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ECOLOGY OF HARD BEECH *(NOTHOFAGUS TRUNCATA)* IN SOUTHERN OUTLIER STANDS IN THE HAAST ECOLOGICAL DISTRICT, SOUTH WESTLAND, NEW ZEALAND

Summary: Vegetation and habitat descriptions are given for sites that span the very limited environmental range of southern outlier stands of hard beech *(Nothofagus truncata)*. These are on well-drained, north to northwest aspect slopes at 44 °S in South Westland, 260km south of the species' previously assumed southern limit. Size class distributions and diameter growth rates of hard beech stems indicate that it is competing effectively with podocarp and broadleaved species, including the two other beeches present. Of the three local species (mountain beech - N. *solandri* var. *cliffortioides* and silver beech - N. *menziesii),* only hard beech showed a significant relationship between stem diameter and age, though diameter growth rates were generally similar among the three species.

The erratic distribution of the three local beech species in the Haast and adjacent Paringa Ecological Districts is discussed in relation to possible glacial refugia.

The scientific and conservation values of the outlier stands are emphasised.

Keywords: *Nothofagus truncata; Nothofagus* biogeography; hard beech forest; tree age-size relations; glacial refugia; South Westland, New Zealand.

Introduction

The unexpected recent discovery of hard beech *(Nothofagus truncata)* at five lowland localities near the Arawata and Waiatoto Rivers in the Haast Ecological District of South Westland (June, 1977) prompted an investigation of its role in these southern forest stands. Elsewhere the species makes a major contribution to beech and mixed beech-podocarp stands, particularly in the North Westland-western Nelson region (Cockayne, 1928; Holloway, 1954; Hinds and Reid, 1957). The stands located by June at 44 °S represent a disjunction of 260km from the previously assumed southern limit of hard beech in a small isolated stand at Breakwater Creek near Kumara (42° 30'S). The five sites described by June are on 'low hills adjoining or protruding from the low-lying coastal plain chiefly on north and west-facing slopes and within an altitudinal range of 30-90m a.s.l.' June reported stands ranging from 0.1 to 5 ha at three of the sites (Nisson Hill, MacFarlane Mound, and Arawata) with' several trees' on Mt McLean and a single hybrid (presumed N. *truncata* x N. *solandri* var. *cliffortioides)* at the fifth site near and south of the Arawata River bridge (Fig. 1). Similar hybrids were also reported from each of the other four stands.

l. Nomenclature follows Allan (1961) for pteridophytes, gymnosperms and dicotyledons, Moore and Edgar (1970) for monocotyledons, except for the grasses which follow Cheeseman (1925), Hamlin (1972) for hepatics and Sainsbury (1955) for mosses, except where authorities are cited.

June (1977) briefly described the forest communities associated with hard beech as ranging 'from tall forest where *Dacrydium cupressinum*', *Metrosideros umbellata, Nothofagus menziesii, N. solandri* var. *cliffortioides* and *N. truncata* co-dominant, to low forest with *M. umbellata,* D. *colensoi, D. intermedium, N. solandri* var. *cliffortioides* and *N. truncata* co-dominant'.

In view of the ecological and biogeographical significance of these forest stands containing hard beech, a more detailed study of its habitat and community relationships was undertaken in December 1978.

Sites

Initially the two most extensive stands were visited, on MacFarlane Mound and Nisson Hill (Fig. 1), and the former was chosen for a detailed study because two other species of beech, mountain *(N. solandri* var. *cliffortioides)* and silver *(N. menziesii)* shared the site with it whereas mountain beech is apparently absent from Nisson Hill. Moreover, the MacFarlane Mound stand of hard beech is both more uniform and less fragmented, occupying more regular terrain than that on Nisson Hill. On MacFarlane Mound hard beech extends over the relatively gentle north to northwest aspect slopes from some 25m below the summit (*c*. 153m) to an abrupt boundary where the slope abuts the poorly-drained coastal plain at c. 15m elevation. Nisson Hill has the distinctive roche moutonnee form, indicating it has been over-

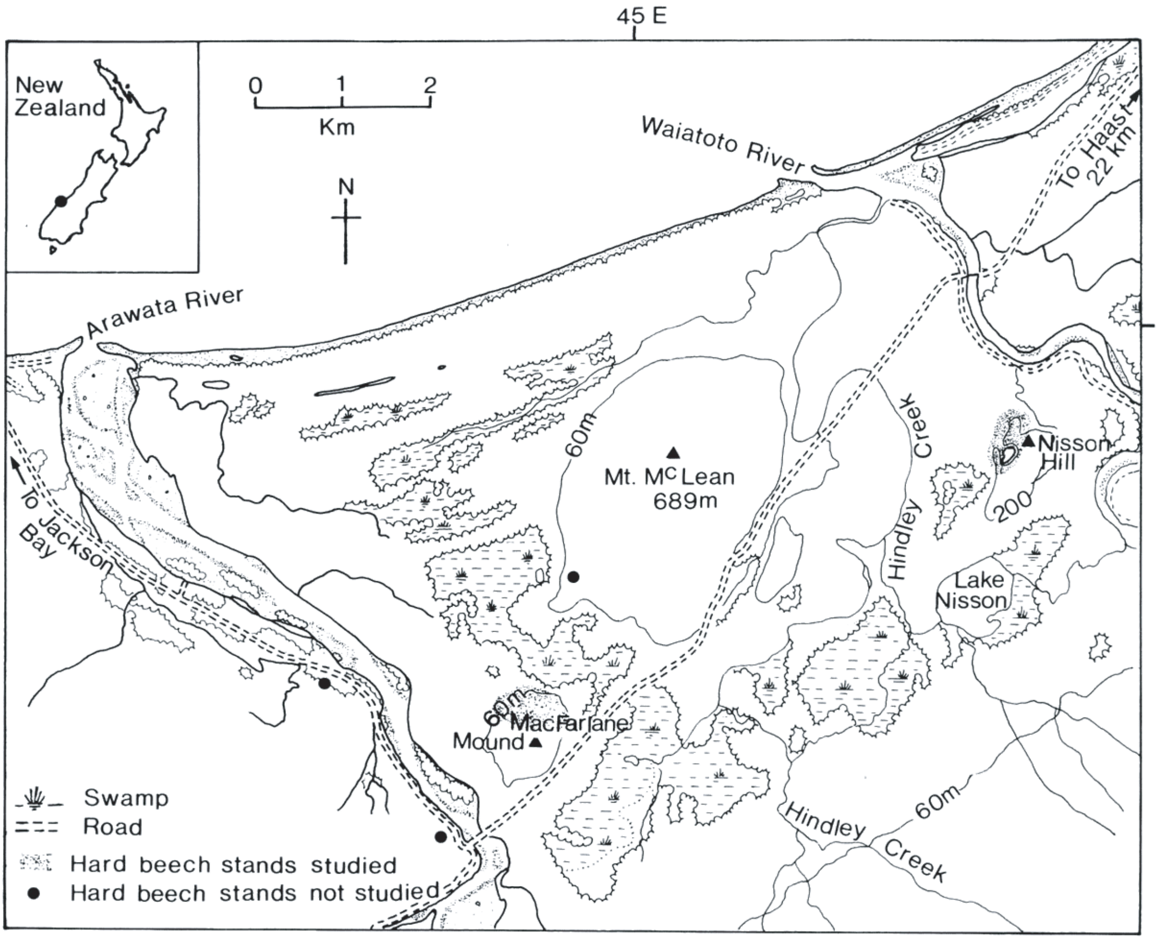

Figure 1: *Southern portion of the Haast Ecological District showing the locations and approximate sizes of the hard beech stands in relation to topography.*

ridden by glacial ice. A long gentle ridge descends to the south from the summit *(c.* 125m), contrasting with the steeper irregularly bluffed slopes to the north and northeast. Hard beech ranges from the summit ridge down the north to northwest aspect slope to c. 15m elevation where the poorly-drained coastal plain again appears to be inhibitory. A small lake on the north-western slope about 60m below the summit is surrounded by hard beech (Fig. 1).

- These two hills are part of a series of eight with a generally similar rounded, ice-worn form and covered by a varying thickness of well-rounded morainic material. The hills range in elevation from *c.* 100m (Bayou Hill) to over 600m (Mt McLean), Nisson Hill and MacFarlane Mound being among the four lowest. They consist of Paleozoic basement rocks which protrude above the low-lying Holocene deposits of the coastal plain (Mutch and McKellar, 1964). These deposits include an impressive series of beach ridges which are intersected by five major rivers and their associated alluvial deposits. Trapped behind the beach ridges and between the rivers are sequences of lowland communities ranging from lagoons and swamps to pakihi bogs and lowland forest (Mark and Smith, 1975; Scott and Rowley, 1975). These features contribute to the distinctive landscape and botanical interest of the Haast Ecological District (Simpson, 1982) comprising the

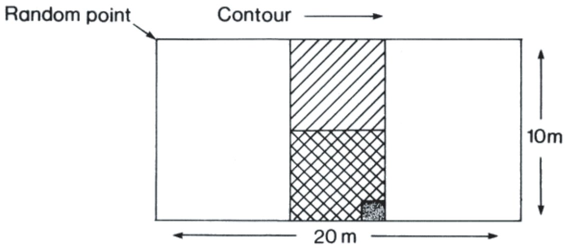

Figure 2: *Diagram of the nested quadrat layout used to sample trees (20 x 10m), small trees (10 x 5m), shrubs and herbs (5 x 5m), and ground cover (1 x 1m).*

coastal plain and emergent hills from the Arawata River northwards some 50km to Ship Creek.

The climate should be similar to that at Haast, 30km north, where mean annual rainfall is 3458mm spread over 190 days with little seasonal variation, and temperatures are mild, with an annual mean of 11.0∞C and a mean daily range of 7.8∞C (Hessell, 1982).

Methods

i) MacFarlane Mound

Quadrats were located on three transects down its northwest aspect slope through the stand of hard beech. Except where converging slightly near the crest of the mound, the transects were c. 300m apart. Quadrats were randomised within $100m^2$ blocks centred along each transect. A 20 x 10m quadrat (long axis along the contour) was laid out to measure trees (> 10cm d.b.h.) by species while smaller quadrats (nested as indicated in Fig. 2) were used to assess numbers of small trees (> 3m tall but < 10cm d.b.h.) by species in 10 x 5m plots, estimated cover of shrubs (woody plants 0.3-3.0m tall) and herbs (herbaceous species> 15cm tall) by species, both in the same 5 x 5m quadrats, and ground cover (herbs <0.15m, excluding bryophytes[2], and woody species < 0.3m tall) in 1 x 1m plots. Tree ferns were recorded as shrubs. Each transect was extended downwards on to the coastal plain to include three further quadrats.

Measurements were made of altitude (aneroid barometer), slope (abney level), aspect (compass), and canopy height (abney level) at each site, and a pit was dug both to describe the soil profile and measure the water table depth, if accessible. Soil samples from five representative sites along one transect were collected for later chemical analyses. In addition, size class distribution of tree and small tree stems of hard beech was assessed on the mid-slope of the stand. Some 356 stems were measured here and wood cores removed from 10 tree stems in each of five size classes with a 30cm increment borer in order to assess growth rates and ages. For a comparison of diameter growth rates between sites and also among the three beech species present in the area, cores were removed from up to three trees of each species, if present, in each large quadrat.

ii) Nisson Hill

Brief qualitative descriptions were made of the vegetation at three sites considered to represent the variation in hard beech stands in this area - the relatively exposed ridge crest of Nisson Hill, its glacially smoothed northern aspect face above the swampy coastal plain, and the gentle, possibly morainic slopes surrounding the small lake about 300m west of the summit, together with a fourth site on the adjoining coastal plain from which hard beech was absent.

Vascular species were listed and scaled for importance at each of these four sites while soil profiles were described and samples collected from each. The sizes (d.b.h.) of hard beech stems were measured at the three sites and cores were removed from representative samples of both hard and silver beech trees to assess and compare growth rates and diameter-age relationships. All cores were stored in plastic drinking straws and later mounted on wooden strips to be counted and measured using a binocular microscope (x 10 lens) with eye-piece micrometer.

Results

Vegetation

i) MacFarlane Mound

2. Representative collections of these from each quadrat have been deposited in the Botany Division, D.S.I.R. (CHR) Herbarium.

Table 1: *Details of site factors and forest vegetation (absolute values for the various strata) on the north-to-northwest aspect slopes of MacFarlane Mound and the adjacent coastal plain, South Westland. Values for sites along three transects have been pooled on the basis of their elevation. Sites 1-3 are on the coastal plain while 4-9 extend up the slope.*

Site Number:	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Altitude (m)	14	14	14	36	52	70	96	126	1367
Mean slope (deg)	0	0	0	21	23	24	15	24	14
Mean aspect (^{O}T)	0	0	0	320	320	300	320	305	305
Mean depth to water table (cm)	10	19	22	>50	>50	>50	>50	>50	>50
Mean canopy height (m)	32	32	32	25	20	18	19	16	15
Total basal area: trees (dm^2 ha^{-1})	10926	10348	9914	6198	5922	3752	4948	4321	3576
Total density: trees (stems ha^{-1})	1125	1050	850	1134	850	717	817	900	1217
Total density: small trees (stems ha^{-1})	1600	3133	2667	3067	4667	4067	6733	6267	5267
Mean percent shrub cover	22	17	25	22	23	22	21	22	28
Mean percent herb cover	26	15	27	37	28	46	26	11	14
Mean percent ground cover (subshrubs)	2.1	10.0	1.9	7.1	6.6	3.7	6.6	4.0	6.9
Mean percent ground cover (herbs)	7.5	6.1	34.9	10.1	9.0	2.6	7.2	8.6	8.8

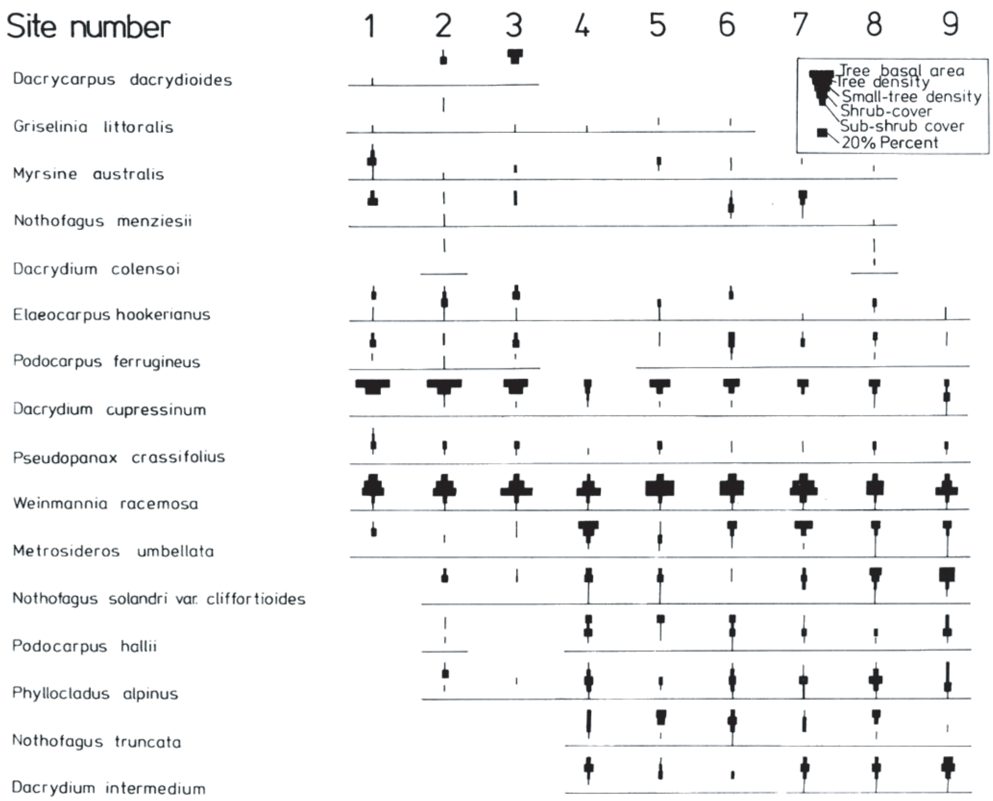

Figure 5: *Relative values for tree basal area, tree density and small tree density, and mean percent cover In shrub and ground (subshrub) tiers (for definitions see text) for the 16 tree species in 9 sites on the north-to-northwest aspect slopes on MacFarlane Mound and the adjacent coastal plain, South Westland. See Table 1 for site descriptions. Horizontal lines represent the distributions of the species between sites.*

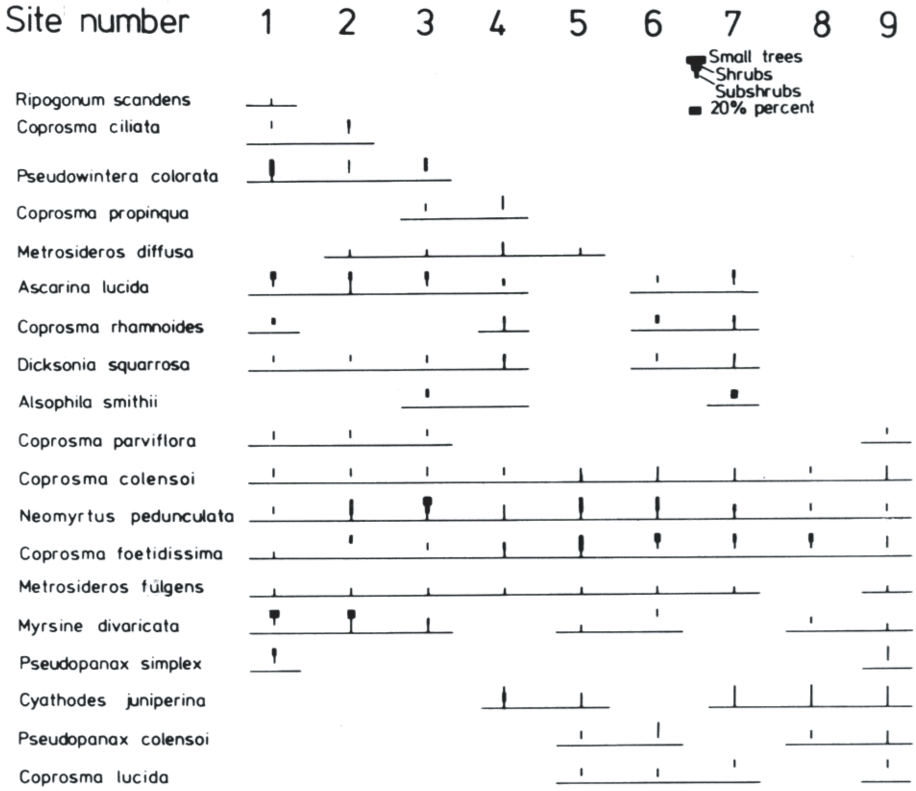

Figure 4: *Relative density of small trees and mean percent cover for shrub and ground (subshrub) tiers (for definitions see text) for the 19 non-tree woody species in 9 sites on the north-to-northwest aspect slopes on MacFarlane Mound and the adjacent coastal plain, South Westland.Horizontal lines represent the distributions of the species between sites.*

The quantitative data on forest vegetation from the northwest aspect slope of MacFarlane Mound have been pooled for the three transects on the basis of plot altitudes (Table 1) and are presented separately for the tree (Fig. 3), small tree, shrub (Fig. 4), herb, and ground layers (Fig. 5), to show variation with site factors, particularly slope, elevation and water table. Absolute (total) values for each of the above strata, together with canopy heights, are included with the site details in Table 1 and relative values for individual species given in Figs. 3-5. Among tree species the presence of *Dacrydium cupressinum* (rimu) and *Weinmannia racemosa* (kamahi) at all sites does not mask the important differences between the forest on the slope, of which hard beech is a characteristic feature, and that of the swampy plain where this beech is essentially absent (Fig. 3). Other species are similarly restricted, *Dacrycarpus dacrydioides* (A. Rich) de Laubenfels to the swamp forest and *Dacrydium intermedium* to the slope. While most of the tree species are present on both sites there is a distinct change in importance between them with *Dacrydium cupressinum* and *Elaeocarpus hookerianus* being more important on the poorly-drained coastal plain, where the water table was within 10-22cm of the ground surface at the time of study, and *Metrosideros umbellata, Podocarpus hallii, Phyllocladus alpinus* and *Nothofagus solandri* var. *cliffortioides* all more important on the well-drained slope. While there is no obvious difference in tree density between the two habitats, total basal area is considerably greater in the 'swamp forest

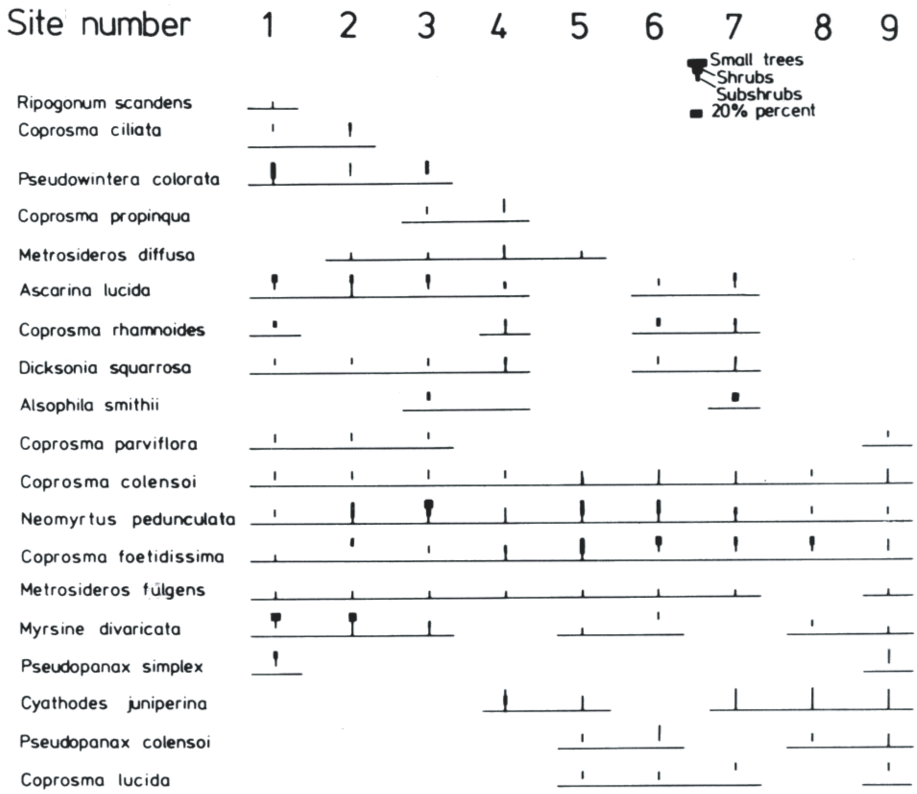

Figure 5: *Mean percent cover for herbaceous species in both the herb and ground layers (for definitions see text) for the 31 herbaceous species recorded in 9 sites on the north-to-northwest aspect slopes on MacFarlane Mound and the adjacent coastal plain, South Westland. Horizontal lines depict distributions of the species between sites.*

(9914-10926 dm^2 ha^{-1}) than on the slope, and the canopy is higher (*c*. 32m). Both canopy height and basal area tend to decrease with elevation from 25m and 6198 dm^2 ha^{-1} at the foot of the slope to 15m and 3576 dm^2 ha^{-1}, respectively, at the highest site (Table 1).

Density of small trees generally shows the reverse trend to that of tree basal area, the lowest values (1600-3133 stems ha $^{-1}$) occurring in the swamp forest, and the highest (5270-6270) recorded toward the top of the slope. Among the small tree species, *Pseudowintera colorata* and *Coprosma ciliata* were recorded only in plots on the coastal plain whereas *Cyathodes juniperina* and *Pseudopanax colensoi* (Hook. f.) Philipson were recorded only on the slope (Fig. 4). Other species *(Dicksonia squarrosa, Alsophila smithii* [Hook.f.] Tryon, *Ascarina lucida, Neomyrtus pedunculata, Coprosma foetidissima, C. colensoi, Myrsine divaricata)* were present on both sites and only some of these *(Myrsine, Ascarina)* behaved differently between them.

Shrub cover generally was less than 10 percent (Table 1) except in the swamp forest where it was estimated to total beteen 13 and 17 percent. Herb cover was more variable (Table 1) with some extensive areas of *Freycinetia baueriana* Endl. spp. *banksii* (A. Cunn.) Stone locally on the slope and most species generally widespread. Only *Astelia grandis, Histiopteris incisa, Polystichum vestitum, Uncinia clavata* and *Trichomanes reniforme* were not recorded on the slope, although *Microlaena avenacea* was important only in the swamp forest (Fig. 5).

Frequency values were determined for the bryophytes (Fig. 6) on the basis of occurrences in plots of equivalent altitude on each of the three

Figure 6: *Frequency values for bryophyte distribution based on 1 x 1m quadrats along three transects through the hard beech stand on the north-northwest aspect slope of MacFarlane Mound. Frequency values are based on presence in 1 x 1m quadrats at similar elevation along each of the three transects. Key at top right. Site details are given in Table* 1.

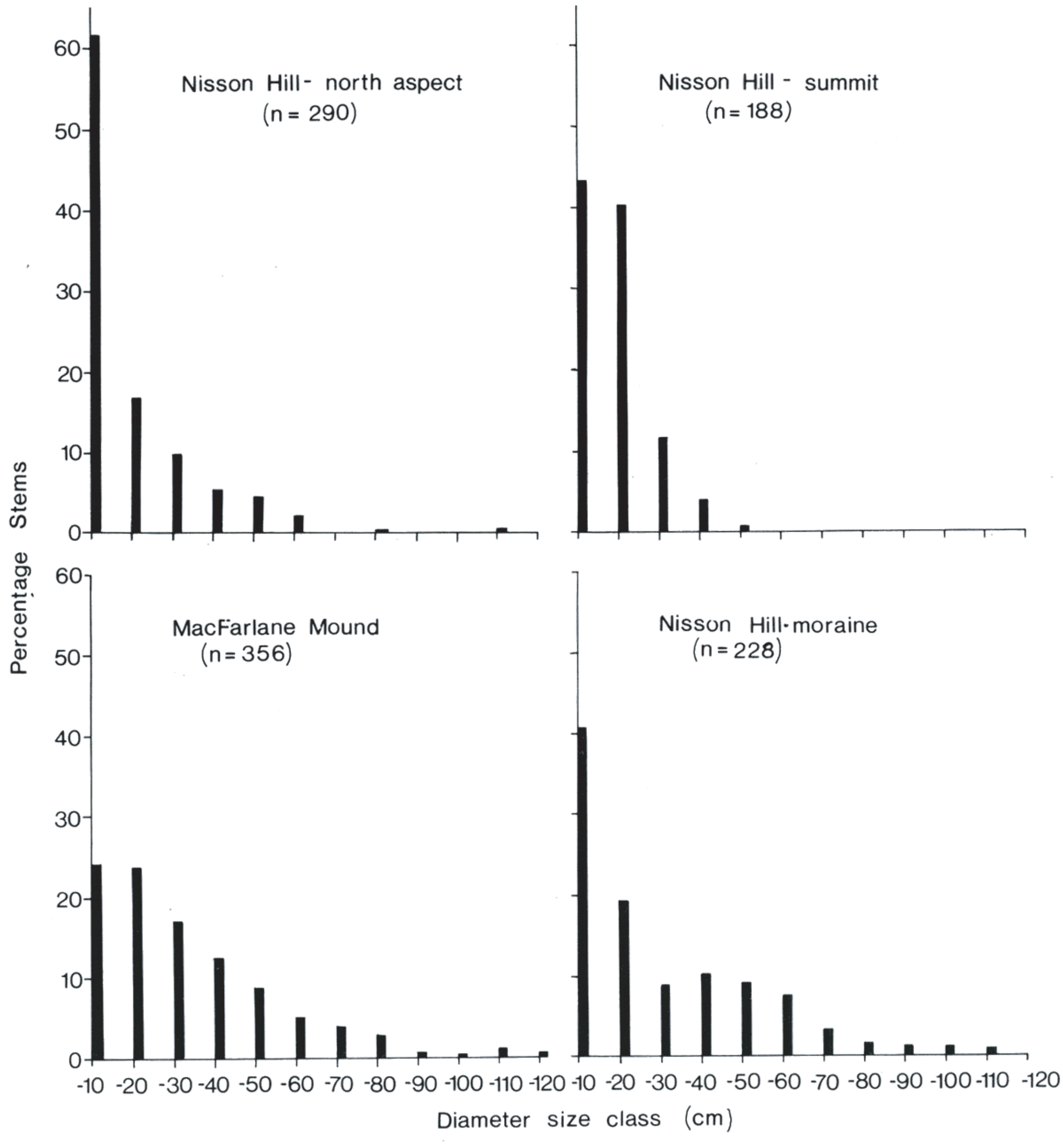

Figure 7: *Size-class distribution for small tree (3.0m tall to 10cm d.b.h.) and tree (> 10cm d.b.h.) sized hard beech stems within 10cm diameter classes, for MacFarlane Mound and three sites on Nisson Hill. The size of each sample is shown.*

transects (but only two plots at the lowest site [1]). Among the hepatics were species restricted to the moister lower slopes *(Trichocolea lanata)* or the drier upper slopes *(Plagiochila retrospectans)* although most were widely distributed, as were most of the 12 mosses collected, including *Hypnodendron colensoi* (HookJ. et Wils.) Mitten; only *Hypnum chrysogaster, Distichophyllum pulchellum, Cladomnion ericoides, Campylopus introflexus* and *Wijkia extenuata* (Brid.) Crum (syn. *Acanthocladium extenuatum* [Brid.] Mitten) showed preferences for the drier upper slope (Fig. 6).

Nowhere on MacFarlane Mound is hard beech the dominant tree species. On the slope, excluding the summit forest from which it is largely absent, hard beech attains a maximum relative density of 14 percent in the mid-slope forest with about 100 trees per hectare. Basal area values for hard beech peak at 1063 dm^2 ha^{-1} on the lower slopes where it contributes 18 percent of the total. Small trees of hard beech are generally most frequent at sites where its density and basal area values in the tree category are well below average; they never comprise more than 4 percent of the total density of stems in this size class.

Dacrydium cupressinum, Metrosideros umbellata and *Weinmannia racemosa* dominate the slope forest with hard beech, mountain beech, and *Podocarpus hallii* regular but minor components. Towards the summit, mountain beech and, *Dacrydium intermedium* increase in dominance while hard beech, D. *cupressinum,* and *Weinmannia* all decline. Within the zone occupied by hard beech the major shrubs are *Neomyrtus pedunculata* and *Coprosma foetidissima* while *Astelia nervosa* and *Blechnum minus* are the most important herbs.

Frequency values for the 18 plots on the slope of MacFarlane Mound and the eight plots on the adjacent coastal plain reveal a range of patterns among the 97 species recorded: 86 from the slope forest, and 82 from the swamp forest with 71 of them shared. (See Appendix 1).

ii) Nisson Hill

A brief qualitative account of the vegetation at four sites is given below while a list of the 81 species from these sites, scaled for general importance, is included in Appendix 1. A similar number of species (42 to 46) was recorded from each of these four sites. Mountain beech is notably absent from this area.

On the summit ridge, the forest has an open canopy 8-12m tall, comprising mostly small trees (usually <20cm d.b.h.) of hard beech, *Dacrydium intermedium, Metrosideros umbellata, Dacrydium cupressinum,* D. *colensoi* and sparse silver beech. Younger trees, together with shrubs of *Phyllocladus alpinus, Pseudopanax crassifolius* (A. Cunn.) Koch, *Dracophyllum longifolium* and *Cyathodes juniperina* form a diffuse shrub tier over an open ground cover of bryophytes (40%), low-growing *Leptospermum scoparium* and scattered clumps of *Gahnia procera, Earina autumnalis* and *Lycopodium volubile*. Soils are generally shallow, less than 20cm deep (see Site 1, Appendix 4 for details).

The low, possibly morainic ridge ponding the small lake, and the lower north to northwest aspect slopes support a taller forest (22-25m) of hard beech, silver beech and occasional podocarps, mainly *Dacrydium cupressinum. Weinmannia racemosa, Podocarpus hallii, P. ferrugineus* and *Dacrydium intermedium* form a broken sub-canopy layer above a diverse small tree and shrub assemblage, principally *Ascarina lucida, Phyllocladus alpinus, Myrsine australis, Coprosma rhamnoides* and *Griselinia littoralis*. The lianes *Ripogonum scandens* and *Freycinetia baueriana* arc locally abundant. Bryophytes (90%) form the major ground cover amongst widely spaced ferns, most frequently *Blechnum capense* and *B. discolor*.

On the glacially-smoothed lower slopes at the northern and of Nisson Hill, hard beech is the dominant canopy tree up to *c*. 23m tall, with *Dacrydium cupressinum* and *Metrosideros umbellata,* and smaller trees of *Weinmannia racemosa, Podocarpus hallii* and *Phyllocladus alpinus*. There is widespread regeneration of the canopy species, including hard beech. The ground cover is largely bryophytes (90%), with few herbs.

On the alluvial plain beyond the northern end of Nisson Hill the forest is of tall silver beech with emergent *Dacrydium cupressinum* and occasional *Podocarpus ferrugineus,* over a sub-canopy of *Weinmannia racemosa, Griselinia littoralis* and *Hedycarya arborea,* in decreasing order of abundance. Lower layers are variable depending on water table levels and deer usage. More common species include *Neomyrtus pedunculata, Coprosma*

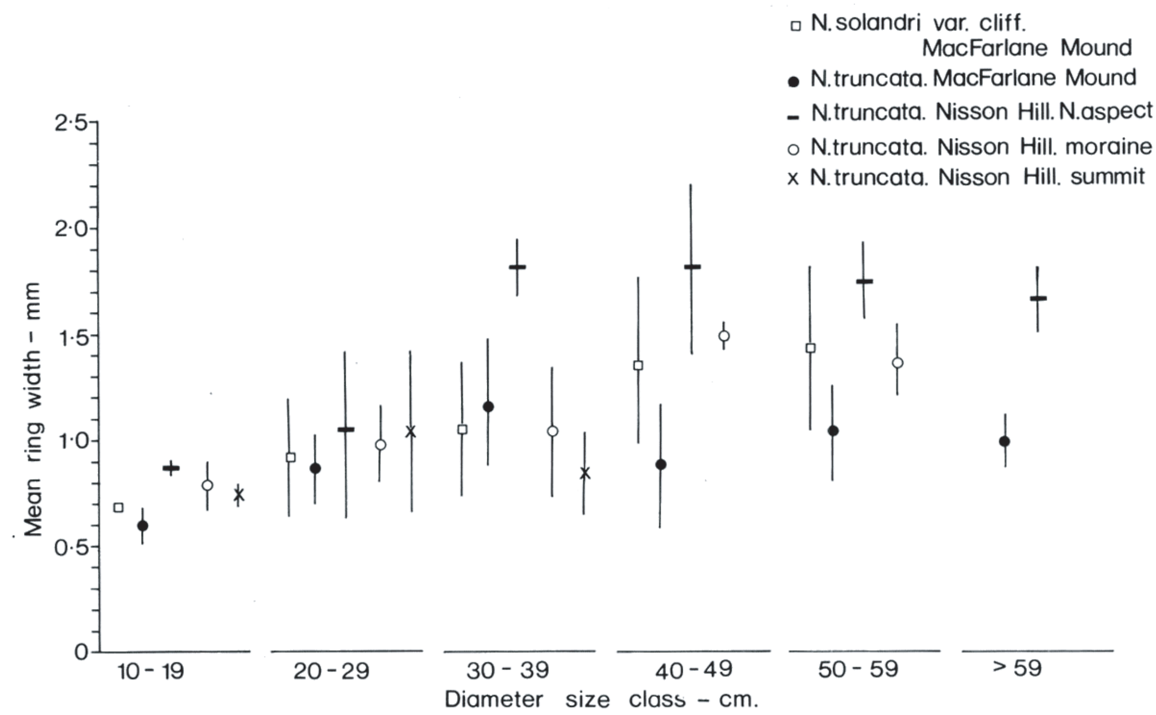

Figure 8: *Values for mean ring widths (with standard errors) for tree-sized stems of mountain beech (N. solandri* var. *cliffortioides)* on MacFarlane Mounds and those of hard beech *(N. truncata)* on MacFarlane Mound, and for three sites on Nisson Hill. Values are presented separately for 10cm diameter size classes.

foetidissima, Dicksonia squarrosa, Rumohra hispida, Todea superba, Blechnum discolor and *Nertera dichondraefolia*.

Size and age classes, and growth rates of the beech species

Size class distributions of hard beech from the main north-west aspect slope of MacFarlane Mound and from three sites on Nisson Hill (summit, undulating moraine in the vicinity of the lake, and north slope) are presented in Figure 7. The distributions are generally reverse J-shaped although the smallest size class recorded (3m tall to 10cm d.b.h.) is hardly more numerous than the next larger class in two of the four stands (MacFarlane Mound and Nisson Hill summit), and the range of size classes present is relatively small on the exposed site near the summit of Nisson Hill, no stems out of the 188 measured being more than 50cm diameter.

Values for mean growth rate of hard beech stems by diameter size classes for the same four sites, together with comparable values for mountain beech stems on MacFarlane Mound (Fig. 8) show a general tendency for rates to be less in the smaller size classes. There are no obvious differences between sites or species except for greater rates in the larger size classes of hard beech (>30cm d.b.h.) growing on the north aspect slope of Nisson Hill. Mean ring widths generally range between 0.6 and 1.8mm.

When diameter growth is assessed in decade increments by size class for hard beech from the two locations, and mountain beech from one (Fig. 9 a-c), there is a generally consistent pattern of increasing growth over time for size classes less than 40 to

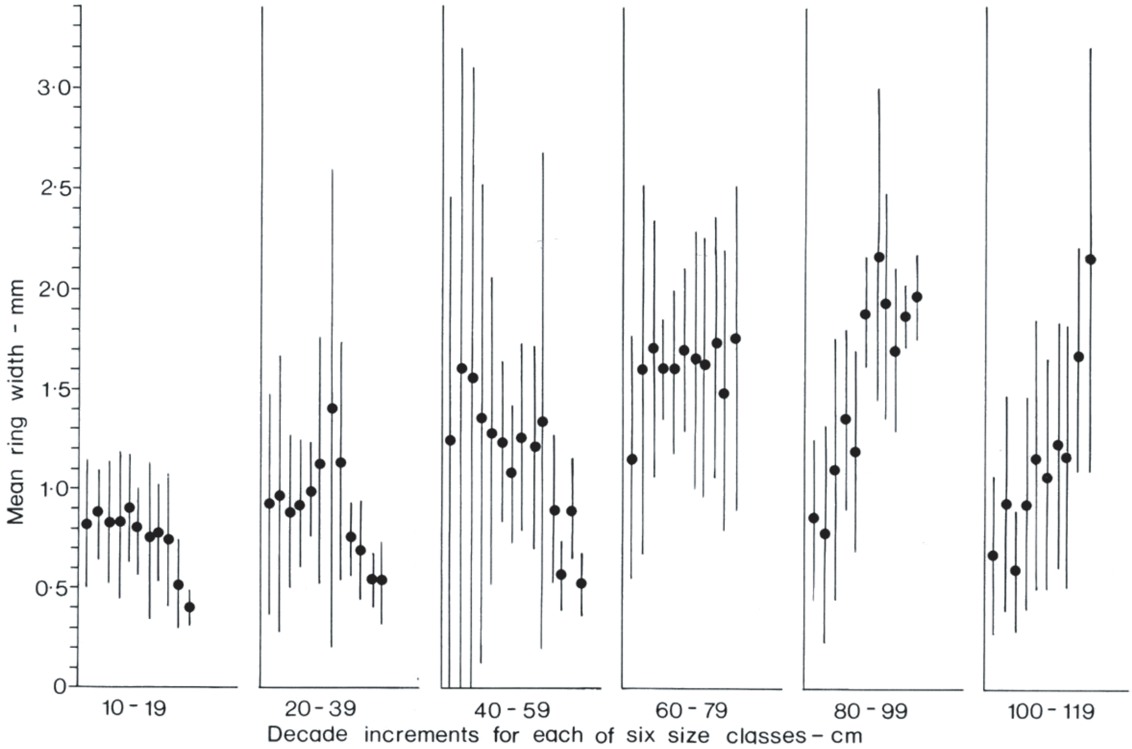

Figure 9: *Values for mean ring widths (with standard errors) for tree-sized stems of hard beech on MacFarlane Mound (a) and Nisson Hill (b), as well as for mountain beech on MacFarlane Mound (c). Values are given within each size class for separate decades with the most recent decade (1968-77) shown on the left side of each group.*

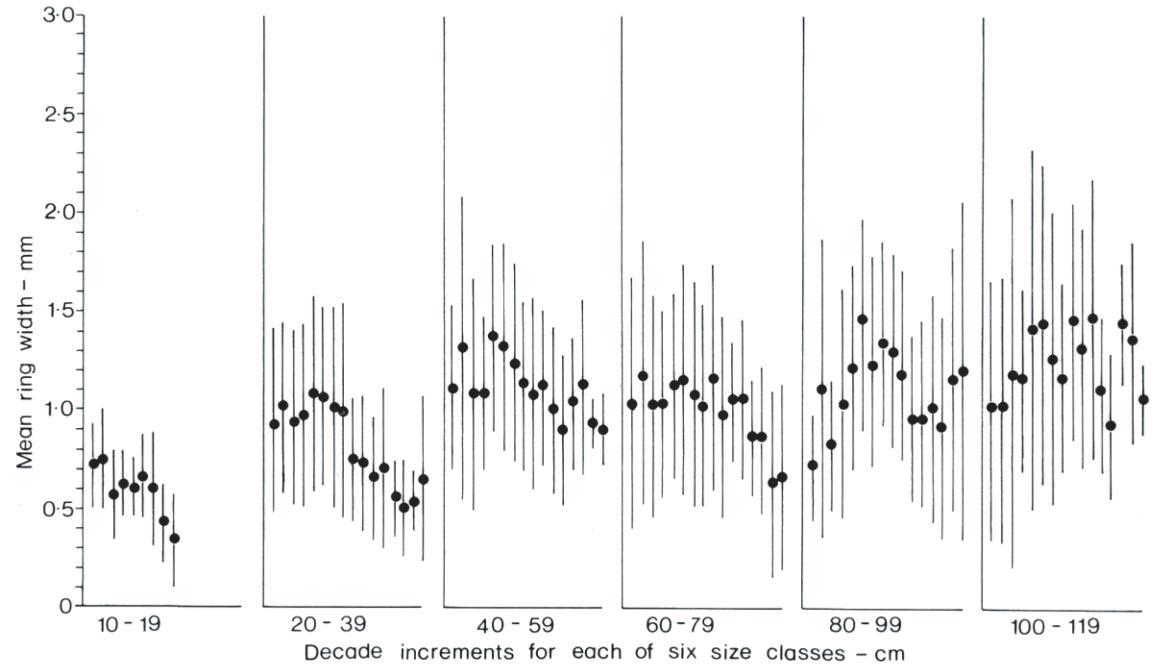

Figure 9b.

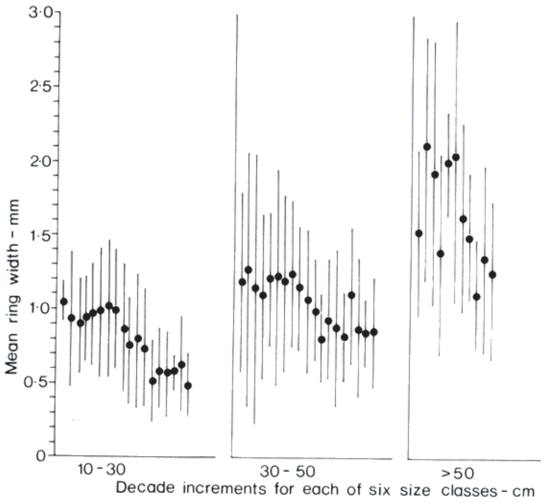

Figure 9c.

50cm d.b.h. but less consistency over time for the larger size classes. Current rates of diameter growth for both the species and sites tend to increase from the smallest size class (0.7-1.0mm mean ring width) to that in stems of 30-40cm d.b.h. (1.1-1.5mm), beyond which the pattern becomes less distinct (Fig. 9).

Mean ring widths for all size classes of the three beech species occurring on the plots down two altitudinal transects on MacFarlane Mound (Fig. 10) show considerable variation and no obvious trends or differences between the two transects, nine sites or three species. Notably, the performance of hard beech is not inferior to that of mountain or silver beech where they occur together.

Tree age was estimated on the basis of stem diameter and the value for mean annual increment, but only for those trees where the extracted core was sufficient to indicate within about 80% of the estimated age. In most cases only slight extrapolations were needed. In all, 176 trees of a total of 195 above 10cm d.b.h. were aged. On MacFarlane Mount the pattern among 89 hard beech trees (Fig. 11) shows a predominance of stems in the 100 to 160-year classes with no tree-sized stems having less than 60 growth rings at a height of 1.2m; the oldest stem was estimated to be approaching 460 years.

Among the 40 hard beech trees sampled from Nisson Hill (Fig. 12) the youngest stem of tree size had only 35 growth rings and the oldest (72.9cm d.b.h.) had 323 rings at a height of 1.2m.

The age-diameter relationships of the tree-sized stems of the three beech species were tested with polynomial regression analyses. For MacFarlane Mound there was a highly significant ($P < 0.001$) relationship between estimated age and diameter among the 89 hard beech stems of tree size (Fig. 11), with the linear regression on age accounting for 34.9 percent of the variation in diameter; there was no significant curvature. The regression equation is:
Diameter (cm) = 15.489 + 0.1370 x age (yrs)
For the 40 stems on Nisson Hill the regression was also highly significant ($P<0.001$) and accounted for 50.4 percent of the variation in diameter (Fig. 12). There was no significant curvature. The regression equation in this case is:

Diameter (cm) = 8.531 + 0.2118 x age (yrs)

Analysis of the Nisson Hill data by sites, using 16 stems from the north slope, 15 from the moraine near the lake and 9 near the summit, yielded significant differences in the intercepts but not in the slopes.

The 41 trees of mountain beech from MacFarlane Mound, by contrast, showed no significant relationship between age and diameter (Fig. 13), with the regression accounting for only 5.5 percent of the variation. The number of growth rings ranged from 81 to 221 at a height of 1.2m. Neither was there a significant relationship between tree age and diameter among the six trees of silver beech from MacFarlane Mound (Fig. 13), possibly because of the small sample - the reression accounted for 41.6 percent of the variation.

Among the 89 trees of hard beech from MacFarlane Mound the estimated ages within each of six size classes were as follows: 10-19cm d.b.h. (10 stems), 114 ± 36yr; 20-29cm (24 stems), 140 ± 41 yr; 30-39cm d.b.h. (20 stems), 134 ± 42yr; 40-49cm (17 stems), 198 ± 86yr; 50-59cm (10 stems), 234 ± 72yr; > 60cm d.b.h. (7 stems), 250 ± 100yr (Fig. 11). Comparable values but for fewer hard beech trees on Nisson Hill (Fig. 12) gave mean ages for the same suite of size classes of 95, 118,135,116,153 and 257yr, respectively. Stems from the northern slope were generally younger than those of similar size from the moraine, at least in the

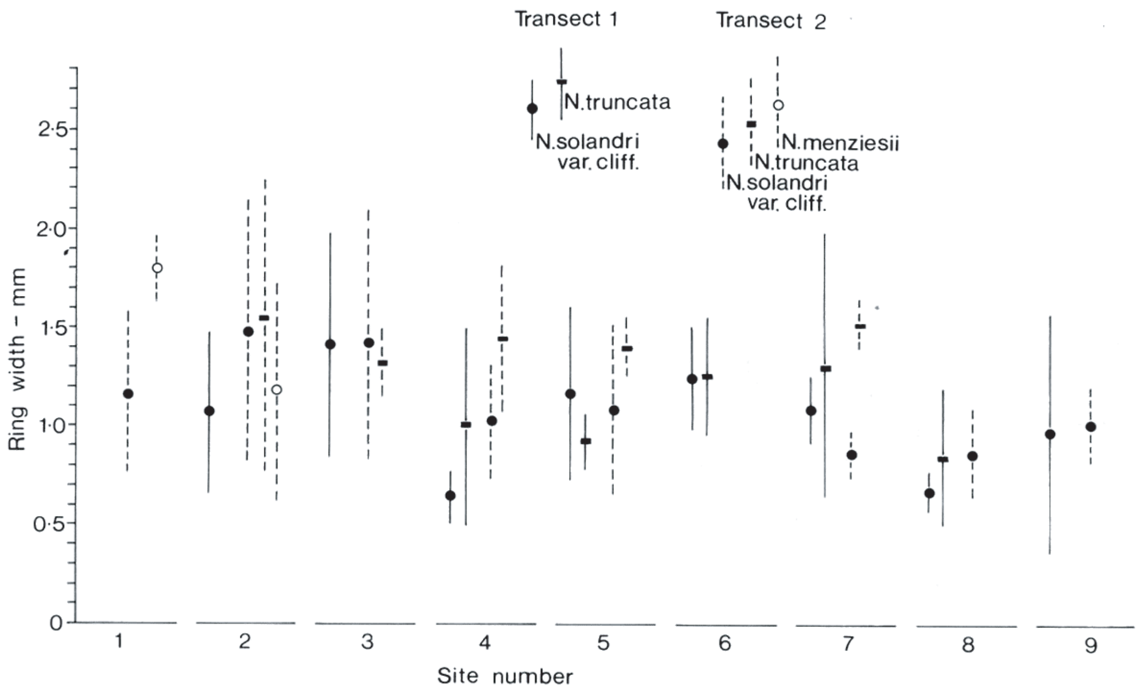

Figure 10: *Mean ring widths (with standard errors) for three beech species along two of the transects on MacFarlane Mound. Site numbers are as in Table 1 where other relevant environmental information* is *presented.*

larger size classes, while the generally small stems from near the summit tended to be older than the mean value for their particular size class.

Soils

Profile descriptions were made at nine sampling sires along one of the transects from the upper slope of MacFarlane Mound (Site 9) to the swamp forest on the edge of the coastal plain (Sites 1-3). At four of the seven sites on the slope, rounded gravels suggestive of morainic material underlay the soil profile, as they do on the rounded summit of the Mound. The profile descriptions (Appendix 2) follow standard soil survey methods (Taylor and Pohlen, 1970). All profiles on the slope were consistent in having greyish brown sandy loam A, and B, horizons whereas the two sires on the coastal plain had brownish black peaty horizons with very high water rabies - within 20cm of the ground surface (Table 1). Chemical analyses of these soils (Appendix 3) revealed uniformly low values for pH (range 4.1-4.9) and the major ions tested. Carbon values were generally high in both A and B horizons on the coastal plain (range 19.2-45 .0 % of dry weight) whereas elsewhere they were generally less than 4 percent.

On Nisson Hill, profiles were described and samples collected from four sites selected to represent the summit, gentle morainic slopes surrounding the lake, the north aspect slope of the hill (all containing hard beech), as well as the swamp forest immediately to the north of the hill, from which hard beech is absent. These results (Appendix 4) indicate greater variation than on MacFarlane Mound bur with generally similar A, horizons associated with hard beech in contrast to the peaty surface layer associated with high water rabies on the swampy coastal plain. Podzolisation was evident from the light grey sandy loam A, horizon on the summit

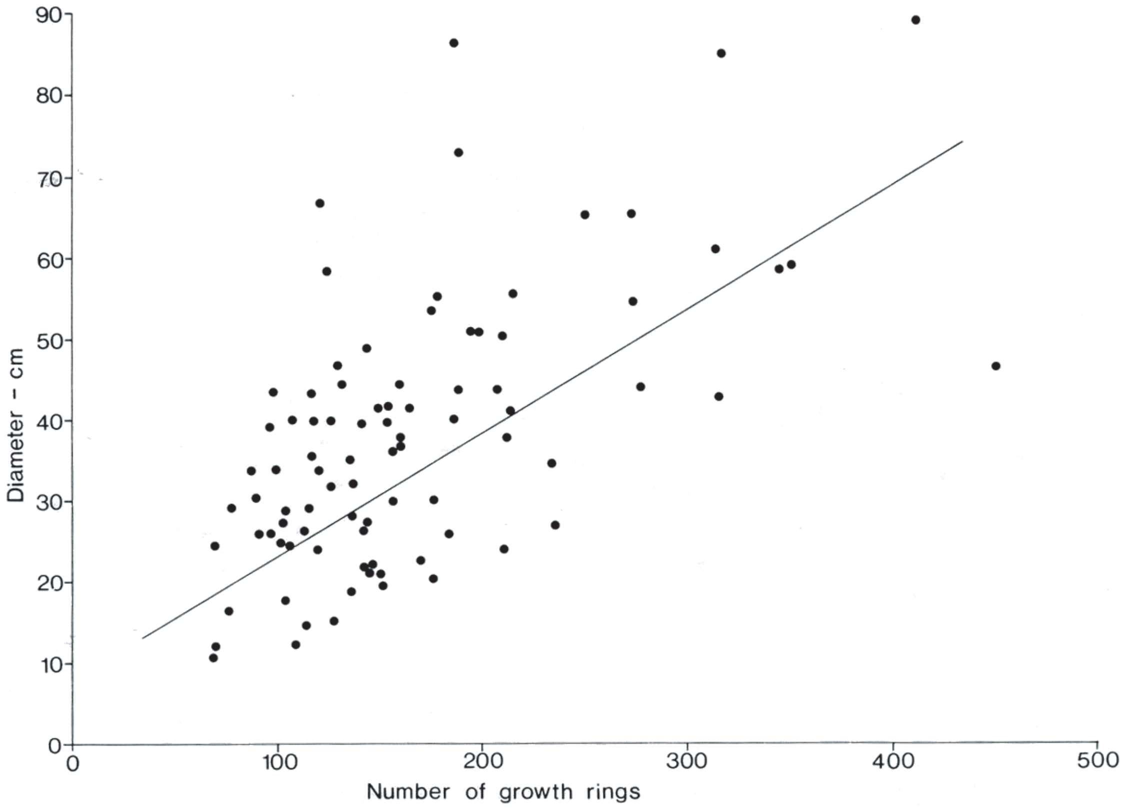

Figure 11: *Relationship between diameter and age (based on number of growth rings) in* 89 *stems of hard beech of tree size on MacFarlane Mound. The regression was highly significant (see text for details).*

ridge of Nisson Hill; on other sites the A, horizons were generally darker, though of a uniformly sandy loam texture. Values for pH were generally somewhat higher on Nisson Hill (range 4.4-5.0) than on MacFarlane Mound but nutrient status was similar (Appendix 5).

Discussion and Conclusions

Ecological features of the two largest stands of hard beech known in the Haast Ecological District of South Westland are of particular interest and importance because of their major biogeographical discontinuity of some 260km with the remainder of the species. Their discovery, together with smaller stands of individual trees and / or hybrids at three other adjacent sites by June (1977) made an important addition to previously known examples of discontinuities between northwestern and southwestern South Island that had been documented and discussed by Wardle (1963) and Burrows (1965). .

Both stands are somewhat larger (*c*. 20-25ha) than indicated by June, but they are obviously restricted by requirements for relatively warm and well drained sites, to north-northwest aspect slopes above the saturated coastal plain. In this respect they conform with site preferences already described for the species in relation to the other beeches where they occur together, particularly in North Westland (Holloway, 1954, pp. 389; 392-5) where 'hard beech stands are characteristic of all dry slopes of warm aspect and of the lower dry ridge crests. At its extreme southerly limit hard beech occupies small local sites on west-facing slopes and the hard beech stands are entirely surrounded by red beech / silver beech stands................. Where drainage is impeded,

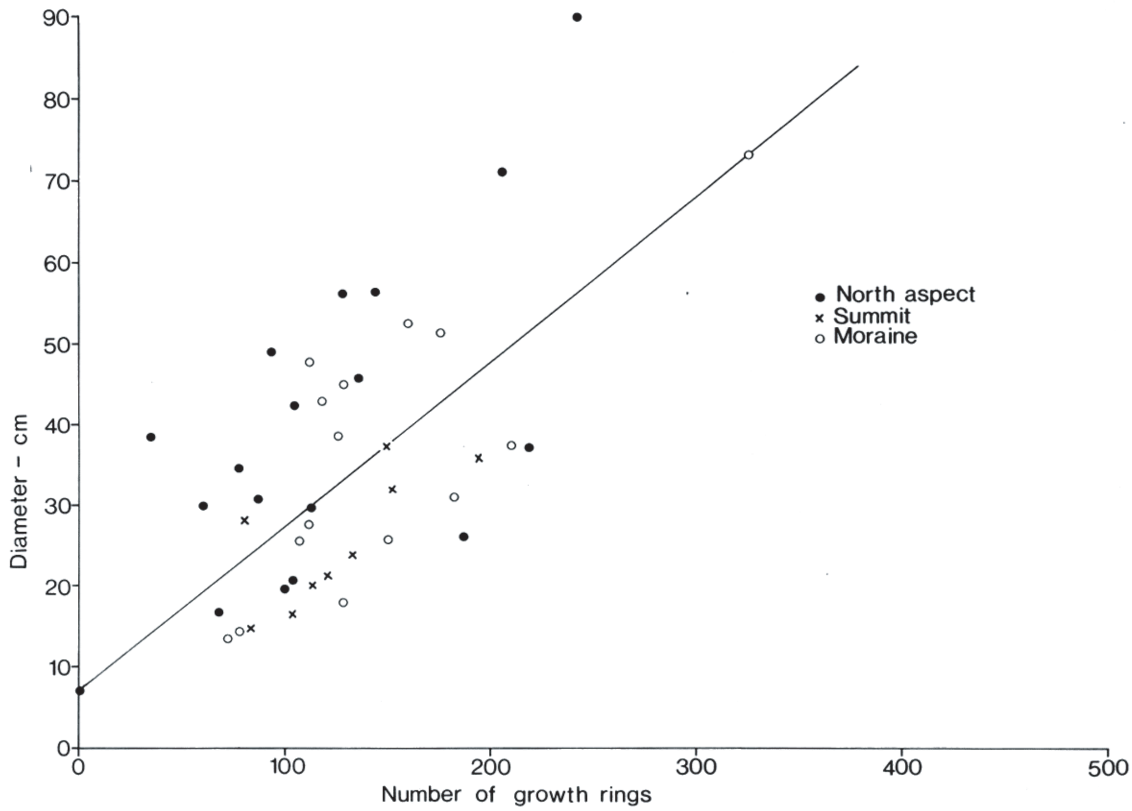

Figure 12: *Relationship between diameter and age (based on number of growth rings) in 40 tree-sized stems of hard beech from Nisson Hill, including 15 stems from the moraine, nine from near the summit and 16 from the north aspect slope.*

mountain and silver beech form stunted communities' (p.395).

Although the forest community containing hard beech was described in detail at only one of the two areas, intensive sampling of hard beech indicated that it is clearly sustaining itself as mixed-aged stands at both, with a wide range of size classes that relate directly to tree age - the largest trees measured being almost 1m d.b.h. in both areas and about 450 years old on MacFarland Mound, and 320 years on Nisson Hill, assuming their growth rings are annual. By contrast, mountain beech trees growing in association with the hard beech on MacFarlane Mound showed no significant relationship between age and diameter. Although the same was true for silver beech trees here, this was more likely a reflection of the very much smaller sample size since a regression with size did account for more than 40 percent of the variation in tree age.

Unfortunately there appear to be no comparable published descriptions of forest stands characterised by hard beech from the North Westland-northwest Nelson or southern North Island areas. The few general descriptions (Wardle, 1984) suggest that the South Westland stands may be unique in terms of their structure and composition, though *Cyathodes juniperina,* a distinctive member of the South Westland communities, is listed as a characteristic species from most of these northern stands (Cockayne, 1928; Wardle, 1984).

Diameter growth rates of hard beech are generally similar to those of mountain beech and silver beech where they occur together on MacFarlane Mound, with all but the smallest size class of trees achieving mean ring widths of about 1mm in both areas. These

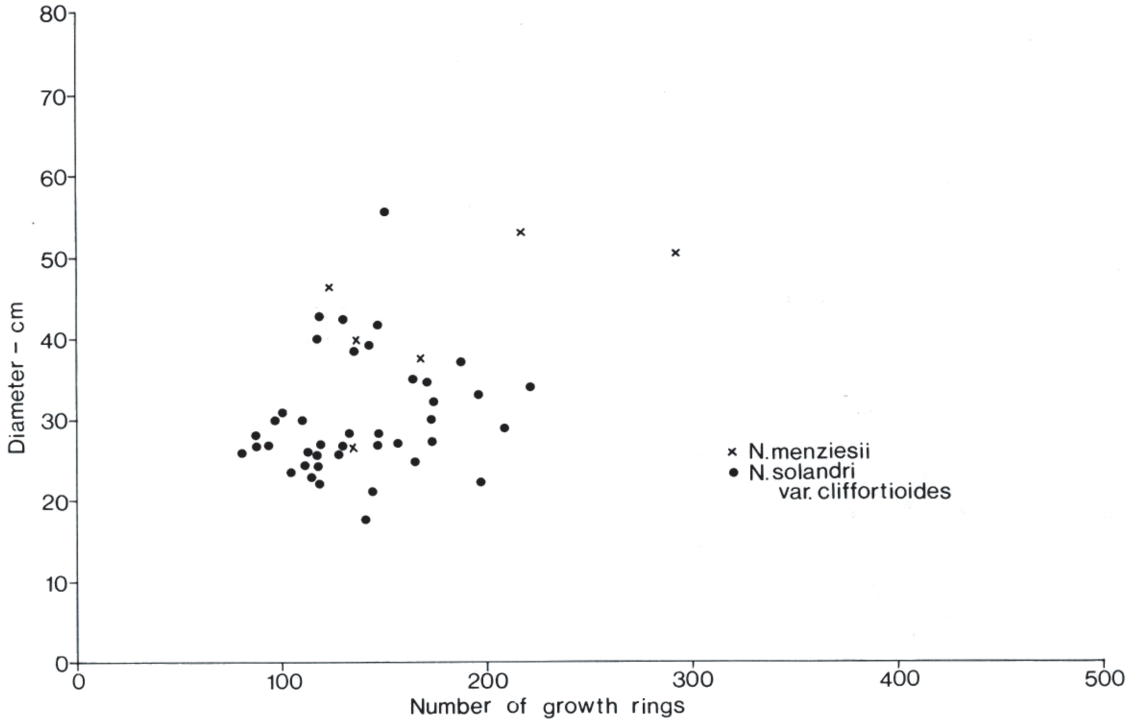

Figure 13: *Relationship between diameter and age (based on number of growth rings) in 41 tree-sized stems of mountain beech and six of silver beech from MacFarlane Mound. The relationships were not significant for either species (for details see text).*

rates are only about one-third those reported by June and Ogden (1978) for red beech *(N. fusca)* on the Ruahine Range at 950-1080m but are within the range reported for red beech in more northern parts of the South Island (Ogden 1978). Red beech is generally considered to be about the closest ecological ally of *N. truncata* (Cockayne, 1928). Growth rates recorded for silver beech on MacFarlane Mound are somewhat less than those given by Wardle (1980) for comparable sites in the adjoining Paringa District.

The absence of silver beech on Nisson Hill is surprising, since it has the widest overall range in a region where beech distribution generally is quite irregular (Mark, 1977; Wardle, 1980). The Paringa Ecological District, which adjoins the Haast District to the north, provides some ecological insight into the anomalous patterns of beech distribution further south. In a transitional zone of relatively low hills near the coast between beech-free areas, silver beech occurs merely as scattered stands up to 6km apart (Wardle, 1980). It is on such sites, and possibly including those beyond the present coastline which were exposed by a lowered sea level, that silver beech is assumed to have survived the heavy glaciation that characterised the district. Wardle argues, from evidence that silver beech was present in the district during the last interglacial, that it survived the ice-age glaciation near the present coast or beyond it and, despite its being 'universally the aggressive species in the forests of South Westland', has not yet achieved its full potential in the district. Mountain beech, which presently is confined to a very limited part of the district (Trig V A near Grave Creek, Bald Hill and the associated Ship Creek catchment), is also considered by Wardle to have persisted here or nearby throughout the ice-age glaciation. It also occurs at Bayou Hill in the Haast District and on the summit of Mt Ellery slightly to the south (Dr P. Wardle pers. comm.).

Wardle (1980 p. 33) also accepts that 'the presence of silver, mountain, red, and even hard beech in the Arawata area, 60km southwest of the

Paringa District, suggests a major refugium there' with' the unglaciated terrain north-west of the Alpine Fault offering the best prospects for forest survival' . Of the four beech species, red beech does not occur on the coastal plain of the Haast District, being restricted to the mid and upper reaches of the Arawata catchment (Holloway, 1954; Mark, 1977) and a few isolated trees in the upper Jackson Valley to the south. Rather than surviving the glaciation in the Haast District there is evidence for its invasion westwards across the main divide from the Dart Valley, at least into the Arawata (including Waipara) catchment (Mark, 1977). P. Wardle (pers. comm.), however, points out that a southeastern refugium would involve survival through very severe inland climates whereas a northwestern refugium would have provided a tolerable glacial climate. Of the remaining beeches, apparently only hard beech is confined to the low-altitude slopes on or surrounding the coastal plain in the Haast District. Silver beech is widespread while mountain beech is of very limited occurrence in this district; its main presence is to the south, in the Arawata catchment (Holloway, 1954; Mark, 1977).

Among the eight prominent knolls on the coastal plain that characterises the Haast District, silver beech is present on all while mountain beech is confined to the two southernmost ones (MacFarlane Mound and Mt McLean) and the northernmost, Bayou Hill, north of the Haast River. The summit of Bayou Hill, c. 100m, carries a dwarfed mixed forest 10-1501 tall of silver and mountain beech with a *Phyllocladus- Weinmannia* understorey. Hard beech, by contrast, is restricted to the three southernmost hills, MacFarlane Mound, Nisson Hill and Mt McLean (here it is restricted to a few trees reported by June (1977) on the spur running out into Sponge Swamp - they were not relocated).

The limited environmental range together with the highly restricted distribution of hard beech in the Haast District certainly imply an equally limited ability to survive the ice-age glaciation here. While the front ranges of the mountains may have supported only small cirque glaciers at moderate altitudes, as Wardle (1980) claims for the Paringa District, there could have been no refugia within the high mountains since large glaciers filled the inner valleys of the Arawata, Waiatoto, Turnbull, Okuru and Haast to about the altitude of the present treeline and to c . 500m where the glaciers emerged from the mountains. As indicated by Johnson, Lee and Wardle (1979), this glacial ice would have over-ridden at least the lower hills north of the Arawata River and sculptured at least the trough now occupied by Lake Ellery and the Smooth water River, thereby implicating all of the sites presently known to be occupied by hard beech. Moreover, glacial till fringes the hill country forming the northern boundary of the Haast District (Nathan and Moar, 1975), and Burrows (1972) reports a capping of till on the Open Bay Islands some 17km off-shore.

However, the last glaciation may have been less extensive in the lowlands that characterise the Haast Ecological District than elsewhere in South Westland, since large lateral moraines are not featured. This may have allowed for forest survival on some localised seaward-facing slopes of the projecting knolls even though these sites do appear to be veneered for the most part with till. P. Wardle (pers. comm.), however, disagrees that the last glaciation was less extensive in the Haast lowlands than elsewhere, commenting that' Large lateral moraines are probably only formed along a defined valley; the Haast and Arawata glaciers may have spread widely over the Haast plain rather than concentrating their debris in high lateral moraines. Most of the material was probably carried out to sea; the bathymetric map shows a shallow shelf bulging for 22km beyond the present coast opposite the Haast River, whereas south of Jackson Head, deep canyons almost reach the coast. The fact that a moraine veneer overlies the isolated granite hills, and that there are large schist boulders at 300ft a.s.l. in the saddle behind Jackson Bay also speaks of extensive glaciation. It is rather puzzling that there are no 'tails' of moraine seaward of any of the low granite hills; or perhaps there are, buried beneath recent sediments.' Alternatively, hard beech might have survived glaciation on seaward-facing slopes of the coastal hills to the south of the Arawata River mouth in the vicinity of Jackson Head or even beyond the present coastline. It could have colonised the sites it currently occupies through seed distributed by fresh water which presumably existed as an extensive lagoon surrounding MacFarlane Mound, Mt McLean and Nisson Hill. Certainly the biological case for hard beech having survived the glaciation near at least one of the sites it currently occupies is compelling.

The ecological and biogeographical significance of these communities containing hard beech demand that provisions for their conservation should be addressed. Fortuitously the MacFarlane Mound area is within the proposed Burmeister Ecological Area which extends from the Arawata River northwards to Hindley Creek (see Fig. 1) and inland from the coast to the slopes of Haast Range where it would border a proposed extension of Mt Aspiring National Park. This area was justified in relation to its ecological diversity and representativeness: it includes pakihi-forest and beach ridge sequences on the coastal plain, together with the domes of Mt McLean and MacFarlane Mound. The Nisson Hill stand of hard beech justifies inclusion in this reserve which ideally should extend northwards to the Waiatoto River. This would also allow Lake Nisson and its shoreline vegetation sequences, together with the tidal riverine communities in the lower Hindley Stream-Dawn Rivulet area to be included.

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Appendix 1: *List of vascular plant species in forest stands on MacFarlane Mound and Nisson Hill, South Westland. Species frequency in plots (see text jor sizes) along transects including slope forest (n* = 18) *containing* Nothofagus truncata *and swamp forest (n* = 8) *beyond the limits of* N. truncata *are presented for MacFarlane Mound. General importance values for three hard beech forest sites on Nisson Hill and one without hard beech on alluvial flats nearby, are given on a* 1-5 *scale as follows:* 5 = *species dominant or co-dominant,* 4 = *abundant or subdominant,* 3 = *common but not very abundant,* 2 = *occasional and* 1 = *rare*.

	MACFARLANE MOUND FREQUENCY		*NISSON HILL RELATIVE IMPORTANCE*			
SPECIES	Swamp forest	Slope forest	Summit ridge forest	North aspect forest	Moraine forest	Swamp forest
TREES, SHRUBS AND LIANES						
Archeria traversii	-	11	-	1	2	-
Aristotelia fruticosa	12	5	-	-	-	-
Ascarina lucida	100	50	-	-	3	1
Coprosma colensoi	75	94	2	2	-	-
Coprosma foetidissima	25	39	1	2	3	4
Coprosma lucid a	37	61	1	1	2	-
Coprosma parviflora	-	5	-	-	-	-
Coprosma propinqua	50	5	-	-	-	-
Coprosma rhamnoides	50	50	2	2	3	-
Corosma rotundifolia	12	-	-	-	-	-
Cyathodes juniperina	-	66	4	2	-	-
Dacrydium colensoi	12	11	5	-	-	-
Dacrydium cupressinum	100	100	5	5	5	5
Dacrydium intermedium	-	50	5	3	1	-
Dacrycarpus dacrydioides	75	-	5	-	-	.-
Dracophyllum longifolium	-	-	3	-	-	-
Elaeocarpus hookerianus	100	72	2	2	2	-
Griselinia littoralis	50	22	-	2	4	4
Hedycarya arborea	50	-	-	-	2	4
Leptospermum scoparium	-	5	3	-	-	-
Metrosideros diffusa	100	83	-	-	-	3
Metrosideros fulgens	75	16	-	2	3	-
Metrosideros perforata	38	33	-	-	-	1
Metrosideros umbellata	37	94	5	5	4	1
Myrsine australis	62	55	-	2	2	1
Myrsine divaricata	75	44	-	2	-	-
Neomyrtus pedunculata	100	77	-	-	3	4
Nothofagus menziesii	62	33	2	-	5	5
Nothofagus solandri var. cliffortioides	25	88	-	-	-	-
Nothofagus truncata	-	78	5	5	5	-
Parsonsia heterophylla	38	-	-	-	-	-
Phyllocladus alpinus	50	100	5	4	2	-
Pittosporum divaricatum	12	-	-	-	-	-
Podocarpus ferrugineus	100	78	-	1	4	5
Podocarpus hallii	38	78	2	3	4	-
Pseudopanax colensoi	62	89	-	1	3	3
Pseudopanax crassifolius	100	100	3	3	-	-
Pseudopanax edgerleyi	-	-	-	-	1	3
Pseudopanax simplex	12	5	-	-	-	2
Pseudowintera colorata	87	17	-	-	-	3
Rubus australis	25	-	-	-	-	-
Weinmannia racemosa	100	100	3	4	5	4
HERBACEOUS DICOTYLEDONS						
Nertera depressa	75	83	-	-	1	1
Nertera dichondraefolia	100	66	-	1	2	3
MONOCOTYLEDONS						
Astelia fragrans	25	-	-	-	-	-
Astelia grandis	25	-	-	-	2	-
Astelia nervosa	62	89	2	2	2	-

Astelia solandri	25	28	2	1	-	2
Baumea teretifolia	12	11	-			
Bulbophyllum pygmaeum	-	-	2			
Corybas oblongus	-	11				
Corybas rivularis	-	17				
Dendrobium cunninghamii	37	72	2	2	-	3
Dianella nigra	25	89	2	2	-	3
Earina autumnalis	50	61	3	2		
Earnia mucronata	12	22	2	-		
Frelcinetia bauriana	25	62	-	-	3	1
Gahnia procera	-	55	3	3	2	-
Gahnia xanthocarpa	50	50	-	-	2	2
Libertia pulchella	100	100	2	-		
Luzuriaga parviflora	50	78	2	2		
Microlaena avenacea	87	-	2	-	-	2
Ripogonum scandens	75	11	-	-	3	3
Uncinia filiformis	12	55	-	-	-	
Uncinia rupestris	12	22	-	-	2	
Uncinia uncinata	-	11	-	-	-	
PTERIDOPHYTES						
Alsophiia smithii	62	22	1	-	-	3
Asplenium bulbiferum	12	-	-	-	1	2
Asplenium flaccidum	50	11	2	-	-	2
Blechnum capense	75	44	-	3	3	2
Blechnum discolor	37	89	1	3	3	4
Blechnum fluviatile	-	-	1	-	-	-
Blechnum minus	100	94	2	3	2	3
Blechnum nigrum	-	-	-	-	-	2
Blechnum patersonii	-	11	-	-	-	1
Ctenopteris heterophylla	75	55	2	2	-	-
Dicksonia squarrosa	100	22	-	-	-	4
Gleichenia cunninghamii	-	44	-	-		
Grammitis billardieri	100	100	2	2		
Histiopteris incisa	12	5	2	-		
Hymenophyllum armstrongii	37	67	2	2		
Hymenophyllum dilatatum	12	16	-	-	1	3
Hymenophyllum demissum	37	28	-	-	2	2
Hymenophyllum flabellatum	25	28	-	1	2	1
Hymenophyllum ferrugineum	25	5	-	-		
Hymenophyllum lyallii	12	28	1	1		
Hymenophyllum multifidum	75	100	2	2		
Hymenophyllum peltatum	62	61	-	-		
Hymenophyllum rarum	37	33	-	1	-	3
Hymenophyllum revolutum	25	50	-	2	2	
Hymenophyllum sanquinolentum	50	50	-	2	2	
Hymenophyllum scabrum	37	5	2	2		
Hypolepls rugosula	-	5	-			
Lindsaea tricomanoides	100	83	1			
Lycopodium scariosum	-	78	3	3		
Lycopodium volubile	-	17				
Polystichum vestitum	12	-				
Rumohra adiantiformis	50	11	1	2	3	3
Rumohra hispida	37	5	-	-	-	4
Todea superba	-	-	-	-	-	3
Trichomanes reniforme	100	100	2	2	2	
Trichomanes strictum	88	22				
Tmespteris tannensis	50	55				
Total species	83	87	46	45	42	44

Appendix 2: *Soil descriptions along an altitudinal sequence, on the northwest aspect slope of MacFarlane Mound, South Westland: Site* 9 *near the summit, Site* 3 *near base of slope, Sites* 2 *and* 1 *on edge of coastal plain swamp forest. Soil descriptions and samples were collected from vegetation plots along Transect* 3.

Site	*Horizon depth (cm)*	*Descriptions follow standard Soil Survey Method (Taylor and Pohlen, 1970)*
1	2 – 0	Podocarp-beech litter
	0 – 30	very dark brown (7.5YR 2/2) moderately decomposed peat; weak granular structure
	30 – 50	very dark greyish brown (10YR 3/2) humic silt; weakly sticky, moderately plastic; massive.
2	2 – 0	mixed litter, weakly decomposed
	0 – 14	very dark brown (7.5YR 2/2), strongly decomposed peat
	14 +	very dark greyish brown (10YR 3/2) sedimentary peat with water table at 20cm.
3	1 – 0	litter
	0 – 12	dark grey (10YR 4/1) sandy loam; abundant fine bleached light grey mottles (10YR 6/1); non-sticky, moderately plastic, very friable; weak fine nut structure and few fine roots, bleached quartz grains
	12 – 24	greyish brown (10YR 5/2) sandy loam; very friable, weakly sticky, weakly plastic; very weak fine nut, few fine weakly weathered, leached gravels.
4	1 – 0	weakly decomposed mixed litter
	0 – 3	dark grey (10YR 4/1) sandy loam; friable; non-sticky, moderately plastic; weakly developed fine nut; many fine roots and bleached quartz grains
	3 – 10	grey (10YR 5/1) sandy loam with abundant light grey bleached mottles (10YR 7/1); friable; massive; non-sticky moderately plastic; few roots.
5	1 – 0	mixed litter
	0 – 4	dark brown (7.5YR 3/2) sandy loam; weakly sticky, moderately plastic, very friable; weak very fine crumb
	4 – 10	grey to light grey (10YR 6/1) humic sand, non-sticky, non-plastic.
6	1 – 0	litter, moderately decomposed
	0 – 5	grey (10YR 5/1) sandy loam; weakly sticky, moderately plastic, very friable; weak fine crumb structure; abundant roots; bleached quartz grains
	5 –23	grey to light grey (10YR 6/0) sandy loam; massive very friable, non sticky and moderately plastic; few roots
	23+	light olive brown (2.5YR 5/4) coarse sandy loam; weakly sticky, moderately plastic; very friable; weak fine nut; many subangular, weakly to strongly weathered gravels.
7	3 – 0	litter, mixed beech-hardwood, weakly decomposed
	0 – 15	grey (7.5YR 5/0) sandy loam; moderately sticky, moderately plastic; very friable; weak to medium nut and fine crumb structure; numerous fine to medium roots
8	2 – 0	litter, weakly decomposed, mainly hard beech
	0 – 12	grey (7.5YR 5/0) fine sandy loam; moderately sticky, weakly plastic, very friable; weak medium to fine nut and fine crumb structure, many roots
	12 – 26	light grey to grey (7.5YR 6/0) sandy loam; many moderately weathered, subangular, weakly cemented granitic gravels; moderately sticky, moderately plastic, massive; many fine strong brown (7.5YR 5/6) mottles associated with weathering granite.
9	2 – 0	weakly decomposed mountain beech litter
	0 – 1	brown to dark brown (7.5YR 4/2) sandy loam; weakly sticky, moderately plastic, very weak fine to medium crumb structure
	1 – 32	grey to light grey (7.5YR 6/0) coarse sandy loam, moderately sticky, moderately plastic, massive, few fine tubular pores
	32 – 35	brown (7.5YR 5/2) sandy loam, with 20% grey (7.5YR 5/0) patches; few subangular, strongly weathered granitic gravels and stones; moderately plastic, moderately sticky; leaf material (rata, kamahi, mountain beech, hard beech).

Appendix 3: Soil *chemical analyses: MacFarlane Mound altitudinal sequence (as for Appendix* 2). *Values for calcium, potassium magnesium and Olsen phosphate are Quick Test units (x25, x4, x1, x0.05 for approximate ppm). Nitrogen and carbon values are percent dry weight.*

Site	*Horizon depth (cm)*	*pH*	*Ca*	*K*	*Mg*	*P*	*N*	*C*
1	0-30	4.5	1	1	28	<1	0.24	45.0
	30-50	4.4	2	2	4	6	0.35	19.4
2	0-14	4.5	1	2	7	<1	0.40	24.0
	14+	4.3	1	2	5	<1	0.10	19.2
3	0-12	4.6	1	2	3	1	0.05	2.1
	12 - 24	4.7	1	1	3	<1	0.04	1.7
4	0-3	4.4	1	4	7	3	0.14	6.1
	3-10	4.5	1	3	3	1	0.07	2.9
5	0-4	4.4	3	6	14	1	0.20	25.6
	4-10	4.4	2	7	1	1	0.10	5.8
6	0-5	4.1	1	3	6	1	0.07	3.7
	5-23	4.5	1	2	2	<1	0.04	1.5
	23+	4.9	1	2	2	<1	0.02	1.2
7	0-15	4.2	1	3	11	3	0.11	1.3
8	0-12	4.2	2	3	9	3	0.08	3.9
	12 - 26	4.7	1	2	4	<1	0.02	1.3
9	0-1	4.1	1	3	9	3	0.09	3.8
	1-32	4.6	1	2	2	1	0.03	1.4
	32 - 35	4.6	1	2	2	1	0.04	2.5

Appendix 4: *Profile descriptions and chemical analyses of soils from four sites on Nisson Hill, South Westland.*

Site 1. Altitude 60m. Low forest (12m) of *Nothofagus truncata, Dacrydium intermedium, Metrosideros umbellata, Dacrydium cupressinum* and D. *colensoi* on shallow soil near summit of Nisson Hill.

Horizon depth (cm)	
5-0	weakly decomposed litter
0-6	(7.5YR 6/1 + 4/2) sandy loam, non-sticky, weakly plastic, very weak fine nut, very friable, many roots, bleaching in form of abundant fine distinct mottles
6-13	(10YR 6/1 + 7/1) grey-light grey sandy loam, weakly sticky, moderately plastic, very friable, very weak fine nut, many roots
13 - 15	(10YR 4/3) sandy loam, moderately sticky, moderately plastic, very friable very weak fine nut. Leaf material (Hard beech + kamahi) and many granitic stones and gravels, weakly weathered, subrounded, with some bleached surfaces and Fe stains.

Site 2. Altitude 60m. Tall (23m) *Nothofagus truncata - Dacrydium cupressinum* forest on moraine near western shores of lake *(c.* 300m west of Nisson HilI).

Horizon depth (cm)	
5-0	weakly decomposed litter
0-10	(7.5YR 4/23) with 10% 7.5YR 5/1 mottles, representing leached material; sandy loam, very weak fine nut and fine crumb; very friable; non-sticky, moderately plastic, many coarse-fine roots.
10 - 22	(10YR 4/2) coarse sandy loam, with many fine mottles (l0YR 5/2); weakly sticky, moderately plastic, very friable. Many bleached angular granitic gravels, (5YR 3/3), few roots.
22 - 32	dark reddish brown (5YR 3/2) coarse sandy loam; very weak fine crumb, very friable, weakly sticky, weakly plastic; many weathered granitic gravels; humus, iron and manganese laminations throughout, strongly weathered granitic lumps - granites weathered to a (10YR 6/4)
32+	(7.5YR 3/4) strong brown to (7.5YR 4/1) dark grey coarse sandy loam. Discontinuous horizon, many schistose granitic gravels, weakly weathered, massive. '

Site 3. Altitude 60m. Tall (c. 23m) *Nothofagus truncata, Dacrydium cupressinum, Metrosideros umbellata* mixed forest over *Weinmannia racemosa* on lower northern aspect slope of Nisson HilI.

Horizon depth (cm)	
0-8	(5YR 2/2) dark reddish brown loamy peat; non-sticky, very friable, moderately plastic, weak-medium crumb, abundant medium-fine roots, moderately decomposed
8-16	(10YR 4/1) sandy loam; weakly sticky, moderately plastic, very friable, massive; many roots and leaf material among fine leached quartz gravels
16 - 22	(l0YR 5/2) with patches of 7.5YR 4/2 mixture of bleached, angular quartz grains with many angular fine gravels; moderately plastic, weakly sticky, massive, very friable
22+	bedrock.

Site 4. Tall *(c.* 28m) *Nothofagus menziesii - Dacrydium cupressinum* forest on deep alluvial sand, possibly on old levee of Nolans Creek, on the coastal plain.

Horizon depth (cm)	
0-10	moderately decomposed peat
10-30	(2.5YR 5/3) greyish brown to light olive brown silt loam, moderately sticky, friable, very plastic, very weak fine block to massive; top of horizon weak to moderate block stain (7.5YR 4/2) humic material; few roots
30 - 50	(5YR 5/2) olive grey sandy silt; very sticky, very plastic, friable, massive, few roots
50+	(2.5YR 5/3) greyish-brown to light olive brown very fine sand (10YR 4/4) mottles, weakly sticky, non-plastic, massive, very friable, few roots.

Appendix 5: *Soil chemical analyses for mineral soil horizons: Nisson Hill (as for Appendix* 4). *Values for calcium, potassium, magnesium and Olsen phosphate are Quick Test units (x25, x4, x1, x0.05 for approximate ppm). Nitrogen and carbon values are percent dry weight*.

	Depth (cm)	*pH*	*Ca*	*K*	*Mg*	*P*	*N*	*C*
Site 1.	*Summit forest*							
	0-6	4.6	2	3	5	1	0.05	3.1
	6-13	4.7	2	3	4	1	0.05	2.9
	13 -15	4.8	1	2	4	1	0.05	3.1
Site 2.	*Tall forest on moraine*							
	0-10	4.5	1	2	5	2	0.05	4.7
	10-22	4.8	1	2	2	2	0.08	3.7
	22-32	4.8	1	1	3	1	0.09	4.5
	32+	4.7	1	2	3	2	0.05	2.3
Site 3.	*Lower slopes of Nisson Hill*							
	0-8	4.4	3	4	5	1	0.20	16.0
	8-16	4.6	2	4	4	1	0.09	4.3
	16 - 22	4.6	2	3	4	1	0.07	3.4
Site 4.	*Tall forest on levee*							
	10 - 30	4.4	2	2	4	1	0.10	5.6
	30 - 50	4.8	1	1	1	1	0.04	1.1
	50+	5.0	1	1	1	22	0.02	0.6