SHORELINE FORESTS OF LAKE TE ANAU, FIORDLAND

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SUMMARY: Those sections of forest along the Te Anau lake shore, resting on unconsolidated material and within *ca.* 3m of the maximum natural lake level (204.3m above mean sea level), could be threatened by the predicted water table effects (Mark *et al.* 1972) of lake manipulation required for hydroelectric development. The floristics and structure of this forest were investigated. Five forest associations have been recognised, apparently related to differences in soil moisture conditions.

INTRODUCTION

Further to the "Applied Ecological Studies of Shoreline Vegetation at Lakes Manapouri and Te Anau, Fiordland" (Johnson 1972a, 1972b, Mark 1972, Mark and Johnson 1972 and Mark *et al.* 1972), in which implications to lakeshore environments of artificially controlled lake levels were discussed, is the following analysis of data collected in May 1971 on the forest composition of the Lake Te Anau shoreline. For a more detailed review of the findings of the 1971 investigation, and for a map indicating the location of sites dealt with in this paper, the reader should refer to the above mentioned authors.

Nomenclature follows Allan (1961) and Moore and Edgar (1970).

METHODS

In each of nine localities, where representative homogeneous forest stands were recognised, up to five sets of quadrats were laid out, each group being nested fractions of one square chain ($404.6m^2$). Plants were grouped into the following size classes:

trees	: diameter at breast height > 10cm
poles	: d.b.h. < 10cm; height > 4.6m.
saplings	: height 0.9-4.6m.
shrubs	: woody plants, height 0.15-0.9m.
tall ferns	: large *Blechnum* spp, *Polystichum vestitum,* tree ferns and other ferns of similar size.
ground layer	: all plants; height < 0.15m.

Diameter at breast height and density were recorded for trees in the whole $404.6m^2$ plot, density of poles and saplings in half of the plot, density of shrubs and cover of the tall ferns in quarter of the plot and presence and cover of species and cover of litter and bare ground in 10 gridded $0.25m^2$ frames placed at alternate half metres along one side of the large quadrat.

RESULTS

Figure I summarises the data for the nine sites. The forest stands are arranged in a sequence reflecting an environmental gradient related to soil moisture: the better drained sites are towards the left of the figure and more saturated sites towards the right.

While varying in their degree of overlap within the forest continuum, all nine sites support distinct plant assemblages, since they were chosen specifically to cover the range of forest types in the study zone. The consequent diversity of species combinations was thus difficult to summarise. Nevertheless five categories have been recognised on the basis of Sφrenson's similarity index (Sφrenson 1948), with due consideration being given to the dominance of the species.

The north Brod Bay stand (site 21) has the greatest overall similarity to the other stands while the Eglinton stand (site 3) is the most distinct.

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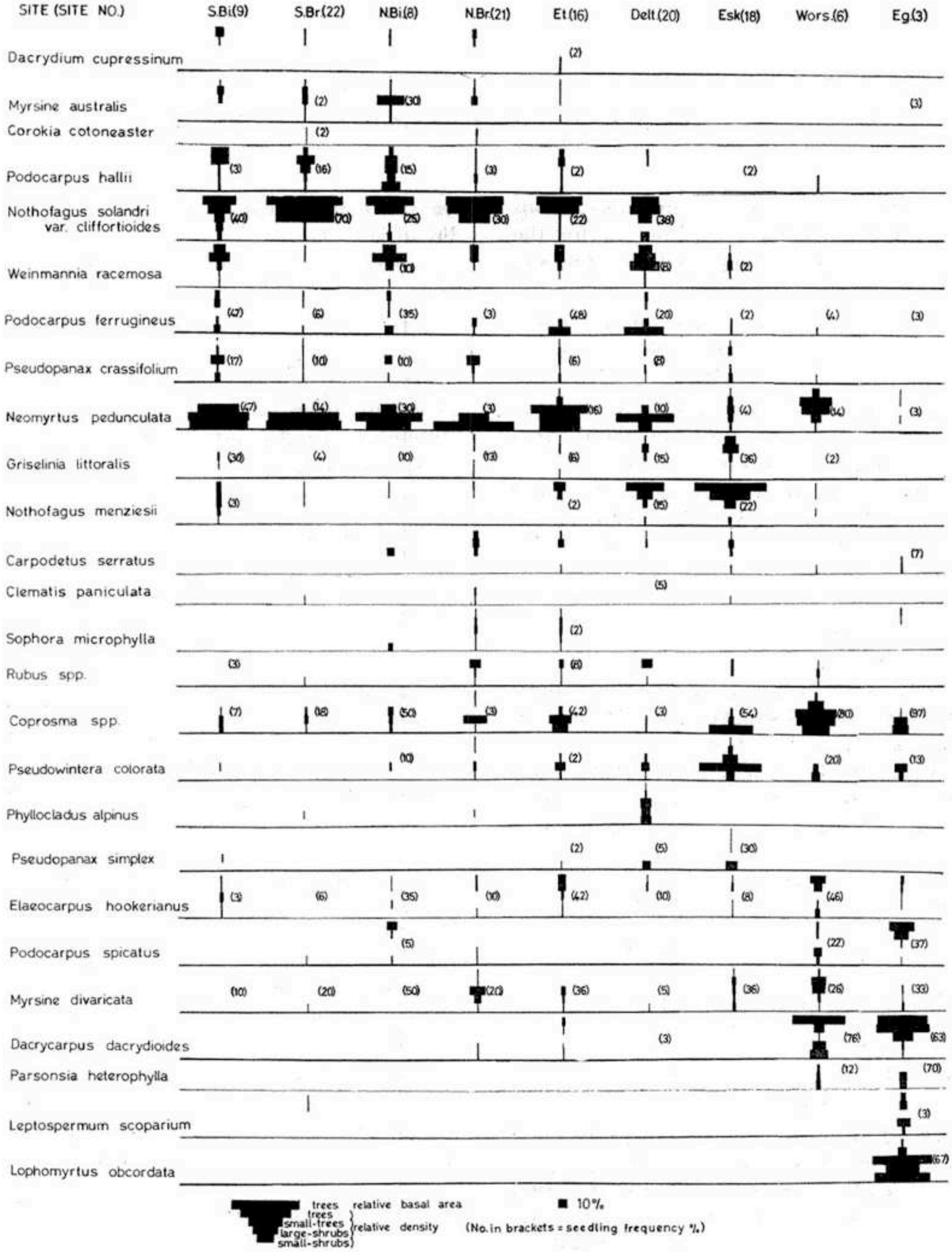

		S.Bi(9)	S.Br(22)	N.Bi(8)	N.Br(21)	Et(16)	Delt(20)	Esk(18)	Wors.(6)	Eg(3)
BASAL AREA (sq.m/hectare)		48	51	87	54	72	108	113	73	90
DENSITY (per hm2)	TREES	568	652	778	956	751	601	494	1,520	944
	POLES	1,520	682	840	724	1,080	297	672	1,420	2,880
	SAPLINGS	3,860	3,330	3,550	2,850	3,260	494	1,250	7,760	7,620
	SHRUBS	7,120	28,000	9,740	32,000	10,600	3,340	4,170	58,000	32,200
TALL FERNS % COVER		6	3	30	3	4	17	57	2	5
GROUND % COVER	BARE	0	1	0	7	1	0	0	0	0
	LITTER	29	77	75	71	77	52	62	67	26
	BRYOPHYTES	57	12	15	15	15	43	26	13	31
	HERBS, SEEDLINGS	14	10	10	7	7	5	12	20	43

FIGURE 1. *Relative basal area of trees, relative density of trees, poles, saplings and shrubs and seedling frequency of the woody species from nine forest stands at Lake Te Anau. Total basal areas and densities of the woody species are shown, together with the cover values for the tall fern and ground tiers.*

A brief account follows of the five associations recognised while a complete floristic list for the shoreline communities is included in Johnson (1972b).

1. *Mountain beech-mixed podocarp forest : north Billy Burn (site 8), south Billy Burn (site 9), south Brod Bay (22).*

Relatively young mountain beech (*Nothofagus solandri* var. *cliffortioides*) (mean basal area (m.b.a.) $=0.09\text{-}0.19m^2$) dominate these stands in association with occasional large stems of Hall's totara (*Podocarpus hallii*), kamahi (*Weinmannia racemosa*), rimu (*Dacrydium cupressinum*), miro (*Podocarpus ferrugineus*) and silver beech (*Nothofagus menziesii*) *.

Mature stems of matai (*Podocarpus spicatus*) (m.b.a. $= 0.87m^2$) are conspicuous only in the stand (8) on the north side of the Billy Burn delta. Dead beech trunks make up more than 10 percent of the standing timber.

There is a moderate development of understorey woody plants while tall ferns are relatively sparse except at site (8) where they attain a 30 percent cover.

This forest type is found backing on to sandy beaches along the western shore of the main body of the lake. These are comparatively free-draining sites which probably receive much less rain than do the western arms of the lake.

2. *Mixed beech-broadleaved**—podocarp forest: north Brod Bay (site 21), Ettrick Burn (16).*

This association is similar to the previous one but supports fewer of the same podocarps. Kahikatea (*Dacrycarpus dacrydioides*) is instead quite important, at least in the shrub and sapling classes. Again the mountain beech stems are immature (m.b.a.$=0.07\text{-}0.11m^2$) and about 10 percent of all standing trunks are of dead beech. On the other hand the average silver beech has about twice this basal area. Broadleaved trees together contribute appreciably to the woody cover, the most important being kamahi, pokaka (*Elaeocarpus hookerianus*), marble leaf (*Carpodetus serratus*) and broad leaf (*Griselinia littoralis*) while the shrub to pole strata are conspicuously occupied by pepper tree (*Pseudowintera colorata*).

Like group (1) this forest type occurs around the less humid, eastern regions of the lake, but the greater representation of species tolerant of impeded drainage in the group (2) sites suggest a difference in soil moisture conditions.

This arrangement of the above five stands is not wholly satisfactory since there are few consistent features differentiating members of the two groups. Both have at least some silver beech associated with the mountain beech together with a range of podocarps and broadleaved species. Apart from those already mentioned, *Myrsine australis* and lancewood (*Pseudopanax crassifolium*) are two small trees common to both groups. The understoreys are moderately well stocked with *Neomyrtus pedunculata*, various small-leaved coprosmas and *Myrsine divaricata*. Manuka (*Leptospermum scoparium*), kowhai (*Sophora microphylla*), *Corokia cotoneaster*, tree tutu (*Coriaria arborea*) and southern rata (*Metrosideros umbellata*) are occasionally present along the lakeside margin of the forest, while the lianes *Rubus* spp. and less commonly *Clematis paniculata* and *Muehlenbeckia australis* occur sporadically in the forest interior. Tall ferns are plentiful only locally and seldom make an important contribution to the understorey.

About three-quarters of the ground is litter covered, one-eighth is covered by bryophytes and the balance by herbs and seedlings. The south Billy Burn stand (site 9) is exceptional in this respect having less than one-third of the ground covered in litter while bryophytes cover the remainder and form extensive, deep cushions on the forest floor. This site, which lies at the base of a steep south facing wave cut platform, is probably more deeply shaded than most of the other sites. [See Fig. 4, Billy Burn site 10, (Mark *et al.* 1972)].

3. *Mature beech-broadleaved forest : Delta Burn (site 20), Esk Burn (18).*

These stands characterise the rain forest near the fiord heads. Overmature silver beech (m.b.a $=0.42m^2$) contributes the bulk of the woody

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* Throughout this description species are listed in order of their relative basal area.

** "Broadleaved" here refers to dicotyledonous trees other than beech.

vegetation although mountain beech trees (m.b.a. $=0.17m^2$) are more numerous at the Delta Burn site. Composition of the Esk Burn forest, as compiled from the plot records, shows mountain beech to be absent, however it does occur on a raised terrace in the vicinity, where a full range of regenerating classes is present [see also transect 18, Fig. 3 (Mark *et al.* 1972)]. Only five percent of the stems are dead beech but some of the larger silver beech trees appear moribund. Podocarps are less important than in the mountain beech forest (0-5% relative dominance as opposed to 7-40%). The Delta Burn stand supports some miro and Hall's totara and the only significant occurrence of mountain toatoa (*Phyllocladus alpinus*). Broadleaved trees, however, are more important; particularly broadleaf (12% relative dominance at Esk Burn), kamahi (14% at Delta Burn), marble leaf, pokaka, lancewood and *Pseudopanax simplex*. The subordinate woody vegetation is dominated by pepper trees, *N. pedunculata, M. divaricata* and coprosmas. Vines of *Rubus* and *Clematis* have minor roles. Although the sub-canopy layers are not particularly well developed there is a compensating proliferation of the tall fern stratum which affords a 17-57 percent cover. The ground is also well covered by bryophytes (15-43%) and herbs and seedlings (5-10%) while litter accounts for the remaining area.

Undoubtedly the regions supporting this forest type receive considerably greater precipitation than those further east. The presence of silver beech, a species relatively intolerant of drought (Wardle 1967), pokaka, broadleaf, peppertree, *P. simplex* and occasional kahikatea seedlings are characteristic of these sites which appear to have saturated soils; nevertheless most of the larger trees stand on locally elevated banks and hummocks in some cases derived from their own root systems. This habit is said to be characteristic of silver beech when growing in boggy situations (Wardle 1967).

4. *Young kahikatea-matai forest : Eglinton River delta (site 3).*

This is represented by a single dense stand (946 trees/ha) of young kahikatea trees (m.b.a. $= 0.05m^2$). A mature element of this Eglinton forest comprises matai, pokaka (both of m.b.a. *ca.* $= 0.09m^2$), manuka (m.b.a. $= 0.03m^2$) and kowhai (m.b.a. $= 0.07m^2$). Almost one-third of the manuka and pokaka stems are dead.

Some features of this stand set it apart from all others seen. Firstly beech is completely absent, and secondly cabbage tree (*Cordyline australis*) and *Lophomyrtus obcordata* are present. Not only is the myrtle's presence unique among the sampled stands but it is extremely abundant having a relative basal area of 2.5 percent which ranks it fifth among the woody components. Although hardly a tree in the usual sense, numerous multileadered individuals just come within the defined tree limit.

Plants in the shrub and pole categories form a dense thicket, in places impenetrable. The major components are the two myrtles, pepper tree, *M. divaricata,* coprosmas, kahikatea regeneration, manuka and marble leaf. Tall ferns are virtually absent.

The ground layer is composed mostly of litter (67%) with less of bryophytes (13%). A large herb-seedling component (20%) is attributable to the notable abundance of young *Parsonsia* vines, the vast number of tree and shrub seedlings and the appreciable cover of *Carex virgata* and *Uncinia uncinata*.

Despite its eastern location and relatively low rainfall, the low elevation of this site determines that it is inundated periodically. Moreover, its swampiness is aggravated by the ponding effect of the storm beach running along its shoreline margin [see site 3 in Fig. 4 (Mark *et al.* 1972)].

This site supports a vigorous young kahikatea stand which has succeeded a swamp vegetation of flax *(Phormium tenax)*, cabbage trees, manuka and kowhai. The mature matai element, however, suggests a relic from a former swamp forest which may have been destroyed by Maori or possibly early European fires.

5. *Mature kahikatea-pokaka forest : Worsley Stream delta (site 6; see Fig. 3, (Mark et al. 1972)).*

This stand probably exemplifies climax forest of swampy deltaic sites below high natural lake level. In many respects this association is intermediate between silver beech forest and pure kahikatea forest. Kahikatea, pokaka, *N. pedunculata*, coprosmas, matai, *M.divaricata* and silver beech dominate the tree layer as defined but only the first two, plus matai and silver beech, emerge above the closed canopy formed by the remaining small trees. These all have mean basal areas greater than $0.09m^2$ (kahikatea$=0.51m^2$) as opposed to the small but numerous canopy trees (m.b.a. *ca.* $=0.02m^2$). Half of the silver beech stems are dead.

As with group (4) sites the subordinate woody layers are exceptionally well stocked with coprosmas, seedlings and saplings of kahikatea and matai together with pepper tree, pokaka, *N. pedunculata* and *M. divaricata*. Most of the small canopy trees are gnarled and apparently ancient with a few moribund. Both the *Rubus* spp. and *Parsonsia heterophylla* are common lianes. Tall ferns make up only a five percent cover.

The unusually high cover of bryophytes (31%) and herbs, etc. (42%) means that litter accounts for only *ca.* 26 percent of the ground cover. The "herbaceous layer", which is composed of numerous kahikatea, *Coprosma* and *Parsowsia* seedlings and hooked sedges, provides a situation reminiscent of the Eglinton site. Another factor in common is the near absence of those podocarps characteristic of the local beech forests.

An anomalous swamp forest occurs at the head of North Fiord (Glaisnock River delta). It supports an assemblage of species closely related to the Worsley swamp forest. The conical emergent trees of pokaka, subordinate canopy of small trees, dense shrub zone and ground layer dominated by sedges, gives a distinctly similar appearance. However, both kahikatea and matai are inexplicably absent. Historical factors, chance establishments or possibly some subtle undetected habitat differences may account for this anomaly. [See Fig. 3, (Mark *et al.* 1972)].

DISCUSSION

In comparison with Johnson's (1972a) data for Lake Manapouri, the Eglinton and Worsley associations would be termed "Swamp Podocarp forest," the Esk stand is not represented and the remainder would be termed "Mountain beech forest." While some other of his recognised forest communities are also present at Lake Te Anau (e.g. "Mountain Beech-Southern Rata Forest"), they were outside the scope of this study as they overlie solid rock substrates.

Type of forest appears to be related to soil moisture as affected by the combined rainfall and drainage characteristics of a site. The known ecology of the forest species and climatic patterns around the lake seem to support this generalisation for Te Anau.

Silver beech is a more fragile species than mountain beech, requiring well drained sites which receive a high rainfall (Wardle 1967). Mountain beech, however, occurs on thin soils in boggy or dry situations thus avoiding the competition on more favourable sites (Wardle 1970). Kamahi is a ubiquitous species which grows on poor soils which may be wet and acidic. It is often successional to rimu (Wardle and Macrae 1966). Rimu is restricted to moist sites in low rainfall areas (Franklin 1968). *Phyllocladus alpinus* occurs in the wetter mountains or, in the east, usually in damp hollows (Wardle 1969).

Beech forest at Lake Te Anau is developed on sites that are sufficiently elevated to receive no more than about 50 days of continuous flooding. Mountain beech predominates on freely draining sites in all but the wetter, western limits of the lake. Scattered trees of rimu, miro, Hall's totara and some broad-leaved species, kamahi often being important, occur chiefly associated with the mountain beech forests. The forest fringe is commonly intermixed with *Coprosma propinqua,* kowhai, manuka, *Corokia cotoneaster,* tree tutu and southern rata. While occurring throughout, silver beech tends to assume dominance only towards the fiord heads. There podocarps are relatively less important on higher, better drained ground but kahikatea and matai are locally dominant on poorly drained sites subject to periodic flooding. Pokaka manuka and pepper tree are also frequently found in areas subject to inundation or where drainage is impeded. The typical swamp forests have a low canopy of myrtles, coprosmas and *Myrsine divaricata* pierced by emergent stems of kahikatea matai, pokaka and occasionally silver beech.

There is a negative correlation between the density of shrub to sapling classes and the development of the tall fern layer. The Esk Burn, Delta Burn, north Billy Burn and possibly south Billy Burn sites demonstrate this effect. It is probably indicative of more intensive browsing by deer than in other areas. The absence, on all mainland sites, of palatable species such as *Coprosma lucida* and *Schefflera digitata* (only seedlings found) suggests the same influence as does the occasional abundance of pepper tree and the regeneration gap in silver beech whose seedlings are highly favoured by deer (Wardle 1967).

On the deltas and especially towards the west, the size of the conifers and beeches is relatively large and the trees are generally of good form. Among these is a giant decadent silver beech growing on the Lugar Burn delta. This was measured at 304cm d.b.h. (basal area $=7.44m^2$) which appears to be a record for this species. The largest podocarp measured was a kahikatea on the Narrows delta with a d.b.h. of 175cm (basal area$=2.42m^2$). In general there is an apparent age gradient from east to west exemplified by the south Billy Burn stand (site 9) with the smallest total tree basal area and the Esk Burn stand (site 18) with the largest. This may also reflect faster growth rates in the west or the tendency for silver beech to be a longer lived species (Wardle, 1967) than mountain beech, with a potential for larger growth.

It is noteworthy that the three stands with total basal areas less than $57m^2/ha$ (the value given by Wardle (1970) as being critical for the supression of regenerating classes) have a much better representation of beech in the shrub to pole tiers than do the other more mature closed stands (see Fig. 1).

Regeneration of silver beech appears barely adequate in the west but is even less successful further east. Wardle (1967), however, points out that it is often only when the canopy is opened that their seedlings become evident. In the beech forests generally, mountain beech, Hall's totara, the myrtles and other shrubs, and to some extent miro, are the only species showing any potential to maintain their present roles. However, the kahikatea stands show strong regeneration of all their major species.

Alteration in lake level regime, for hydro-electric development, would affect soil moisture conditions around the lake edge to an extent dependent on slope, soil depth, texture, structure and organic content and porosity of the underlying sediments. These changed conditions in turn would be eventually reflected by adjustments in the forests overlying these soils. It is doubtful, however, that the precise changes are predictable with our present understanding of forest dynamics.

While certain species (as detailed earlier) may be competitively superior to occupants of an existing situation in a new, wetter soil environment, other factors may prohibit expected replacements. Although induced wetter soils in the east may imitate naturally wet conditions in the west, climatic differences along an obvious west to east gradient could affect the outcome of any return to equilibrium. Humidity, temperature and sunlight would be variables operating along this gradient.

The Eglinton delta forest may suggest the effects of a high water table in the east; but reduction in flat areas suitable for the development of swamp forest, destruction of beaches and levees important in maintaining high water tables in some parts, instability of saturated ungraded slopes closer to the water's edge and immediate death of marginal trees could retard successions back to stable communities. The elimination of many local seed sources for swamp forest and other forest fringe species may well delay establishment of these associations at higher levels. These effects are inherent in an operation of lake levels grossly above natural fluctuations.

Finally, the predicted changes may only bring about that which is in slow process at the present time; some of the existing forests are possibly out of phase with existing climates (Holloway 1954).

Lakeshore communities support a relatively rich flora because of the diverse habitats which are compressed into a more or less narrow belt. This adds considerable interest and aesthetic character to the natural shoreline.

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