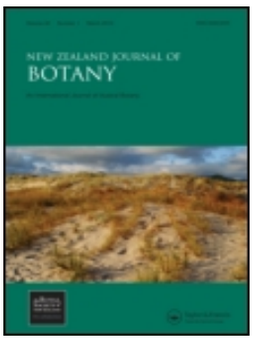

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Vegetation and Landscape of the West Cape District, Fiordland, New Zealand

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ABSTRACT

The region between Dusky Sound and Chalky Inlet is a rolling peneplain gently inclined from sea cliffs to rounded mountain slopes 8 km inland. Granite outcrops as hillocks, and depressions are generally underlain by cemented gravels. The area appears to be unglaciated. The climate is probably like that of similar terrain at Puysegur Point, 27 km to the south-east, which receives less than a third of the rainfall of the precipitous country further north at Milford Sound and Deep Cove, although the number of rain days is greater. Persistent westerly winds and low hours of sunshine can be assumed.

Site and vegetation classes form a gradient from forest and seral communities on unconsolidated, unweathered substrata (A), through tall forest on stable soils (B), to stunted vegetation on infertile soils (C). The last is the most extensive, and has an extreme manifestation in areas of gentle topography where the needle-leaved snow tussock, *Chionochloa acicularis*, is dominant. Representative transects show the reduction in height of vegetation from A to C, and changes in dominant and subordinate species. Coastal and upland (>350 m) vegetation is briefly described.

Salt spray appears to be an important factor in the formation of peat, which blankets most Class B sites to depths of up to 1 m, and occurs discontinuously on Class C sites. The gradient A–C is largely one of increasing podzolisation and worsening drainage, *Chionochloa* grassland replacing woody vegetation where the leached, humic silt loam containing roots is either less than 15–20 cm deep, or completely waterlogged. Plants of *Leptospermum scoparium*, *Dacrydium intermedium*, and *D. biforme* on these sites develop into low-growing clones of layering shoots.

Floristic peculiarities of the area include abundance of *Sprengelia incarnata*, apparent absence of *Phyllocladus alpinus*, *Hedycarya arborea*, and *Hoheria glabrata*, and, in one locality, the absence of *Nothofagus* from apparently suitable sites.

INTRODUCTION: PHYSICAL FEATURES

"The country is more level than I expected: the shore is bounded by rocky cliffs, from the summit of which there is a gentle slope for

a distance of six miles to an elevation of about 1500 ft, backed by smooth rounded ridges—the summits of which are 3000 ft above the sea. This slope extends from Chalky Inlet to Dusky Sound, but is divided by the valley of a stream that enters the sea at the West Cape, which has its rise apparently from the west side of Stopper—a lofty mountain at the head of Edwardson's Sound. The dark woods which cover this slope are occasionally broken by patches of yellow, where there are open grassy spots, and its uniformity is broken by a few sharp cones—not unlike those on the seaward slope of Saddle Hill. I have no doubt, however, that a close inspection would prove the surface of this country to be far more rugged than its appearance from the seaward indicates".

This extract from James Hector's report pertains to 22 June 1863, when he travelled by sea between Chalky Inlet and Dusky Sound, and described country which is very different in topography and vegetation from other parts of western Fiordland. A rolling peneplain rises gradually from sea cliffs 30 m high to rounded mountain slopes 8 km inland (Figs 1–3), and it is only beyond the crests of these mountains that the usual precipitous, glaciated topography begins. Forest grows in narrow incised valleys, but the peneplain itself is clothed mainly in tussock and scrub. The locality is rarely visited, red deer are the only introduced herbivores, no signs of fire were seen, and the vegetation is in a nearly virgin condition. We spent nine days in the area in February 1972 examining the vegetation, landing by float plane on Lake Fraser, and walking down the Newton River valley to a base

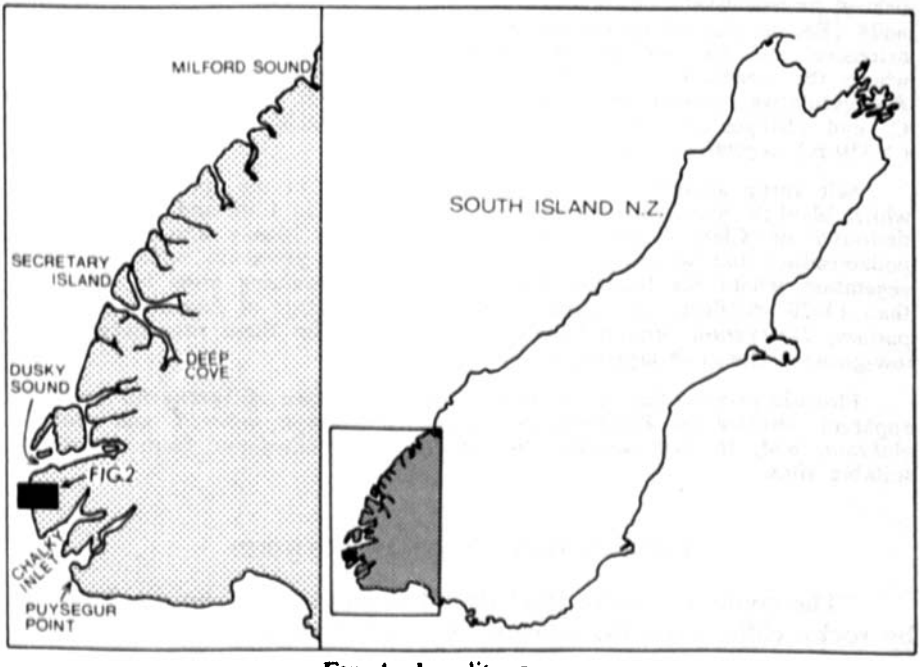

FIG. 1—Locality map.

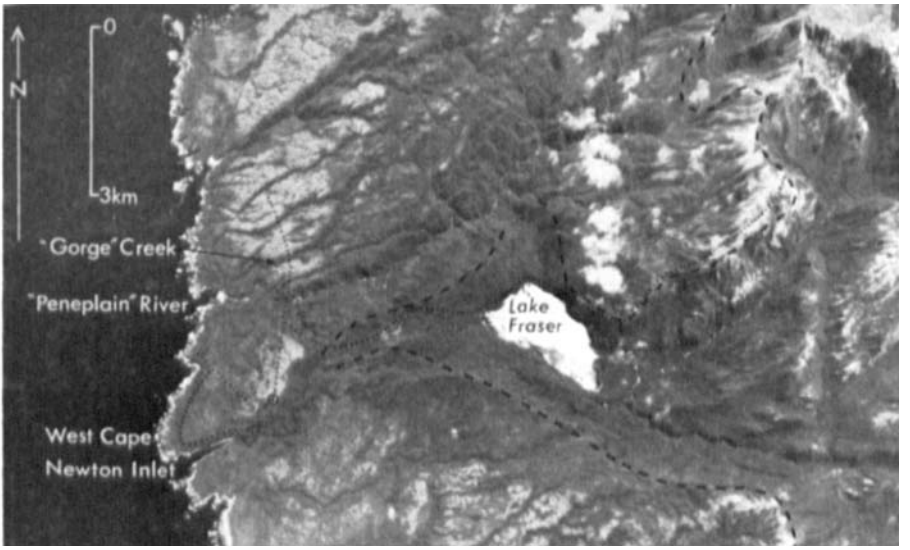

FIG. 2—Aerial photograph of West Cape and Lake Fraser area, showing the routes traversed (dotted line), the base camp (open circle), and the approximate western limits of glaciation.
(Crown copyright, *Department of Lands and Survey*).

camp on a tussock plain 2½ km north-east of West Cape, where supplies had been cached by helicopter. Our studies were mainly in the vicinity of this camp, but the coastal vegetation was also examined, and the uplands north-east of Lake Fraser were briefly visited. Routes traversed are shown in Fig. 2. Most of the plants mentioned in the text and in Tables 1 and 2 are represented by herbarium specimens at Otago University (OTA).

The rock throughout is Kakapo granite. The peneplain is mapped as a flight of marine benches up to 450 m elevation (Wood 1960), but on the ground the levels of these benches are obscured by the irregular topography of hillocks and depressions (Fig. 4). The hillocks are relatively steep outcrops of granite, probably weathered stacks, and the depressions are generally underlain by rounded gravels which are presumably old beach deposits.* Except where rivers have cut down, the peneplain has developed a dense but shallow drainage pattern and its seaward edge consists of a bench, 300–600 m wide, which is clearly of marine origin (Fig. 5). It has a flat surface of peat overlying gravel or solid rock, which is broken both by perched marine boulders near the present coastline and by outcrops closely resembling those jutting from the sea 30 m below.

* Mr I. C. McKellar, Geological Survey, Dunedin, examined samples of these pebbles and reports that some are clearly of the same granite as the stacks. Others may have come from Ordovician rocks to the south towards Cape Providence, but they are not sufficiently distinctive to preclude smaller local sources.

FIG. 3—Near-panoramic view eastwards and south-eastwards across the peneplain to the mountains.
a: campsite; b: depression containing Lake Fraser; c: upland area visited.

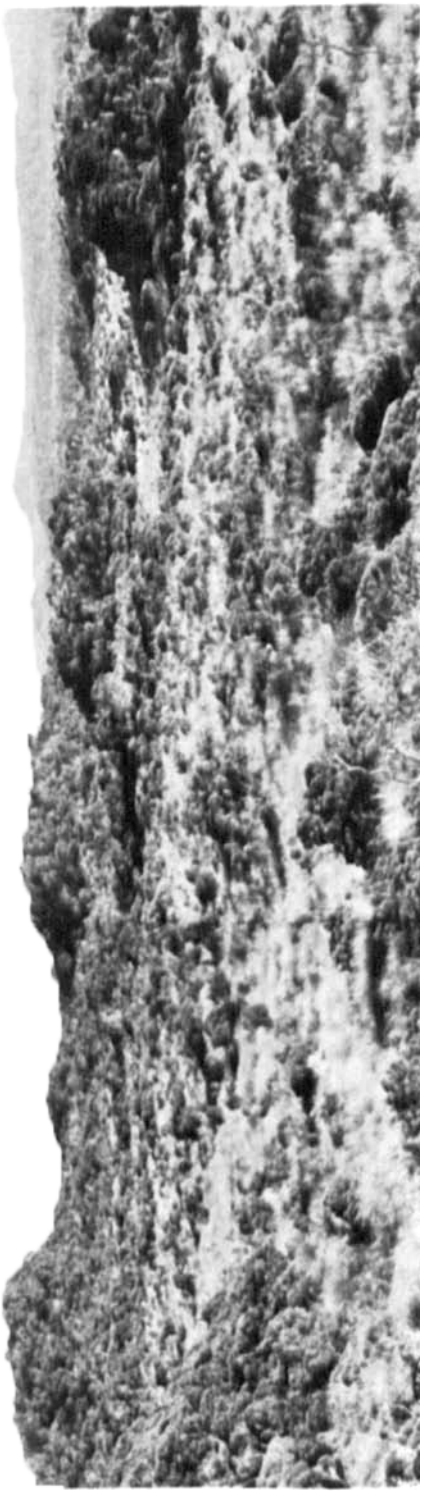

FIG. 4—Hillock and depression terrain of the peneplain.

FIG. 5—Coastline with stacks and a boulder beach, and the 30 m marine bench with stack-like outcrops. A community of *Carex pleiostachys* is behind the beach.

The peneplain appears to be unglaciated, although bounded to the north and south by fiords. However, Lake Fraser was apparently excavated by ice which breached the coastal range, and a glacier probably extended down the Newton River valley almost to the coast, leaving boulders now exposed in the river bed, and cemented moraine exposed on the valley side below our base camp. Ice also flowed northwards from Lake Fraser to the unnamed "Peneplain" River.

In their middle reaches, "Peneplain" River and Newton River flow parallel and less than 1 km apart, the latter reaching the sea at Newton Inlet. As the valley floors lie within 30 m of sea level, gradients are such that the eastern higher land between them has been dissected into ridges and gullies. The country south of Newton River slopes gently back to the foot of the coastal range, unbroken except for dendritic streams which deepen into narrow gorges towards their mouths. North of "Peneplain" River, dendritic drainage patterns are modified by linear structural features, possibly faults.

The seaward slopes of the coastal range rise gently, continuing the peneplain to its crest at about 750 m (Fig. 6). The slopes falling inland or down to Lake Fraser have been glacially oversteepened, but cirques are present only on Mt Bradshaw, which rises to 970 m.

Climate

The nearest climate station that measures both rainfall and temperature is at the head of Milford Sound, 176 km to the north-east. Deep Cove, 74 km to the north-east, and Puysegur Point, 27 km to the

Fig. 6—Summit area at 500–600 m, north of Lake Fraser.

south-east, measure rainfall only. Available data for rainfall (Meteorological Office 1960–6 and 1967–9) and temperature (Official Year Book 1972) are:

	Mean annual rainfall to 1969 (mm)	Mean annual rain days to 1960	1961–9	Mean temperatures Annual	January daily max.	July daily min.
Milford Sound	6434	194	207	10.1°c	18°c	2°c
Deep Cove	5740					
Puysegur Point	1819	252	255			

Puysegur Point is on the outer coast in a region where the high mountains lie well inland as at West Cape, whereas Milford Sound and Deep Cove are at the heads of deep fiords. Undoubtedly, Puysegur Point provides by far the best guide to the climate of West Cape. It is probably significant ecologically that though the rainfall is less than a third of that at the fiord stations, the number of rain days is greater. Indeed, the only station in the New Zealand region which experiences more rain days is Campbell Island. Puysegur Point and West Cape must be characterised by low sunshine and strong persistent westerly winds, but no data are available.

Classification and Recording of Vegetation

Three broad site and vegetation classes were recognised on Secretary Island, which is 80 km further north on the Fiordland coast (Wardle *et al.* 1970). Class A sites occur on unconsolidated, unweathered substrata such as talus and recent alluvium. Class B sites are on stable soils which show obvious weathering and profile development with free to slightly impeded drainage, and at low altitudes carry the tallest, most complex forest. Class C sites have shallow, infertile soils, usually with impeded drainage, and are associated with stunted vegetation.

In the West Cape district, the same three classes are present, but in quite different proportions. Typical Class A vegetation is extensive only on very steep slopes around Lake Fraser. Tall Class B forest clothes the floor and lower slopes of the deeper valleys (Fig. 7), tending to develop Class A characteristics in steep gullies and on the youngest alluvial flats along the Newton and "Peneplain" Rivers. It also extends on to the upper slopes and ridges on the eastern, dissected part of the peneplain between these rivers, and occupies less exposed parts of the 30 m marine bench. Class C vegetation is the most extensive and includes a gradation from low forest to tussock grassland and bog. It occupies nearly the whole of the peneplain and the western slopes of the coastal range, and descends some distance down the upper slopes of the valleys.

Gradations are also present between Class B tall forest and Class C low forest. Indeed, the entire range from Class B forest to grassland may span only about 100 m where there is a significant change in

FIG. 7—Class B forest on the north side of the valley of "Gorge" Creek, and Class C tall scrub on the south side.

slope. To illustrate this gradation, vegetation profiles of a strip 2 m wide were sketched along two representative transects. Particular stages in the sequence were sampled quantitatively in ten quadrats placed along selected lines in each. The steepness of the gradient made any less subjective placing impracticable. Quadrat size was varied for different height classes as follows:

Height class (m)	Quadrat size (m)	Value recorded	Vegetation type: Tall forest (B)	Low forest (C)	Tall scrub	Low scrub	Scrub grassland	Grassland
0–0.3	1 × 1	% cover	+	+	+	+	+	+
0.3–0.6	1 × 1	% cover	+	+	+	+	+	+
0.6–4.0	4 × 4	% cover	+	+	+	+	+	+
>4.0	10 × 10	% canopy cover, density, basal area	+	+	—	—	—	—

Smaller quadrats were nested within the larger ones, which were spaced at intervals equal to the dimension of the largest quadrat used in the particular stand.

Tables 1 and 2 show the distribution of the species among the communities with percentage cover values from the six quadrats. Fig. 8 gives vegetation profiles associated with changes of slope on the marine bench, and Fig. 9 presents several quantitative values, recorded for the more important species, from six stands.

TABLE 1—Distribution of species among communities; table arranged to emphasise the floristic gradient from Classes A–C on lowland sites. For the six sampled stands percentage canopy cover (where applicable) precedes, and maximum percentage understorey cover follows, the stroke (/).

A dash (–) means <1%. Otherwise the code is:— * Dominant or co-dominant in tier.
+ Present in most stands
○ Occasionally present
s Only seedlings present
e Epiphyte

	Tall forest A	Transition	Transition	Tall forest B	Transition	Low forest C	Tall scrub C	Low scrub C	Low scrub-grassland	Grassland C	Bog	Upland grassland & scrub	Coastal scrub & rock
A. VASCULAR PLANTS													
Fuchsia excorticata	+			/–									
Coprosma wallii	○												
C. astonii	○												
Rubus cissoides		+											
Carpodetus serratus		+											
Coprosma rhamnoides			+										
Ripogonum scandens	+	•	+	/–									
Cyathea smithii	+	+		/–									
Asplenium bulbiferum	+	+		/–									
Microlaena avenacea	+	•		/–									
Schefflera digitata	+		+	/–									
Pseudowintera colorata	+	+	+	/–									
Myrsine australis	+	•		/–									
Blechnum capense	+			/–									
Metrosideros diffusa		+	+	/–									
Blechnum discolor		•	+	/1									
Metrosideros fulgens		+	•	/1									
Rumohra adiantiformis		+	+	/4									
Ascarina lucida		s	+	/–									
Hymenophyllum dilatatum			e	e									
H. demissum			+	/–									
H. sanguinolentum			+	/–									

Phymatodes diversifolium			+	/–					
Rubus australis			+	○	○				
Dicksonia squarrosa			•	/2					
Nertera cf. *dichondraefolia*			+	/1					
Podocarpus ferrugineus		s	○	28/3	s	/–			
Myrsine divaricata		•	+	/–		/–			
Asplenium flaccidum			e	e		e			+
Nertera depressa			•	/1		/–			
Nothofagus menziesii			•	–/–	?	–/–			
Rumohra hispida				/–					
Uncinia spp.				/–					
Pseudopanax crassifolius		s	+	/–		/–			
Elaeocarpus hookerianus				/–		–/–			
Trichomanes strictum				/–		/–			
Archeria traversii				/–		/–			
Earina mucronata					e				
Coprosma foetidissima		+	•	/1	+	/3	/–		
Dacrydium cupressinum		s	+	13/–	+	22/–	3/–		
Griselinia littoralis			e	/–		/–			
Pseudopanax simplex			+	/–		–/–	–/–		
Lycopodium varium				/–	+	/–	/–		
Astelia nervosa				/–		/–	/–		
Earina autumnalis			e	e	e	e	e		
Dendrobium cunninghamii			e	e		e	e		+
Pittosporum colensoi				/–					
Hymenophyllum scabrum				e					
Hymenophyllum lyallii				e					
Coprosma lucida				/–					+
Libertia pulchella				/–		/–		○	
Hymenophyllum flabellatum				e	?	e			
Blechnum fluviatile				/–	?	/–			
Dracophyllum menziesii					•	/8			
Pseudopanax colensoi vars *ternatus* & *fiordensis*	+	•	+	/–		/–	/–		+
Blechnum cf. *minus*		•	•	/7	+	/–	/–	•	
Trichomanes reniforme		+	•	/11	+	/2	/–		
Coprosma colensoi		+	+	/–	+	/–	/–		
Podocarpus hallii			+	26/–	•	9/3	/–		

	Tall forest A	Transition	Transition	Tall forest B	Transition	Low forest C	Tall scrub C	Low scrub C	Low scrub-grassland	Grassland C	Bog	Upland grassland & scrub	Coastal scrub & rock
Neomyrtus pedunculata			+	/7	•	/12	/–						
Luzuriaga parviflora				/–	+	/–	/–						
Hymenophyllum bivalve				/–	?	/–	/–						
Corybas sp. *(oblongus?)*				/–		/–	/–						
Pseudopanax linearis						s							
Blechnum vulcanicum						/–							
Hymenophyllum multifidum						/–	/–					•	•
Phormium cookianum						/–	/–						
Pittosporum rigidum						/–	/–						○
Bulbophyllum pygmaeum						e	e						
Tmesipteris tannensis	+			/–	+	/–		○					
Grammitis billardieri	e		e	/–		/–	/–	/–					
Weinmannia racemosa	•		•	14/1	•	14/2	–/–	/–					
Grammitis heterophylla				e	?	e	e	/–					
Metrosideros umbellata	+		+	9/–	•	8/–	1/–	–/–	/–	/–	○	+	
Pimelea gnidia						/–		/–				○	
Cyathodes juniperina				○	+	/4	1/4	–/–	–/–			○	
Nothofagus solandri var. *cliffortioides*				–/–	•	8/1	22/2	11/1	○			•	
Dacrydium biforme				s	•	14/–	9/–	–/–	5/–	–/–		•	
D. intermedium					+	5/4	32/15	14/1	13/7	1/1	+		
Gahnia procera						/–	/–	–/–	1/–	–/–		+	
Pterostylis graminea						/–	/–	/–	/–	○			
Leptospermum scoparium						–/–	19/5	47/6	37/25	–/6	+	•	
Dracophyllum longifolium						–/–	4/2	3/–	3/2	1/1	+	+	•
Thelymitra venosa						○	/–	/–	/–	/–			
Drymoanthus adversus							e						
Aporostylis bifolia							/–	/–	/–	/–		○	
Pentachondra pumila							/–	/–	/–	/–		⊥	
Prasophyllum colensoi							/–	/–	/–	/–		○	

Gleichenia circinata			/5	/9	1/5	5/10	+	
Lycopodium ramulosum			/1	/33	/12	/13	+	+
Calorophus minor			/–	/–	/–	–/5	+	
Cyathodes empetrifolia			/–	/–	/–	/–		○
Gentiana cf. *montana*				/–	/–	/–	+	○
Astelia linearis var. *novae-zelandiae*				/–	/–	/–		+
Oreobolus strictus				/1	/–	/–		+
Chionochloa acicularis				8/7	14/18	56/53	+	•
Sprengelia incarnata				–/–	–/–	–/–	+	
Schoenus pauciflorus				/–	/–	–/–		○
Drosera spathulata				/–	/–	/–	○	○
Lepidosperma australe					–/–	–/–	+	
Schizaea fistulosa					/–	/–		○
Carpha alpina					/–	–/–		•
Oreobolus impar					/–	/–		+
Bulbinella sp.					/–	/–		+
Oreostylidium subulatum						/–	○	
Hemiphues suffocata						/–	○	
Centrolepis ciliata						/–	+	
Liparophyllum gunnii						/–	○	
Oreobolus pectinatus						/–	○	+
Donatia novae-zelandiae							+	•
Scirpus aucklandicus							○	
Gentiana lineata							○	○
Baumea tenax							○	
B. BRYOPHYTES								
Dicranoloma sp.		•	/9	/–	/–	/4		
Rhacomitrium lanuginosum						/–		•
Other bryophytes	/45	/37	/44	/11	/–	/–		

TABLE 2—Species not listed in Table 1; those dominant in their community or tier are marked with an asterisk.

FURTHER SPECIES OF UPLAND GRASSLAND AND SCRUB:

Lycopodium fastigiatum, Drosera stenopetala, Gaultheria depressa, Dracophyllum politum, D. pearsonii (= politum × longifolium?), D. rosmarinifolium, Myrsine nummularia, Coprosma crenulata, Celmisia holosericea, Olearia colensoi*, Forstera sedifolia, Euphrasia dyeri, Gaimardia setacea, Lyperanthus antarcticus, Chionochloa crassiuscula, Deyeuxia aucklandica, Microlaena thomsonii*, Uncinia viridis.*

FURTHER COASTAL SPECIES:

Hymenophyllum minimum, Histiopteris incisa, Asplenium obtusatum, Blechnum fluviatile, B.* cf. *durum, Colobanthus apetalus, Rumex neglectus, Epilobium komarovianum, Coriaria arborea, Anisotome lyallii*, Gaultheria rupestris, Olearia oporina*, O. arborescens, Senecio reinoldii, Cotula squalida* subsp. *mediana, Pratia angulata, Ourisia crosbyi, Hebe elliptica*, Parahebe catarractae, Thelymitra longifolia, Poa astonii*, P. breviglumis, Notodanthonia* cf. *setifolia*, Chionochloa conspicua, Scirpus practextatus, Carex pleiostachys*, Uncinia angustifolia;* also *Stellaria parviflora* (not collected).

SERAL SPECIES ON INLAND SLIPS OR LAKE-SHORE GRAVEL:

Lycopodium volubile, Blechnum* cf. *procerum*, Pseudopanax anomalus, Coprosma antipoda; Cortaderia richardii* (not collected).

NEWTON RIVER: MUD ON BANK OR SUBMERGED:

Hypnodendron marginatum (aquatic form), *Isoetes alpinus, Ranunculus rivularis, Elatine gratioloides, Myriophyllum* (sp. possibly *propinquum*), *Schizeilema nitens, Lilaeopsis* sp., *Glossostigma elatinoides, Potamogeton suboblongus, Scirpus habrus;* also *Pratia angulata* (not collected).

DESCRIPTION OF PLANT COMMUNITIES

CLASS A

On steep forested slopes, spurs with a degree of instability lack beeches and podocarps, and *Weinmannia racemosa* dominates. In intervening gullies, most of the canopy is formed by small trees such as *Myrsine australis, Pseudopanax colensoi, Pseudowintera colorata,* and *Fuchsia excorticata.* The tree fern *Cyathea smithii* is common, and there are thickets of *Ripogonum scandens. Asplenium bulbiferum* would have been abundant in the past, but has been nearly eliminated by deer.

Slopes overlooking Lake Fraser which are too steep and unstable for forest support dense *Blechnum procerum* in the steepest places, and *Lycopodium volubile* elsewhere. Associated species include *Cortaderia richardii, Ascarina lucida,* and *Leptospermum scoparium.*

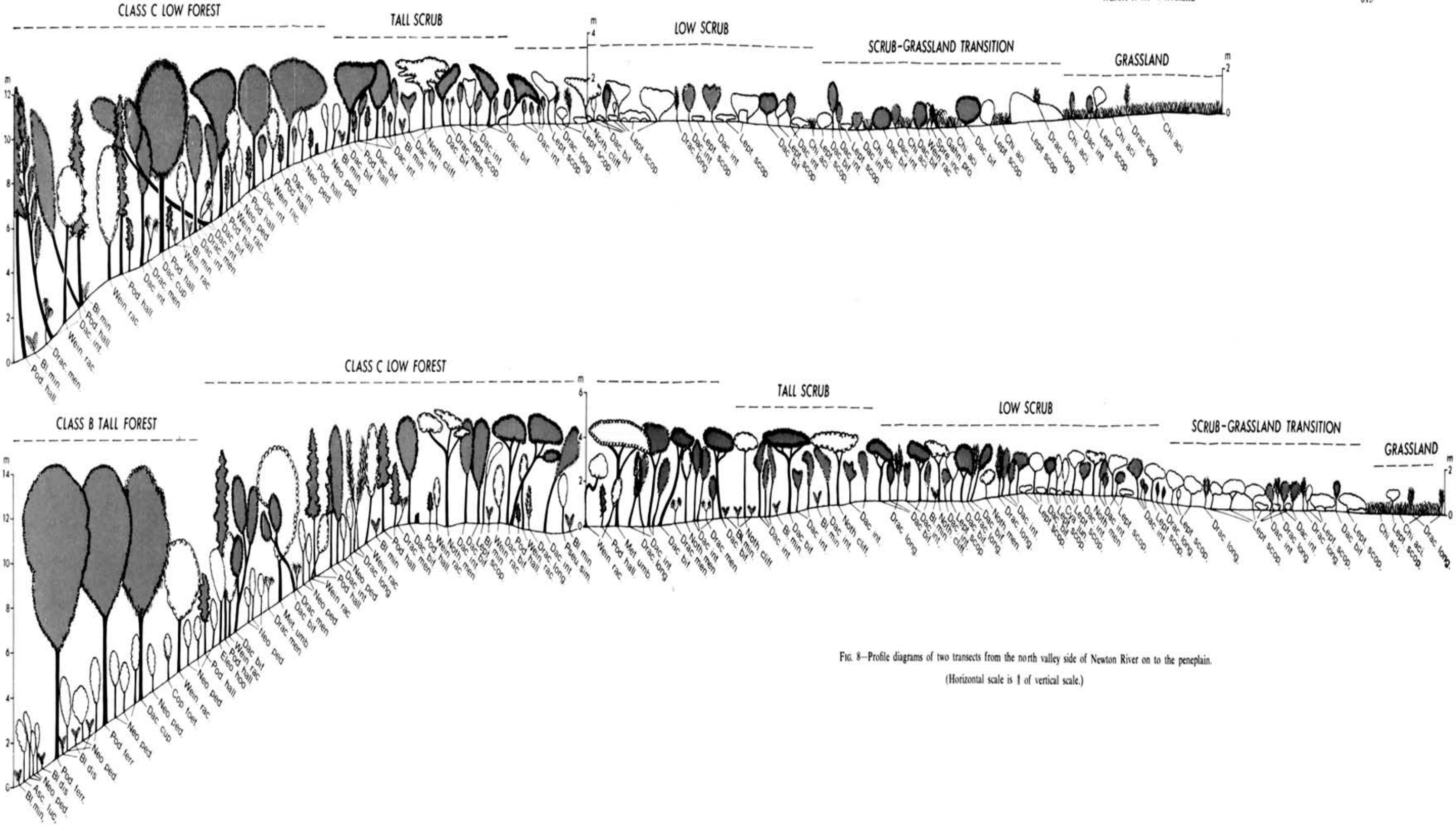

FIG. 8—Profile diagrams of two transects from the north valley side of Newton River on to the peneplain. (Horizontal scale is ⅓ of vertical scale.)

CLASS B

Weinmannia racemosa can be the commonest tree in the canopy of forest on Class B sites, but *Dacrydium cupressinum, Podocarpus hallii, P. ferrugineus,* and *Metrosideros umbellata* are invariably present, and each may contribute more basal area to the stand than does *Weinmannia.* Inland, both *Nothofagus menziesii* and *N. solandri* are usually important, but towards the coast *N. menziesii* is almost confined to the flats bordering the Newton and "Peneplain" Rivers; both species are absent from "Gorge" Creek, only podocarps and broad-leaved hardwoods contributing to its Class B forest.

Pseudopanax simplex is the most frequent small tree, but the very browse-susceptible *P. colensoi* was probably as important before the spread of deer. *P. crassifolius* also is usually present. *Neomyrtus pedunculata* is the main shrub, but *Coprosma foetidissima* is always present, and probably also has been much reduced by browsing. Other common shrubs are *Coprosma colensoi, Dracophyllum menziesii* (on steep slopes adjacent to Class C vegetation), *Pseudowintera colorata,* and *Dicksonia squarrosa* (the last two mainly on flat terraces somewhat transitional between Classes A and B).

The main fern is *Blechnum* cf. *minus,* but *B. discolor* usually also occurs. *Trichomanes reniforme* covers roots, logs, and bases of trees, and usually there are patches of *Nertera depressa* and *N.* sp. cf. *dichondraefolia* on the ground.

CLASS C

The best-developed stands, on sites transitional to Class B forest, have their main canopy at about 14 m. Heights decrease as the habitat becomes less favourable. Where the shrub canopy is lowered to about 1.5 m, gaps appear and grassland species, including *Chionochloa acicularis,* enter and may dominate. There is also a decrease in number of species, 68 vascular species being listed from Class B forest, 49 from Class C forest, and 31 from grassland.

The forest on the Class C sites is characterised by large bushes and low trees of *Dacrydium biforme.* This dominates wet depressions, but elsewhere it shares the canopy with various proportions of *Dacrydium intermedium, Podocarpus hallii, Metrosideros umbellata, Weinmannia racemosa* (only as slender plants), and *Nothofagus solandri. Dacrydium cupressinum* is always present and usually conspicuous, but, except in the tallest stands, it does not project above the general canopy (Fig. 10). The shrub layer consists of regeneration of these species, together with *Dracophyllum menziesii, D. longifolium, Cyathodes juniperina, Neomyrtus pedunculata,* and occasional *Leptospermum scoparium.* Tall herbs are sparsely present; *Blechnum* cf. *minus* is still the commonest species, and *Gahnia procera* is of some importance. There is usually a hummocky moss layer, mainly of *Dicranoloma.* This kind of forest is best developed on the upper slopes of

the valleys and the adjacent peneplain margins. Pockets also occur on terraces in the Newton River valley about 0.8 km below Lake Fraser.

In tall scrub (2–5 m), dominance is usually shared between *Dacrydium biforme*, *D. intermedium*, and *Nothofagus solandri*, the first-named tending to be taller and of greater girth. *Leptospermum scoparium* and *Dracophyllum longifolium* also reach the canopy. The shrub layer consists mainly of layering juvenile shoots of these two dacrydiums and of *Leptospermum*. Tall herbs are again sparse; usually *Gleichenia circinata* is the main species. Moss hummocks occur, but usually most of the floor is covered with litter.

In low scrub, where the canopy is at 0.5–2 m, *Leptospermum scoparium* either dominates, or shares dominance with *Dacrydium intermedium* and to a less extent with *D. biforme* and very stunted plants of *Nothofagus solandri*. Occasional equally stunted plants of *Weinmannia racemosa* and *Metrosideros umbellata* also occur. The ground cover beneath the shrubs includes layering *Leptospermum* together with *Lycopodium ramulosum* and *Gleichenia circinata*. There are openings in which grassland species dominate. These low shrub communities are ecotonal, and in some instances there is evidence of shifting community margins (see p. 623).

The densest stands of almost purely herbaceous vegetation occur on saturated, peaty, silt loam in flat depressions. Here *Chionochloa acicularis*, *Calorophus minor*, and *Gleichenia circinata* form a dense cover, with scattered stunted shrubs of *Dacrydium intermedium* and *Leptospermum scoparium* only 2–15 cm high, and taller (to 30 cm) ones of the spindly *Sprengelia incarnata*. Wherever drainage improves, the proportion of *Chionochloa* tussocks to other tall herbs increases, and also the proportion and height of shrubs increase, the main

FIG. 10—Transition from Class C forest with stunted trees of *Dacrydium cupressinum* to *Chionochloa acicularis* grassland in foreground.

species still being *Dacrydium intermedium*, *Leptospermum*, and *Sprengelia*. *Lycopodium ramulosum* is the most important sub-canopy species throughout the grassland and mixed grassland-low scrub. Locally, *Hemiphues suffocata* is common.

In very wet hollows in the grassland the *Chionochloa* tussocks tend to yield dominance to *Calorophus minor* or *Lepidosperma australe*, and cushions of *Centrolepis ciliata* border pools. On extremely wet and infertile sites, *Donatia novae-zelandiae* appears, and rarely also *Liparophyllum gunnii*, *Gentiana lineata*, and *Oreobolus pectinatus*.

Upland vegetation

The forested, glacially over-steepened slopes overlooking the lake give way at about 350 m to broad spurs and basins sloping seawards, which are evidently non-glaciated and support a mosaic of low forest, scrub, and grassland similar to that on the coastal plateaux. Below 500 m low forest predominates on the broad spurs. Much of the cover consists of *Nothofagus solandri* and *Dacrydium biforme*, but other important species are *D. intermedium*, stunted *Weinmannia racemosa* (below 450 m), *Leptospermum scoparium*, and *Olearia colensoi* (mainly above 450 m). Above 500 m grassland predominates, low forest and scrub being confined to sites sheltered from westerly wind (*see* Fig. 6). Typically, these sites are immediately below the crests of ridges. The maximum altitude of tree limit was not determined.

Grassland examined at 520 m is dominated by *Chionochloa acicularis*, with variable proportions of stunted shrubs, mainly *Leptospermum* and *Dacrydium biforme*. *Carpha alpina* and *Lycopodium ramulosum* are the main low-growing species. On wet ground there are patches of cushion bog dominated by *Dracophyllum pronum*, *Donatia*, and *Rhacomitrium*. Where the 15–20 cm of sandy silt loam forming the topsoil has been eroded (probably by wind) to expose the underlying stones and boulders, the erosion pavement is colonised mainly by *Donatia* and *Microlaena thomsonii*. Scrub patches are dominated by *Leptospermum* and *Olearia colensoi*, with less *Nothofagus solandri* and *Dacrydium biforme*, but the two last-named rise to dominance where shelter permits low forest. *Sprengelia incarnata* is absent at this altitude.

Coastal vegetation

Towards the seaward edge of the 30 m marine bench, the effect of exposure on the forest is first shown by *Nothofagus solandri* dropping out and *Dacrydium cupressinum* and *Podocarpus ferrugineus* developing low, broad crowns. The canopy is reduced to a height of 6–10 m, and the coastal species *Dracophyllum longifolium*, *Olearia oporina*, *Senecio reinoldii*, *Hebe elliptica*, and *Phormium cookianum* appear in the understorey. On cliff tops and headlands, the forest is

FIG. 11—Tall scrub on the 30 m marine bench, with *Dracophyllum longifolium* and dead *Olearia oporina* in the upper storey, and regenerating *Olearia* in the lower.

replaced by dense scrub of *Olearia oporina* and *Dracophyllum longifolium*. There are scattered large clumps of *Phormium cookianum*. Stunted representatives of forest trees, especially *Metrosideros umbellata* and *Myrsine australis*, occur in sheltered niches. The floor, which has been much modified by deer, is carpeted by a succulent form of *Nertera depressa*, and banks are clothed with *Blechnum capense*. Thriving plants of the *Olearia* tend to form thickets about 1 m tall, whereas at about 4 m there are the remains of a former canopy, now consisting of living *Dracophyllum* and dead *Olearia* (Fig.11). This situation recalls the death of stands of the related *O. colensoi* in the Tararua Range and elsewhere (Wardle *et al.* 1971).

The scrub of *Dracophyllum longifolium* and *Olearia oporina* also drapes the upper parts of the granite cliffs, and descends to the shore wherever there is shelter. The *Dracophyllum* shrubs are about 4 m long, but grow almost horizontally from the cliff, and the *Olearia* forms an understorey. Other species are *Senecio reinoldii*, *Pseudopanax colensoi* var. *ternatus*, *Hebe elliptica*, *Blechnum banksii*, and *Asplenium obtusatum*. These communities are unstable, and apt to slip on to the gravel or boulder beach. There is an apparently rapid succession in which encrustations of bryophytes spread from crevices and build up peaty humus. Both bare crevices and the moss and peat are then colonised by seedlings of the shrubs and herbs mentioned above. Other pioneer species are *Nertera depressa* and *Anisotome lyallii*.

More exposed rock shows a gradation towards the bareness of the supralittoral zone. *Phormium cookianum* tends to dominate the last continuous vegetation, and is accompanied by shrubs of *Dracophyllum longifolium, Hebe elliptica, Olearia oporina,* and some stunted plants of *Metrosideros umbellata* and *Griselinia littoralis. Anisotome lyallii, Poa astonii,* and *Notodanthonia* cf. *setifolia* are the main plants of the most exposed sites.

In places, the coastal cliffs are interrupted by talus. The climax vegetation here is *Dracophyllum/Olearia* scrub, but, perhaps under the influence of deer, the succession is dominated by *Histiopteris incisa.* Below these slopes there are tussocky areas dominated by *Carex pleiostachys.*

On the steep, bouldery, but more sheltered slope near the head of Newton Inlet, typical coastal scrub forms only a fringe to low-canopied forest, dominated by *Weinmannia, Senecio reinoldii,* and *Metrosideros umbellata.*

Soil and Peat

Soil development in the West Cape area is characterised by accumulation of blanket peat and by podzolisation leading to impeded drainage. The blanket peat is best developed under scrub and forest on the 30 m marine bench, where it is about 1 m thick, and on Class B sites inland, where it covers forested slopes of up to 40°. It covers nearly flat ground around the shore of Lake Fraser, yet is absent on alluvial terraces carrying mature forest 400 m inland from the mouth of the Newton River (see p. 621).

On Class C sites, peat occurs to depths of over 1 m under both forest and scrub, but its distribution is discontinuous. In other stands of forest and scrub and in grassland generally, the organic layer is thin, and the A horizon consists mainly of very wet, humic, sandy silt loam. On the granite knolls dotting the peneplain north of "Peneplain" River caps of peat tend to extend from the summits down to the leeward (south-easterly) slopes, coinciding approximately with the occurrence of scrub patches in the grassland.

Wright & Miller (1952) also noted the strong tendency for blanket peats to occur under forest in south-west Fiordland. This contrasts with the general absence of peat on Secretary Island, or of ombrogenous peat generally in Westland, but invites comparison with the Pegasus district of Stewart Island, the subantarctic islands, and the Chatham Islands, where blanket peat is extensive. The differences between these localities in lithology and latitude (and, by inference, temperature) are far greater than the corresponding differences between West Cape and Secretary Island, but common features may be comparatively low relief, numerous rain days (p. 606), and exposure to strong salt-laden winds. Wright (1959) cites field evidence from the Chathams that salt blown inland causes slow break-down of forest litter and accumulation of blanket peat. Gorham (1953) ascribes the

high base status of Irish blanket peats to salt spray. The difference in occurrence of peat between Secretary Island and the West Cape area certainly fits this explanation. Whereas the bold coastline in the more northern parts of Fiordland would tend to hold a cushion of calm air against westerly storms, as is well known for Westland, the gently sloping coastal plateau behind West Cape is exposed to the full sweep of storms. Significantly, the only blanket peat seen on Secretary Island was on exposed rocks and headlands along the shoreline of Doubtful Sound (Wardle *et al.* 1970).

Under tall forest on the 30 m marine bench, peat has formed mainly from tree litter. Recognisable leaf remains and apparently sound seeds of *Podocarpus ferrugineus* occur to a depth of 4 cm; the last seed fragments to decay are still recognisable down to 6 cm. On forested Class C sites, moss hummocks contribute a large proportion of the humus, moss remains being sometimes recognisable at depths over 20 cm. The rate of accumulation of peat is not known, but it is certainly rapid on the coastal cliffs. Here, scrub and the blanket peat supporting it are apt to slide off, exposing the granite. During re-establishment of vegetation, bryophytes and filamentous algae have built up to 15 cm of peat on surfaces where shrubs have reached only seedling size.

Early stages of podzolisation occur on the forested alluvial terraces mentioned previously, near the mouth of the Newton River. The following soil profile was described on a terrace 2 m above river level where the forest is dominated mainly by *Nothofagus menziesii* in the upper part of the canopy, and *Weinmannia racemosa* in the lower part:

0– 3 cm	litter and transition,
3– 13 cm	greyish-brown sandy loam; dark grey mottles; soft; crumb structure; bleached quartz grains present; many roots; fairly sharp boundary,
13– 23 cm	variegated greyish-brown and reddish-brown sandy loam; very slightly cemented; crumb structure; quartz grains with brown surface staining; reddish-brown colours in matrix and staining of quartz grains increases with depth; sharp boundary,
23– 33 cm	light grey silty sand; reddish-brown mottles; water-rounded granite pebbles,
33–>45 cm	yellowish-brown sand; grey mottles; water-rounded stones.

The second terrace is 7 m above the river, and carries forest dominated by podocarps and *Weinmannia*, beeches being absent. The soil is:

0 – 1 cm	litter and transition,
1 – 30 cm	dark brown silt loam; fine crumb structure; small bleached quartz grains in upper part; slightly lighter colour and more compact with increasing depth; fairly sharp boundary,
30 – 50 cm	variegated grey and light grey sandy loam; weak crumb structure; occasional rounded pebbles; darker patches tend to follow old root channels; sharp boundary,
50 – 68 cm	reddish-brown fine sandy loam; moderately cemented,
68 – 68.5 cm	reddish-black (above), reddish-brown (below) hard pan; sharp transition,
68.5–>80 cm	yellowish-brown sand; weakly cemented.

On the 30 m marine bench the blanket peat, which is silty towards its base, is underlain by 8 cm of light grey sand, mainly of quartz fragments. Below this is a black hard pan, 4 cm thick, formed in the top layer of underlying beach gravels. On steep Class B sites with blanket peat, the effects of podzolisation are still present, but the upper mineral horizon shows mixing of humus, grey-brown and yellow-brown silt loam, and weathering fragments of rock. The depth of this zone is at least 30 cm, in contrast to steep Class C sites, where less than 10 cm of mineral soil intervenes between peat and solid rock.

The following four profiles were described from the peneplain at 100 m a.s.l.

(a) Flat area with dense growth of *Chionochloa acicularis, Calorophus minor,* and *Gleichenia circinata.* Shrubs sparse and very stunted. Soil saturated to surface. Thin litter carrying a pale, gelatinous, algal gloea.

0– 50 cm	very dark greyish-brown humic silt loam; bleached quartz grains increasing with depth to give sandy texture below 45 cm,
50– 60 cm	brownish-grey sandy loam; bleached quartz grains,
60– 63 cm	light grey sand between predominant boulders; occasional water-rounded pebbles,
63– 66 cm	dark brown sand, slightly cemented between predominant boulders; some roots present,
66–>74 cm	dark reddish-brown sand, not cemented between predominant boulders.

(b) Gently rolling area, with *Chionochloa acicularis* dominant, and shrubs to 1–1.8 m tall. Litter nearly absent.

0 – 15 cm	greyish-brown silt loam; sparse quartz grains; roots present,
15 – 23 cm	greyish-brown gravelly coarse sand; mainly strongly bleached quartz grains to 5 mm diameter; other weathered granite minerals present; sharp boundary,
23 – 24.5 cm	reddish-brown, moderately cemented, iron-humus pan with red coloration stronger below,
24.5–>45 cm	brownish-yellow sand; quartz grains with surface staining predominant; unweathered rounded pebbles present. There are occasional boulders, some of which project above the surface of the ground.

(c) Gently rolling area near the edge of the peneplain above Newton River. Low forest with upper canopy at 5 m mainly *Dacrydium biforme* and lower canopy mainly *D. intermedium.* Surface mainly *Dacrydium* litter, but more than 5% covered by bryophyte hummocks.

0– 45 cm	reddish-brown peat; bark fragments recognisable down to 8 cm; silt content increases with depth; gradual transition,
45– 70 cm	greyish-brown humic silt loam with red tinge; plastic; structureless,
>70 cm	sand and weathered stones.

(d) Flat drainage hollow, dominated by *Dacrydium biforme* to 8 m tall. Floor nearly covered by hummocks of bryophyte including *Sphagnum.* These are up to 23 cm thick and contain decaying moss grading into fibrous, reddish-brown peat. The following profile was described between hummocks:

0– 28 cm dark greyish-brown silt loam; small quartz grains; roots throughout,
28– 60 cm gravelly coarse sand of quartz grains to 5 mm diameter; occasional rounded granite pebbles at depth; some roots present; horizon saturated,
>60 cm weathered granite, not clear whether basement granite or boulders.

Within Class C, vegetation is clearly related to site. Herbaceous vegetation occurs where the upper horizon of humic silt loam is less than 12–20 cm deep, as in profile (b), or is deeper but completely waterlogged, as in profile (a). Any improvement in conditions, such as occurs where the humic silt loam of the A horizon is thicker or the slope steeper, favours dominance by shrubs or, with further improvement, by trees. Some drainage channels also support woody vegetation; that these are sites where excess water is moved at depths below the main rooting horizon is suggested by profile (d), where the layer of quartz sand is thick enough to provide an aquifer. Other drainage channels are occupied by wet grassland or bog. These are waterlogged to the surface, and in at least some instances, vertical drainage is impeded by thick hard pans developed in the top of the gravels beneath the quartz sand. Exposure to north-west wind can also differentiate sharply between scrub and grassland (and between presence and absence of blanket peat), especially on knolls.

The high mineral content of the humic silt loams, and especially the bleached quartz grains occurring through them, indicate that the humus does not represent surface accumulation of plant litter. Instead, we suggest that surface accumulation is small because of low productivity of the vegetation and insolation of the soil surface. Because these soils are very wet, however, dead roots, rhizomes, and buried litter accumulate within the mineral soil as fine, structureless humus.

The mineral component of the upper horizons of the soils on the peneplain basins does not seem to be derived from the immediately underlying gravel or rock, for there is no transitional zone of weathering. Probably, it represents colluviated material derived by exfoliation from the granite knolls during the last glaciation. The accumulation of larger quartz particles as a discrete layer at the base of the humic silt loam is a curious feature.

There are signs that humus accumulation is presently inactive in the ecotones between scrub and grassland. *Chionochloa* tussocks within the scrub margins tend to stand on peaty pedestals up to 25 cm tall, and to be dying or dead. The pedestals seem to result from shrinkage of the humic silt loam between them, perhaps after drying of the soil. In other places, openings in the scrub expose peaty surfaces which support a crust of lichen and algae and which do not seem to be added to by litter or moss. Erosion of peat caps on some knolls and small rock outcrops was also noted. Possibly a slightly drier climate is indicated, but tracking by deer may also have had an effect on some sites; deer are certainly causing considerable erosion of peat beneath coastal scrub and forest.

Growth Forms

The conditions on the peneplain have evoked remarkable growth forms, especially in *Leptospermum scoparium*. The *Leptospermum* appears to be the usual form distributed throughout the South Island, which normally grows into a tall shrub. There is no evidence that the low-growing forms have any genetic distinctness, in contrast to the situation on gley podzol soils near Charleston in south-western Nelson, where the prostrate habit has proved to be inherited (Wardle, unpublished).

The wet and presumably acid and infertile conditions limit height growth in the leading shoots and cause layering and rooting of side shoots so that the plant becomes virtually rhizomatous. However, clones differ in height, e.g., from 2 cm to 1.2 m, under apparently identical conditions. The larger plants have exaggerated development of dead phloem around the thicker stems and roots beneath the soil surface (M. N. Philipson, pers. comm.). Instead of bark of the normal thickness of 1–2 mm, there is a spongy mass up to 4 cm thick. Although this tissue is so porous that it can take up to six times its weight of water, it is dry under field conditions. This suggests that because water does not enter laterally, the tissue promotes aeration of the roots, and thereby removes a factor inhibiting height growth.

Similar layering clones are characteristic of *Dacrydium intermedium* and *D. biforme*, although no thickening of outer stem tissues was found. *Weinmannia racemosa*, *Dracophyllum longifolium*, *Nothofagus solandri*, and *Metrosideros umbellata* are also subject to extreme stunting, but show relatively slight tendency to layer. *Sprengelia incarnata*, on the other hand, maintains its erect, spindly stems in the grassland, but the plants are distinguished by extraordinarily small root systems.

Stunted clones of *Leptospermum* and the two dacrydiums also form much of the undergrowth in Class C forest and tall scrub; here the lack of height growth seems due to a combination of shade and infertile soils. The contrast between erect mature shrubs and trees and the layering juveniles forming wide patches a few centimetres tall is particularly striking in *Dacrydium biforme*, where the adult and juvenile possess cupressoid and *Taxus*-like foliage respectively.

Distribution of Species

Comparison with Secretary Island (Wardle & Mark 1970) suggests that a number of forest species occurring in western Fiordland do not extend as far south as West Cape. This may reflect the shorter time that we spent at West Cape, but trees such as *Phyllocladus alpinus*, *Hedycarya arborea*, and *Hoheria glabrata* could scarcely have been overlooked. On the other hand, *Metrosideros fulgens* is quite a

FIG. 12—Forest with *Nothofagus solandri* var. *cliffortioides* trees at the head of Newton Inlet.

common liane on Class B sites near West Cape, but it was not found on Secretary Island. *Sprengelia incarnata*, as far as is known, is confined in New Zealand to coastal grass and low scrub areas between Puysegur Point and Resolution Island, but is common in Tasmania (Moore 1969). The only possible endemic taxon collected is a *Bulbinella* (OTA 32760, 32761) that keys to *B. gibbsii* var *balanifera*, although it resembles *B. modesta* in its appearance and habitats. Otherwise most of the species found in the West Cape area that were not listed for Secretary Island are fresh-water aquatics and plants of gravel beaches, which reflect the greater extent of these habitats near West Cape (Table 2).

Within the area, the distribution of the two species of *Nothofagus* is of interest. Only *N. solandri* was seen above about 300 m, on the 30 m marine bench, or on the slopes leading down to Newton Inlet (Fig. 12). Otherwise both species have the same general range, except that *N. menziesii* occurs only very sparingly on Class C sites and does not reach the coast. Neither species was seen at "Gorge" Creek and points north-west even on apparently suitable sites, although they appear before the shores of Dusky Sound are reached.

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REFERENCES

GORHAM, EVILLE 1953: A note on the acidity and base status of raised and blanket bogs. *Journal of Ecology 41:* 153–6.

HECTOR, JAMES 1863: Geological expedition to the west coast of Otago, New Zealand. *Otago Provincial Government Gazette Vol VI No 274:* 435–68.

MOORE, L. B. 1969: *Sprengelia incarnata* Sm.: an Australian plant in Fiordland. *N.Z. Journal of Botany 7:* 96–9.

NEW ZEALAND METEOROLOGICAL OFFICE 1960–66: "Meteorological Observations", Government Printer, Wellington.

NEW ZEALAND METEOROLOGICAL OFFICE 1967–69: "Rainfall Observations". Government Printer, Wellington.

NEW ZEALAND DEPARTMENT OF STATISTICS 1972: "New Zealand Official Year Book". Government Printer, Wellington. 1170 pp.

WARDLE, P.; FIELD, T. R. O.; SPAIN, A. V. 1971: Biological Flora of New Zealand 5. *Olearia colensoi* Hook. f. (Compositae) Leatherwood, tupari. *N.Z. Journal of Botany 9:* 186–214.

WARDLE, P.; MARK, A. F. 1970: Vegetation studies on Secretary Island, Fiordland Part 10: vascular plants recorded from Secretary Island. *N.Z. Journal of Botany 8:* 22–9.

WARDLE, P.; MARK, A. F.; BAYLIS, G. T. S. 1970: Vegetation studies on Secretary Island, Fiordland Part 9: additions to parts 1, 2, 4, and 6. *N.Z. Journal of Botany 8:* 3–21.

WOOD, B. L. 1960: Sheet 27—Fiord (1st ed.) "Geological Map of New Zealand 1:250,000". N.Z. Department of Scientific and Industrial Research, Wellington.

WRIGHT, A. C. S. 1959: Soils of Chatham Island (Rekohu). *N.Z. Soil Bureau, Bulletin 19:* 60 pp.

WRIGHT, A. C. S.; MILLER, R. B. 1952: Soils of south-west Fiordland. *N.Z. Soil Bureau, Bulletin (new series) 7:* 31 pp.