* forest.
- A2 — Mountain beech-*Coprosma pseudocuneata-Polystichum* forest.
- A3 — Mountain beech-broadleaf-*Hebe* forest.
- A4 — Simple mountain beech forest.
- A5 — Mountain beech-*Coprosma parviflora-Blechnum* forest.

Class B — Associations found both north and south of the Wairau fault.
- B1 — Mountain beech-silver beech-*Hebe* forest.
- B2 — Mountain beech-silver beech-broadleaf forest.
- B3 — Mountain beech-red beech-silver beech forest.
- B4 — Silver beech-red beech-*Podocarpus hallii* forest.
- B5 — Red beech-silver beech-broadleaf forest.

Class C — Associations found only north of the Wairau fault.
- C1 — Silver beech-mountain beech-*Coprosma ciliata-Polystichum* forest.
- C2 — Red beech-silver beech-kamahi forest.
- C3 — Kamahi-red beech-silver beech-rata forest.

The distribution, habitat, composition and structure of each is described below with species arranged in order of decreasing frequency. Species occurring in 30% or more of the plots in at least one association are listed in Table 1.

A1 — Mountain beech-*Phyllocladus* forest

This minor association which forms 2.5% of the total forest area is confined to high altitude sites close to timberline. In the Wairau catchment it occurs predominantly

TABLE 1—The percent frequency of the major species for each association

Species	Association												
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3
Acaena novae-zealandiae	18				69	7		2			17		4
Aristotelia fruticosa	18	3	9	2	62	33	22	11		5	67	4	
A. serrata								11	16			21	57
Asplenium flaccidum		3	4		23			10	39	26	33	13	52
Astelia nervosa		22		2		10	33	5	3		46	4	26
Blechnum capense						3		13	42			42	65
B. discolor								4	58			67	100
B. fluviatile								10	32	5	17	29	61
B. lanceolatum		3						2	3			13	30
B. minus								9	45	11		4	13
B. penna-marina	36	22		2	92	30	33	46	7	16	17	17	4
Carpodetus serratus								58	45	16		63	78
Chiloglottis cornuta				2		17	11	12	3		33	13	
Clematis australis	9				31			14	10	5		42	26
Coprosma australis												13	44
C. ciliata	9	38	9	2	23	13	22	19	36	16	100	8	13
C. foetidissima						3		2	55			21	70
C. linariifolia		16			39	13	11	77	52	16	33	50	26
C. microcarpa		19	48		77	37	56	92	74	63	17	100	48
C. parviflora		6		13	85	33	33	51	42	21	33	29	48
C. pseudocuneata	46	84	39	13	8	73	100	37	58	21	83	33	4
C. rhamnoides	9	3			8	10	11	67	45	26	17	54	26
Corybas triloba						3	11	27	32		67	25	4
Cyathea smithii							11		23			8	70
Cyathodes fasciculata								35	13			88	52
C. juniperina		6	44	9	31		67	74	29	11		83	9
Dacrydium cupressinum									3			33	61
Dracophyllum longifolium	18		4				44	2				13	
Elaeocarpus hookerianus		3						20	55	11		46	48
Fuchsia excorticata					8		11	18	13	21			30
Gaultheria antipoda			4	4		7	44	27				13	
G. crassa	27	16			8		33	3	3				
G. depressa	27	13		11	8		56	3			17		
Grammitis billardieri		56	22	32		37	100	60	90	79	50	63	78
Griselinia littoralis		44	48	11	31	67	100	98	100	90	67	96	96
Hebe canterburiensis	27	63	61	2	39	90	78	64	16		100	17	4
Histiopteris incisa		19			23			13	29	16	17	33	25
Hymenophyllum multifidum	9	63	9	4	8	37	44	18	77	21	83	21	91
Hypolepis millefolium	18	22		2	62	13	11	17	3	32		4	9
Lagenophora petiolata	18				69	3		12	3	5			4
Leptospermum ericoides					15	3		17	10			83	30
Melicytus ramiflorus									3			8	35
Metrosideros diffusa									7				35
M. umbellata		3						2	16			13	48
Mycelis muralis	55	22		2	8			12		5			
Myrsine divaricata		31	13		31	20	56	55	71	42	100	8	4
Nertera dichondraefolia	9				15			9	10		17	21	52
Nothofagus cliffortioides	100	100	100	100	100	100	100	96	26	68	67	67	17
N. fusca		16	4	8		13	22	80	97	100	17	96	74
N. menziesii		6		19		50	56	35	100	100	100	79	96
N. truncata												4	30
Ourisia macrophylla		31			15	30	11	1			17	4	
Oxalis lactea		3			15			4			67		
Phyllocladus alpinus	46	3	9	11	31	3	44	6		5			
Pittosporum colensoi								17	3			38	13
P. patulum		22	13	4	31	30	44	3					
Poa colensoi	36			4	23	10		5			33	4	
Podocarpus ferrugineus									3			33	74
P. hallii	9	3	4		15	7	78	70	97	16	50	42	65
P. nivalis	36			15	15		11				17		
Polystichum vestitum	27	63		4	77	43	22	45	36	37	100	8	22
Pseudopanax anomalum		6						10	36	16	17	8	13
P. colensoi	46	66	13	4	39	63	89	28	32	11	50	29	13
P. crassifolium								80	58			83	96
P. simplex					8			27	68	32		17	56
Pseudowintera axillaris									3			21	52
P. colorata								1	71		17	17	70
Rubus cissoides		25	22	2	31		56	69	48	26	17	42	53
Sonchus oleraceus			4	4	92	30	33	26	6	5	17	17	13
Tmesipteris tannensis													30
Uncinia filiformis		19	4	2		43	22	5		26	83	8	9
Weinmannia racemosa								3	32			79	100

at timberline on the St Arnaud Range but does descend to the valley floor in the headwaters of the Rainbow, Branch and Leatham Rivers. It occurs at a mean altitude of 1268 m but ranges from 1079 m to 1468 m.

It is variable in composition and always contains a number of species the range of which extends well beyond timberline. The canopy, which has a mean height of 10.2 m, is composed solely of mountain beech (*Nothofagus solandri* var. *cliffortioides*) which may be reduced to 2-3 m tall on very exposed sites. Subcanopy trees are absent and the shrub tier is generally of moderate density, composed mainly of *Phyllocladus alpinus, Coprosma pseudocuneata* and *Pseudopanax colensoi. Podocarpus nivalis, Gaultheria crassa, G. depressa, Hebe canterburiensis, Aristotelia fruticosa* and various *Dracophyllum* species are also present in the shrub tier.

Blechnum penna-marina, a number of *Celmisia* species and a number of other herbaceous and small woody species are also present on the forest floor.

A2 — Mountain beech-*Coprosma pseudocuneata-Polystichum* forest

This association (which forms 8.7% of the forest area) occurs predominantly near timberline on the Raglan Range, although it is also found on the St Arnaud Range occupying a zone below the mountain beech-*Phyllocladus* association. It occurs predominantly on face sites at a mean altitude of 1212 m.

The mean height of the moderately dense canopy which is dominated by mountain beech is 11.1 m. Broadleaf and *Coprosma linariifolia* form an open subcanopy while the shrub tier is dominated by *Coprosma pseudocuneata.* Minor shrub species include *Pseudopanax colensoi, Hebe canterburiensis, Coprosma ciliata, Myrsine divaricata, Pittosporum patulum, Coprosma microcarpa, Gaultheria crassa* and *G. depressa.* Moderate ground cover is provided by *Polystichum vestitum* and a number of herbaceous species. Moss is very common on the forest floor.

A3 — Mountain beech-broadleaf-*Hebe* forest

This association which forms 6.3% of the forests is found throughout the south bank but is most common in the more eastern areas. On the western side of the Raglan Range the association occupies a zone below the mountain beech-*Coprosma pseudocuneata-Polystichum* association. To the east of the Raglan Range this association forms the timberline right through to the limit of the existing forest in the Avon catchment. It occurs at a mean altitude of 1204 m on face and spur sites.

Mountain beech forms the canopy, which has a mean height of 12.2 m and moderate density. The light subcanopy consists of broadleaf and *Podocarpus hallii.* Shrubs are uncommon but *Hebe canterburiensis, Coprosma microcarpa, Cyathodes juniperina, Coprosma pseudocuneata, Mysine divaricata, Pseudopanax colensoi* and *Pittosporum patulum* are occasionally present. Herbs and ferns are rare, *Ranunculus hirtus* and *Grammitis billardieri* being the most common of these. Moss is very uncommon on the forest floor.

A4 — Simple mountain beech forest

This moderately important association forms an estimated 12.9% of the total forest area. It is found in the upper Wairau and throughout the south bank forests

between 750 m and 1400 m. The association is most often found on face sites of moderate slope and good drainage but is usually confined to dry ridge sites at low altitude.

The mountain beech canopy is moderately dense and has a mean top height of 11.65 m. There is occasionally a sparse subcanopy which may contain broadleaf, silver beech (*Nothofagus menziesii*) or *Pittosporum patulum.* The major species in the open shrub tier are *Coprosma pseudocuneata* and *C. parviflora* but *Podocarpus nivalis, Gaultheria depressa* and *Phyllocladus alpinus* may also be present. The main ground cover vegetation consists of *Grammitis billardieri* and moss.

A5 — Mountain beech-*Coprosma parviflora-Blechnum* forest

This minor association which accounts for 3.6% of the total forest area was only sampled in the headwaters of the Rainbow and Branch Rivers. It occurs at a mean altitude of 1127 m on well drained slopes which have shallow soils and an average slope of 31 degrees.

The open canopy has a mean top height of 15 m and is composed mainly of mountain beech, with occasional *Podocarpus hallii.* There is a light subcanopy of small trees such as broadleaf, *Pseudopanax crassifolium, Coprosma linariifolia* and occasionally kanuka (*Leptospermum ericoides*). The open shrub tier is composed mainly of *Coprosma parviflora, C. microcarpa* and *Aristotelia fruticosa* but contains a large number of other shrub species. Nearly 50% of the forest floor is covered by a number of herb and fern species, the most important being *Polystichum vestitum, Blechnum penna-marina, Sonchus oleraceus, Acaena novae-zelandiae* and *Lagenophora petiolata.*

B1 — Mountain beech-silver beech-*Hebe* forest

This association which forms 8.2% of the total forest cover is confined to the western parts of the Wairau catchment, being found only as far east as the Leatham River on the south bank and Top Valley Stream on the north bank. It occurs at a mean altitude of 1176 m on sites with shallow soils. It is an important timberline association in the western, north bank forests.

The canopy which is dominated by mountain beech, but may contain silver beech, is of moderate density and has an average top height of 12.6 m. There is a moderate subcanopy composed mainly of broadleaf and *Coprosma linariifolia* and to a lesser extent *Pittosporum patulum, Podocarpus hallii* and kanuka. *Hebe canterburiensis* and *Coprosma pseudocuneata* predominate in the moderately dense shrub tier which may also contain *Aristotelia fruticosa, Coprosma microcarpa, C. parviflora, C. ciliata, C. rhamnoides* and *Myrsine divaricata.* Ground cover is provided by *Uncinia filiformis, Polystichum vestitum* and moss.

B2 — Mountain beech-silver beech-broadleaf forest

This minor association forms about 2.5% of the total forest area. It is found on very steep slopes (mean 40 degrees) at a mean altitude of 1078 m on the St Arnaud, Richmond and Raglan Ranges. It is found most often on face sites which have shallow well drained soils containing large amounts of rock material.

The association is one of the more complex of those dominated by mountain beech as it contains a mean number of 20 vascular plant species per plot. The dense canopy has a mean top height of 12 m and is dominated by mountain beech but *Podocarpus hallii,* silver beech and more rarely, red beech (*Nothofagus fusca*) may be present. The dense subcanopy is dominated by broadleaf with *Fuchsia excorticata* and *Coprosma linariifolia* less frequent. The shrub understorey is also dense and is dominated by *Hebe canterburiensis, Coprosma pseudocuneata* and *Pseudopanax colensoi. Cyathodes juniperina, Coprosma microcarpa, Gaultheria depressa, Myrsine divaricata, Dracophyllum longifolium* and *Gautheria antipoda* are of intermediate importance and *Coprosma parviflora, Gaultheria crassa, Aristotelia fruticosa, Coprosma ciliata, Olearia arborescens, Pittosporum divaricatum* and *Coprosma rhamnoides* are less often present. There are a large number of ground species in this association, including *Sonchus oleraceus, Helichrysum bellidioides, Phormium colensoi, Uncinia filiformis* and various orchids.

B3 — Mountain beech-red beech-silver beech

This major association forms 27.7% of the total forest cover in the catchment. It is found throughout the south bank forests but is restricted to the area west of Top Valley Stream on the north bank. The association occurs at a mean altitude of 908 m on well drained face sites.

The moderately dense canopy which has a mean height of 16.3 m is dominated by red beech and mountain beech but usually also contains silver beech and *Podocarpus hallii.* There is a well developed sub-canopy of small trees dominated by broadleaf, *Pseudopanax crassifolium* and *Coprosma linariifolia,* but also containing *Carpodetus serratus, Elaeocarpus hookerianus, Fuchsia excorticata, Leptospermum ericoides, Pittosporum tenuifolium* and *Aristotelia serrata. Coprosma microcarpa* and *Cyathodes juniperina* dominate the shrub tier which contains a number of other species. The ferns *Polystichum vestitum, Grammitis billardieri* and *Blechnum penna-marina* and herbs *Ranunculus hirtus* and *Sonchus oleraceus* are the most common forest floor species.

B4 — Silver beech-red beech-*Podocarpus hallii* forest

This association which occurs at a mean altitude of 860 m forms 8.5% of the total forest area. It is only of minor importance in the south bank forests but is common throughout the north bank. In the western part of the north bank it extends upslope from the valley bottom but in the eastern north bank it occupies an altitudinal zone above associations C2 and C3.

The canopy is of moderate density, reaches a mean top height of 18.9 m and is dominated jointly by silver beech and red beech with *Podocarpus hallii,* mountain beech, kamahi (*Weinmannia racemosa*) and rata (*Metrosideros umbellata*) also being present. Broadleaf and kamahi dominate the understorey which also contains *Pseudopanax crassifolium, Elaeocarpus hookerianus, Coprosma linariifolia, Carpodetus serratus, Fuchsia excorticata* and *Aristotelia serrata.* The major shrub species are *Pseudowintera colorata, Myrsine divaricata* and *Coprosma microcarpa.* The orchid *Corybas macranthus* and the ferns *Blechnum discolor, B. minus, B. capense, Grammitis billardieri* and *Hymenophyllum multifidum* make up the bulk of the forest floor vegetation.

B5 — Red beech-silver beech-broadleaf forest

This association is found at a mean altitude of 801 m in the main Wairau Valley on the south bank and in the extreme west of the north bank. Although it forms only 5.2% of the total forest cover, locally it is an important forest type. It occurs on well drained face and terrace sites which have a mean slope of 24 degrees.

The canopy, which is dominated by red beech and silver beech, but contains small amounts of mountain beech and *Podocarpus hallii,* is of moderate density and has a mean top height of 18.1 m. Broadleaf is the major species in the subcanopy, which also contains *Fuchsia excorticata, Carpodetus serratus, Coprosma linariifolia, Pseudopanax crassifolium* and *Elaeocarpus hookerianus.* The open shrub tier is dominated by *Coprosma microcarpa* and *Myrsine divaricata,* while ground cover is provided by *Uncinia filiformis, U. rupestris, Polystichum vestitum, Grammitis billardieri* and a number of other minor species.

C1 — Silver beech-*Coprosma ciliata-Polystichum* forest

This minor association (1.6% of total forest) is found at high altitude on the Richmond Range where it forms a narrow band at timberline. The mean altitude at which it occurs is 1216 m but it may descend to 1040 m in the valley heads close to the main range. The soils on which it occurs tend to be shallower and more free-draining than those at lower altitude.

The association is one of the more complex with a mean number of 23 vascular species per plot. The dense canopy has a mean height of 12.4 m and is dominated by silver beech, but mountain beech and *Podocarpus hallii* are locally important. The subcanopy contains broadleaf and occasionally *Libocedrus bidwillii* at the western end of the range, while *Coprosma ciliata, Myrsine divaricata, Coprosma pseudocuneata* and *Hebe canterburiensis* dominate the diverse shrub tier. *Uncinia filiformis* and *Polystichum vestitum* are the dominant ground species although a number of other herbaceous species may be present.

C2 — Red beech-silver beech-kamahi forest

This association, which occurs at a mean altitude of 689 m and forms 6.6% of the total forest, is concentrated in an area between Top Valley Stream in the west and Bartletts Creek in the east. At the eastern end of its distribution it occupies a zone above the kamahi-red beech-silver beech-rata forest, but in the west it descends to valley bottom. The association most often occupies face sites with shallow soils and good drainage.

The association is one of the more complex with a mean of 23.7 vascular species per plot. The open forest canopy has a mean top height of 19.5 m and is dominated by red beech and silver beech but also contains moderate amounts of kamahi, mountain beech and black beech (*Nothofagus solandri*). The subcanopy is moderately dense and is dominated by broadleaf and kamahi with *Podocarpus hallii, P. totara,* miro (*P. ferrugineus*), rimu (*Dacrydium cupressinum*), *Pseudopanax crassifolium, Carpodetus serratus,* rata (*Metrosideros umbellata*), *Elaeocarpus hookerianus, Coprosma australis* and *C. linariifolia* also being present. The podocarp species rarely reach stand top height

in this association. The shrub tier is dominated by *Coprosma microcarpa, Cyathodes fasciculata* and *C. juniperina,* but may also contain *Coprosma rhamnoides, C. pseudocuneata, C. parviflora, C. foetidissima, Aristotelia serrata, Pseudowintera axillaris, P. colorata, Hebe canterburiensis* and *Dracophyllum urvilleanum. Blechnum discolor* is the major fern species on the forest floor which supports very few herbaceous species.

C3 — Kamahi-red beech-silver beech-rata forest

Although this association forms only 5.7% of the total forest cover it is most important east of Top Valley Stream. The mean altitude at which it occurs is 540 m, with a range from 240 m to 872 m. This association occurs most often on face sites where soils are well drained and of moderate depth.

This association is the most complex in the Wairau forests with a mean of 31 vascular species per plot. The canopy has a mean height of 20 m and is fairly open. Silver beech, red beech and kamahi are the dominant species in the canopy but occasional *Nothofagus truncata,* rimu, rata, miro and *Podocarpus hallii* do occur. The subcanopy is moderately dense and may contain black beech, broadleaf, *Carpodetus serratus,* kanuka, *Pittosporum colensoi, P. eugenioides, Melicytus ramiflorus, Elaeocarpus hookerianus, Pseudopanax simplex, P. crassifolium, Myrsine australis, Hedycarya arborea, Coprosma linariifolia, C. lucida, C. australis* and *Cyathea smithii.* The moderately dense understorey is dominated by *Pseudowintera colorata, P. axillaris, Cyathodes fasciculata, Coprosma microcarpa* and *C. parviflora. Coprosma rhamnoides, C. ciliata, C. foetidissima* and the lianes *Rubus cissoides, Ripogonum scandens* and *Metrosideros diffusa* may be present. *Blechnum discolor* and *Hymenophyllum multifidum* are nearly always present, but other ferns, e.g., *Cyathea dealbata, Blechnum capense, B. fluviatile, B. lanceolatum, B. minus, Asplenium flaccidum, Histiopteris incisa* and *Polystichum vestitum* are also found. *Nertera dichonfraefolia* is the major forest floor herb.

Distribution of the Associations

This is related to changes in altitude (Fig. 2), site stability, rainfall and the severity of winter conditions, especially at high altitude.

In the south-west of the catchment, associations dominated by mountain beech form the total forest cover above 914 m. In this area soils tend to be shallow and stony and slopes are steep and may be unstable. Snow frequently falls to well below timberline in the main valleys and the valley head forests are subject to severe frosts and snow avalanche damage. Drought conditions exist on these shallow soils during the summer months. Below 914 m, associations, in which red and silver beech may be important, form large areas on gentler slopes with deeper and more stable soils. Red beech, which locally forms impressive stands, generally reaches its maximum altitude in moist gully sites, the dry rocky ridges being occupied by simple mountain beech forest. Silver beech tends to occupy a subcanopy position throughout the south bank forests, probably because climatic conditions are marginal for its growth.

The timberline forests of the western north bank are similar to those of the south bank being dominated by "mountain beech-silver beech-*Hebe* forest" on dry rocky sites at high altitude. The important "mountain beech-red beech-silver beech"

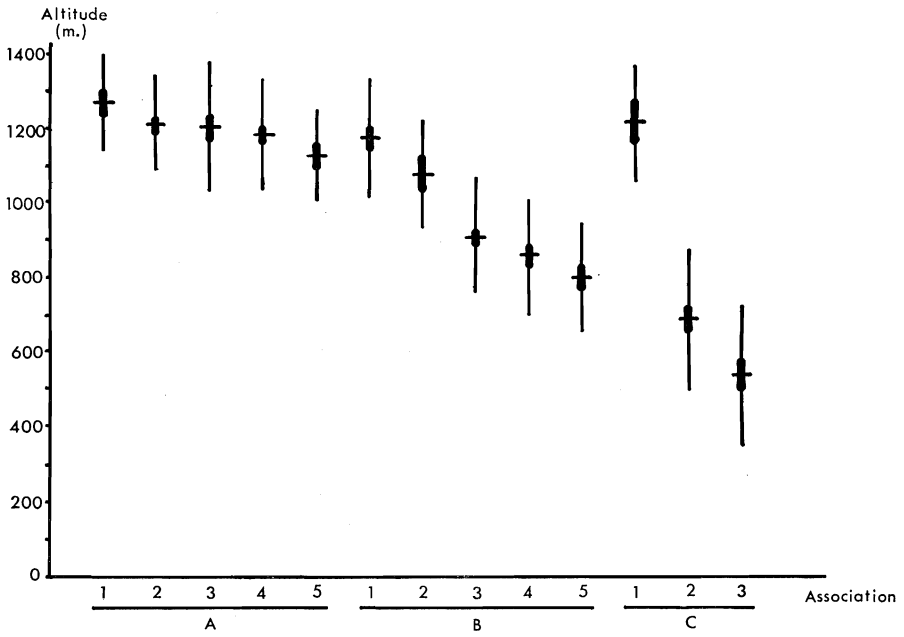

FIG. 2—Altitudinal range; mean, standard error and standard deviation are given for each of the associations described in the text

association which may extend from valley bottom to timberline, provides the bulk of the north bank forest cover west of Top Valley Stream.

To the east of Top Valley Stream, black beech tends to replace mountain beech, and hard beech replaces red beech on some sites at low altitude, while silver beech becomes a major timberline species. Kamahi and a number of podocarp species are important on the warm, but frequently very dry, sites at low altitude. Rata occurs scattered throughout the north-eastern forests and reaches maximum abundance on the steep schist bluffs in the heads of the main tributaries.

There is considerable variation in the complexity of the associations (Fig. 4). The least complex is A4, "simple mountain beech forest", which has a mean of 3.92 vascular species per plot. The most complex is C3, "kamahi-red beech-silver beech-rata forest", with 31 vascular species per plot.

Complexity generally decreases with increase in altitude; but there are exceptions as associations which form the upper or lower forest margins tend to contain species whose range extends beyond the forest area.

Stand height is greatest in the associations occupying the lowest altitude sites (Fig. 3).

The Present Condition of the Forests

(1) *Forest floor ground cover*

Past condition and trend surveys (Manson, 1972) have shown that high populations of browsing animals cause a decrease in the amount of protective vegetation cover

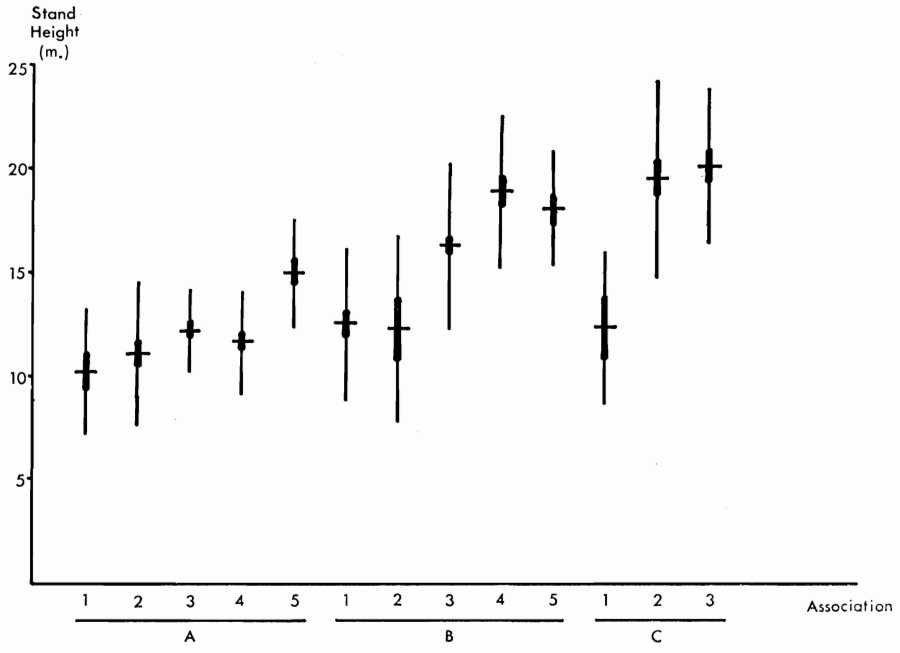

FIG. 3—Stand heights; mean, standard error and standard deviation are shown for each of the associations

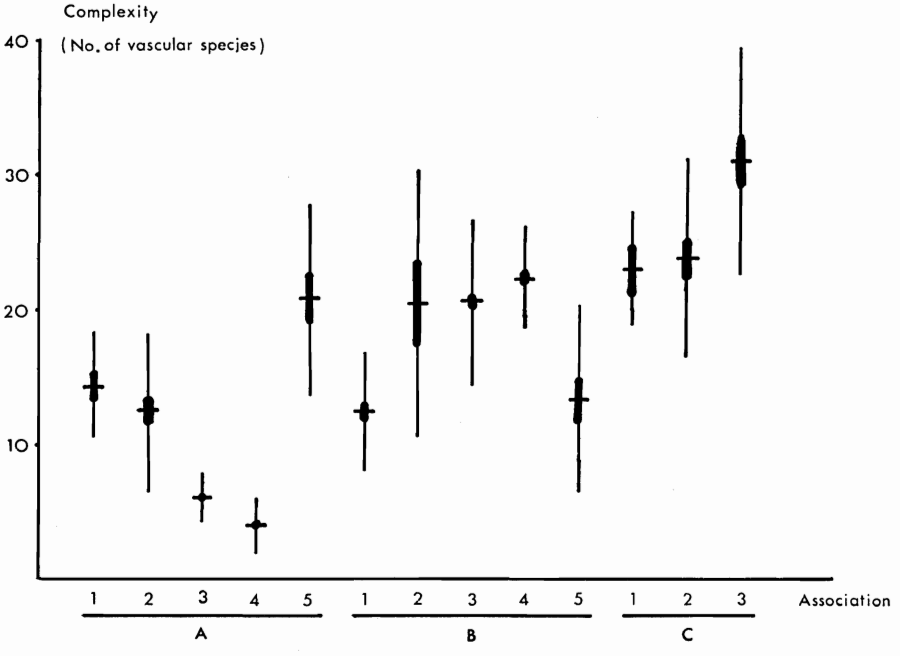

FIG. 4—Stand complexity; mean, standard error and standard deviation for the number of vascular plant species in each association

on the forest floor. It has been shown that this highly undesirable development can be reversible; removal of the animals generally results in an increase in the amount of vegetation.

Data presented in Table 2 illustrate that at the present time vegetative cover (moss + vascular vegetation) on the forest floor is at fairly high levels, ranging from 25% to 64% in different associations.

TABLE 2—Ground cover for the Wairau forest associations (values as percentages)

Ground cover	Association												
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3
Moss	18	37	16	23	4	20	29	11	9	18	17	7	9
Vegetation	32	27	20	21	49	24	30	21	24	19	44	19	44
Litter	28	26	46	42	31	41	30	46	57	58	22	52	34
Rock	10	5	14	8	15	12	9	17	8	3	14	15	10
Soil	12	5	4	6	1	3	2	5	2	2	3	7	3

As the level of vegetative ground cover that can be expected in undisturbed forest is unknown, it is not possible to define which forest types have been most disturbed by the activities of browsing animals and consequently which ones will be most likely to respond to any further reduction in animal browsing pressure. The data will, however, provide a useful baseline against which future remeasurements can be compared.

(2) *Tree Regeneration*

Densities of seedlings in the 15 cm to 1.35 m size class are presented in Table 3. A zero value in this table indicates that the species concerned is an important component

TABLE 3—Density (stems per ha) of tree seedlings in the 15 cm to 1.35 m size class

Species	Association												
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3
Nothofagus cliffortioides	5588	7512	6200	7869	26823	8234	3804	2221		87	276	345	
Phyllocladus alpinus	184				85		2454			87			
Nothofagus menziesii				118		755	491	38	428	1425	737	622	0
Griselinia littoralis				0	0	55	0	109	71	145	0	0	53
Podocarpus hallii					0		3190	678	838	58	0	92	26
Nothofagus fusca						0	123	1833	624	960	92	461	237
Pseudopanax crassifolium					0	0	0	55	18	0	0	322	26
Carpodetus serratus								93	36	0		138	53
Elaeocarpus hookerianus								11	18	0		23	0
Pseudowintera colorata									1604		0	0	289
Weinmannia racemosa									36			23	447
Metrosideros umbellata								27	0			0	0
Podocarpus totara									108			92	
Melicytus ramiflorus												0	0
Nothofagus solandri												23	0
Nothofagus truncata													79
Pseudowintera axillaris												0	211
Total	5772	7512	6200	7987	26908	9044	10062	5065	3781	2732	1105	2142	1421

of the overstorey in a particular association and that it is failing to regenerate. Blank spaces indicate that a species is absent or only of minor importance in a particular association.

It is clear that in most instances the most palatable species such as broadleaf (*Griselinia littoralis*) and lancewood (*Pseudopanax crassifolium*) are failing to regenerate and in cases where regeneration is occurring, the density of stems is generally low. In the associations where palatable species are failing to regenerate, a change in canopy composition can be expected in the future if animal browsing pressure is maintained at its present level. However, it is not possible at present to estimate if this change in composition will adversely affect the protective value of the vegetation.

Total regeneration densities are highest in those associations which have mountain beech as a major component, high density regeneration being a characteristic of the species. The relatively unpalatable nature of mountain beech and its ability to grow rapidly on most sites given suitable light conditions should assure that mountain beech canopies are maintained in good condition.

The low regeneration densities of major canopy species found in the associations important to the eastern part of the north bank forests (C2, C3 and B4) may be the result of the activities of browsing animals, but the different regeneration characteristics of the species in these associations are also likely to be a significant factor. In either case it is the forest associations with the lowest regeneration densities (and also possibly the lowest potential for regeneration) which need the greatest protection from the activities of browsing animals.

(3) *Canopy Density*

The density of the forest canopy has an important influence on both its effectiveness as a rain interceptor and the density of regeneration which can occur. Canopy density has been calculated for the upper three tiers in each association using the formula of Wardle *et al.* (1971):

$$\text{Density} = \frac{3\ (\text{f. dense}) + 2\ (\text{f. mod.}) + 1\ (\text{f. light})}{3\ (\text{total no. of plots})} \times \frac{100}{1}$$

where f = frequency of plots with dense, medium and open tiers.

TABLE 4—Tier density for the three upper tiers of each of the Wairau associations

	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3
T1 (12.2+ m)	3	16	23	18	38	37	15	55	53	65	11	45	40
T2 (4.6–12.2 m)	48	70	77	77	42	71	75	65	61	65	67	68	52
T3 (1.8–4.6 m)	22	41	30	35	27	47	70	52	55	42	61	48	43
Total	73	127	130	130	107	155	160	172	169	172	139	161	135

Table 4 shows that canopy density varies between associations; A1 having the lightest and B3 and B5 the heaviest.

(4) *Stand Basal Area*

In areas where animal browsing pressure is light, basal area is loosely related to the density of tree regeneration, a low basal area being associated with a high density of regeneration. High animal numbers are one factor which can cause regeneration failure on low basal area sites, which may then be open to occupation by unpalatable fern and shrub species. These species can continue to inhibit tree regeneration even after browse pressure has been reduced.

Associations A1, A5 and B3 have mean basal areas well below the average for all associations (Table 5) and must be considered to be most susceptible to the type of animal damage described above, even although they support average to high regeneration densities.

TABLE 5—Mean basal area (m^2/ha) for the Wairau associations

Association													
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	Mean
37.5	47.3	45.5	48.9	36.0	46.2	42.6	38.4	51.0	47.9	53.2	46.2	50.3	45.6

The mean basal area of the Wairau forests is significantly lower than that of other catchments containing forests of similar composition but the significance of this is as yet unknown.

(5) *Size Class Distribution*

A number of associations show a marked deficit of stems in the 0 to 5 cm d.b.h. size class (Table 6). This deficit, which is indicative of a long past history of forest use by browsing animals, is particularly evident in the mountain beech associations which dominate the forests of the south bank. However, the density of stems below breast height in these associations indicates that recovery is occurring. Survival of these seedling stems should adequately fill existing gaps in the forest structure.

The associations forming the bulk of the north bank forests do not show this deficit of stems in the 0 to 5 cm d.b.h. size class. This is probably the result of a shorter and less intense history of use by browsing animals. Associations without a deficit in the total number of stems in the 0-5 cm d.b.h. size class do, however, usually show deficits in this size class for the more palatable species such as kamahi and broadleaf. Replacement of palatable species by unpalatables such as pepperwood and totara may have occurred in some associations.

TABLE 6—Mean stand structure for each forest association (density values in stems per ha)

Species	Upper points of 5 cm diameter classes														
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	> 70
Association A1															
Nothofagus cliffortioides	613	918	643	263	142	91	66	18	30	0	0				
Association A2															
Nothofagus cliffortioides	1177	2229	883	273	124	72	32	28	17	6	6				
Griselinia littoralis	2	14	3												
Total	1179	2243	886	273	124	72	32	28	17	6	6				
Association A3															
Nothofagus cliffortioides	835	1472	771	306	154	93	49	26	17	7	3				
Griselinia littoralis	0	7	1	1											
Total	835	1479	772	307	154	93	49	26	17	7	3				
Association A4															
Nothofagus cliffortioides	938	1949	840	318	161	85	53	20	13	3	4				
N. menziesii	19	19	12	7	5	2	2	1	0	1	1				
Total	957	1968	852	325	166	87	55	21	13	4	5				
Association A5															
Nothofagus cliffortioides	571	482	332	248	120	75	51	24	2	8	4				
Griselinia littoralis	4	37	12	8	2	2									
Coprosma linariifolia	33	60	14	4											
Minor Species	36	12													
Total	644	591	358	260	122	77	51	24	2	8	4				
Association B1															
Nothofagus cliffortioides	2111	1089	627	320	154	84	42	22	14	9	3	3			
N. menziesii	146	53	24	10	4	3	3	2	0	3	1	0	0	0	1
Minor species	3	10	7	3	1	1									
Total	2260	1152	658	333	159	88	45	24	14	12	4	3	0	0	1
Association B2															
Nothofagus cliffortioides	1936	2368	843	196	87	54	33	21	6	3	0				
N. menziesii	190	178	66	24	9	9	3								
Griselinia littoralis	15	76	3	0	3										
Minor species	45	18	3	0	6	0	3								
Total	2186	2640	915	220	105	65	39	21	6	3	0				
Association B3															
Nothofagus cliffortioides	422	255	194	121	69	43	22	12	10	3	2	2			
N. fusca	181	38	31	25	13	10	6	7	4	3	4	3	1	3	7
N. menziesii	58	36	15	10	6	8	4	2	1	1	1	1			
Podocarpus hallii	150	30	12	3	5	2									
Griselinia littoralis	27	103	57	21	7	4	1								
Coprosma linariifolia	53	75	12	1											
Leptospermum ericoides	21	23	11	5	2	1									
L. scoparium	18	20	15	4	3										
Carpodetus serratus	4	18	15	4	2										
Minor species	9	14	8	1											
Total	943	612	370	195	107	70	33	21	15	7	7	6	1	3	7

TABLE 6—Continued

Species	Upper points of 5 cm diameter classes														
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	> 70
Association B4															
Nothofagus fusca	386	113	61	27	22	9	11	11	7	7	7	10	3	5	18
N. menziesii	227	197	72	44	34	19	12	9	11	8	6	7	3	5	6
Podocarpus hallii	209	62	23	12	3	3	5	1	1						1
Weinmannia racemosa	62	76	29	11	9	4	2	2	1					1	
Griselinia littoralis	6	54	52	25	11	5	2	1							
Elaeocarpus hookerianus	20	3	4	2	2	3	2								
Carpodetus serratus		21	14	5	2										
Podocarpus totara	24	3	2	2											
Pseudowintera colarata	562	42	1												
Minor species	25	30	12	6	4	3	3	0	2	0	1				
Total	1542	594	261	131	85	46	37	24	22	15	14	17	6	11	25
Association B5															
Nothofagus menziesii	462	339	121	54	29	17	13	13	1	3	9	1	3	0	3
N. cliffortioides	146	143	83	58	25	21	11	4	3	1				1	
N. fusca	92	114	76	38	25	22	14	17	5	16	9	7	7	9	8
Griselinia littoralis	3	7	8	4	1										
Carpodetus serratus	8	9	8	1											
Coprosma linariifolia	14	12	4												
Podocarpus hallii	16	1	4												
Minor species	0	3	1												
Total	741	628	305	155	80	60	38	34	9	20	18	8	10	10	11
Association C1															
Nothofagus menziesii	446	87	42	46	25	29	25	8	4	17	13	8	8	0	17
N. cliffortioides	2910	902	374	116	62	46	33	13	4	0	4	0	0	4	0
N. fusca	188	29	29	4	8										
Griselinia littoralis	96	46	42	0	4										
Libocedrus bidwillii	0	0	4	8											
Total	3640	1064	491	174	99	75	58	21	8	17	17	8	8	4	17
Association C2															
Nothofagus fusca	211	50	40	14	18	5	9	7	9	5	6	6	5	3	11
N. menziesii	6	24	16	11	10	8	6	4	2	1	4	1	0	1	6
Weinmannia racemosa	58	135	104	50	27	16	6	5	1	0	1				
Leptospermum ericioides	159	190	84	23	23	9	0	2							
Griselinia littoralis	3	42	37	7	0	1	0	1							
Podocarpus totara	144	14	8	2	4	2	0	1							
P. hallii	112	4	3	1	1										
Minor species	43	34	23	23	20	8	3	3	3	1	4	4	0	3	1
Total	736	493	315	131	103	49	24	23	15	7	15	11	5	7	18
Association C3															
Nothofagus menziesii	5	6	12	10	6	8	8	7	2	1	5	4	1	4	5
N. fusca	2	4	0	1	2	4	1	1	6	4	0	2	1	0	16
Weinmannia racemosa	214	353	172	95	57	30	23	13	6	7	5	1	2		
Nothofagus truncata	32	8	1	1	0	4	2	1	4	1	0	2	2	1	4
Podocarpus hallii	38	8	1	1	2	1									
Pseudowintera colorata	238	10													
P. axillaris	23	17	2												
Minor species	38	44	30	25	21	6	5	1	2	2	0	1	0	1	1
Total	590	450	218	133	88	53	39	23	20	15	10	10	6	6	26

The Overall Condition of each Association

The overall condition of each association has been estimated using seedling density, total stem density, basal area and canopy density data. Low seedling density, low total stem density, low basal area and low canopy density have been taken to indicate poor condition or susceptibility to further animal damage. Each association has been placed in sequence for the four condition measurements, from 1 for best condition to 13 for poorest condition (Table 7).

TABLE 7—Condition of each Association

	Best				Average								Worst
	1	2	3	4	5	6	7	8	9	10	11	12	13
Seedling density	A5	B2	B1	A4	A2	A3	A1	B3	B4	B5	C2	C3	C1
Total stem density	B2	C1	A2	B1	A4	A3	A1	B4	B3	B5	A5	C2	C3
Basal area	C1	B4	C3	A4	B5	A2	B1	C2	A3	B2	B3	A1	A5
Canopy density	B3	B5	B4	C2	B2	B1	C1	C3	A4	A3	A2	A5	A1
Association	B2	B1	B4	A4	C1	A2	B5	B3	A3	C2	C3	A5	A1

The sum of the four placings for each association is indicative of its condition, an association with a low sum of placings being in better condition than one with a high sum of placings. The associations are listed in order from best to poorest condition in the last row of Table 7.

The associations in poorest condition are those close to timberline in the south bank valley heads. Association A1 forms timberline in the western part of the south bank forests and association A3 is the dominant timberline association east of the Raglan Range. In contrast the north bank associations, C2 and C3, which are in poor condition, are found at relatively low altitude and do not extend to timberline.

The associations in best condition, B1 and B2, are found chiefly on the mid-slope in the western part of both the north and south bank forests.

The mean forest condition for each of the six blocks (Figure 1) has been calculated and they are listed below from best to poorest. The area of forest (ha) and the percentage of the total area covered by forest is also included.

Block	Area of forest	% of total forest
1 Upper Wairau	7,130	15.7
2 Dip Flat	12,720	45.2
5 Goulter	15,000	48.7
3 Branch-Leatham	13,930	25.0
4 Waihopai	9,190	6.3
6 Onamalutu	19,090	46.9

Forest condition appears to decline with increasing distance from St Arnaud Range in the extreme west of the catchment. Poorer present forest condition in the more eastern forest areas may be the result of lower rainfall and slower response of these forests to removal of animals or the result of higher numbers of browsing animals at present.

FIG. 5—Timberline on the St Arnaud Range (foreground) and Raglan Range exceeds 1500 m in the vicinity of Dip Flat. The open nature of the canopy close to the timberline can be seen on the Raglan Range

DISCUSSION AND CONCLUSIONS

An interim resurvey of forest plots established in 1959-60 in the Branch and Leatham catchments during 1970-71 resulted in two points being made clear. The first was that there had been a marked improvement in the condition of the forests in these tributaries since the plots were established. It was concluded that this improvement was the result of a large reduction in the number of browsing animals in the area. The second was that although the existing plots had fulfilled a purpose, more plots, and plots of a different design, were required throughout the Wairau catchment.

The task of establishing these plots has been completed and the results of the survey have shown that the bulk of the forest with the exception of that close to timberline, is in condition better than or equal to the Branch-Leatham forests which are improving in overall condition. However, the forests east of the Leatham River and Top Valley Stream have been shown to be in poorer condition and this is likely to be the result of the dry climate and the higher than average incidence of both noxious and domestic browsing animals.

ACKNOWLEDGMENT

We wish to thank M. MacKenzie and J. Orwin for their help in the preparation of this report.

REFERENCES

ALLAN, H. H. 1961: "Flora of New Zealand." Vol. 1, Government Printer, Wellington. 1085 pp.

CHEESEMAN, T. F. 1925: "Manual of the New Zealand Flora." 2nd ed., Government Printer, Wellington. 1199 pp.

HOLLOWAY, J. T. 1961: The Wairau River Catchment, Marlborough. Condition and Trends on the Class VIII Lands. **N.Z. For. Res. Inst., Protection Forestry Report No. 31** (unpubl.).

MANSON, B. R. and HAYWARD, J. D. 1971: Interim report on trends in the forest and scrublands of the Branch and Leatham tributaries of the Wairau. **N.Z. For. Res. Inst., Protection Forestry Report No. 107** (unpubl.).

MANSON, B. R. 1972: 1971-72 Resurvey of the Forest Plots in the Waimakariri Catchment. **N.Z. For. Res. Inst., Protection Forestry Report No. 114** (unpubl.).

MOORE, L. B. and EDGAR, E. 1970: "Flora of New Zealand." Vol. 2, Government Printer, Wellington. 354 pp.

NEW ZEALAND METEOROLOGICAL SERVICE 1972: "Rainfall observations for 1971." **N.Z. Met. Serv. Misc. Publ. 110.** 57 pp.

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

WARDLE, J. 1970: Ecology of **Nothofagus solandri. N.Z. J. Bot.** 494-646.

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