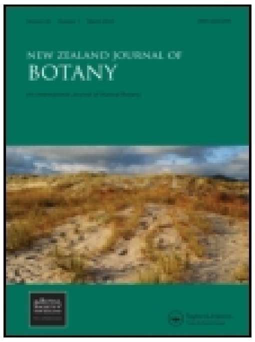

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Vegetation of the Raised Beaches at Cape Turakirae, Wellington, New Zealand

R. G. Bagnall

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R. G. BAGNALL*

Department of University Extension,
Victoria University of Wellington, Private Bag,
Wellington, New Zealand

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ABSTRACT

The vegetation pattern over remaining areas of the raised marine beaches at Cape Turakirae (southern North Island, New Zealand) is described and mapped. Also included are: a list of vascular plant species, a study of peat depths, an examination of the soils and root growth in a raised beach ridge, discussion of likely vegetation changes, and recommendations on management of the area. The vegetation pattern is shown to be determined primarily by burning and browsing which are limiting growth of shrub and forest vegetation on the older beaches. On all raised beaches the vegetation and soils of the ridges contrast strongly with those of the platforms. A chronosequence across the raised beaches is evident in the peat depths, the vegetation, and the plant species growing on each beach.

The aims of this study were: to elucidate evidence of a chronosequence in the vegetation and soils across the series of raised marine beaches; to clarify the effects of the major environmental factors on the vegetation; and to compile a record of higher plants, vegetation, and major substrate features of the area, for use in further research and against which further series could be compared. Other aims were to identify and examine factors likely to be important in future management of the scientific reserves in the area.

*This study was carried out by a Department of University Extension research group under the leadership of the author. Active members were: T. Black, T. Boyle, E. Bradford, A. B. Grant, S. E. C. Harding, N. Knuckey, R. Lucas, P. Mildenhall, L. S. O'Neill, M. H. O'Neill, M. A. Silk, A. D. Warden, and P. G. Whitmore.

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THE STUDY AREA

GENERAL

The study area (Figs 1–3), at the southern end of the Rimutaka Range approximately 17 km SE of Wellington, covers approximately 1.4 km^2 (2.4 × 0.6 km). It extends from a fenceline 1.5 km NE of Cape Turakirae (NZMS 1, Sheet N164 474049 and 480041) parallel to the coastline for 2.4 km (NZMS 1, Sheet N164 496066 and 450061). The seaward border is the upper high-tide mark and the landward (NW) border is approximately the 130-m contour on the seaward hill slopes.

Much of the study area below 30 m altitude has been purchased recently as scientific reserve by the Crown. The reserve areas (Fig. 3) total 69.53 ha, originally stated (Stevens 1969) to be 97.1 ha. The SW survey boundary is coincident with the main SW reserve boundary.

CLIMATE*

The mean annual rainfall at Baring Head (Fig. 1), 5 km to the NW and topographically similarly situated to the study area, is 942 mm (S.D. 150, range 583–1 245) over 36 years to December 1972. Monthly means over the same period are: January 65, February 66, March 66, April 67, May 98, June 93, July 103, August 90, September 71, October 75, November 62, December 85 mm.

The months in each summer season (September–April) in which rainfall was <0.5 of the monthly mean are given as follows as an indication of drought frequency, and are here termed drought months. Of a total of 38 seasons (1935–36 to 1972–73) 29 had 1 or more drought months; of these 2 had 4 drought months, 7 had only 3 drought months, 13 had only 2 drought months, and 7 had only 1 drought month. Five seasons had 3 consecutive drought months (1938–39, 1947–48, 1948–49, 1961–62, 1970–71) and 7 seasons had 2 consecutive drought months (1936–37, 1937–38, 1942–43, 1951–52, 1953–54, 1967–68, 1968–69). The occurrence of years with 2 or more consecutive drought months is thus approximately once in every 3 years. Bondy (1950) records for Kelburn a total of 42 absolute droughts† and 41 partial droughts† in 83 years.

Anemometer records were made at Baring Head from April 1944 to June 1946. Compared with concurrent recordings at Moa Point, Wellington, the two stations showed very similar characteristics, although gusts were somewhat higher at Baring Head (N. G. Robertson, New

*Data supplied by the New Zealand Meteorological Service.
†*see* Appendix 3.

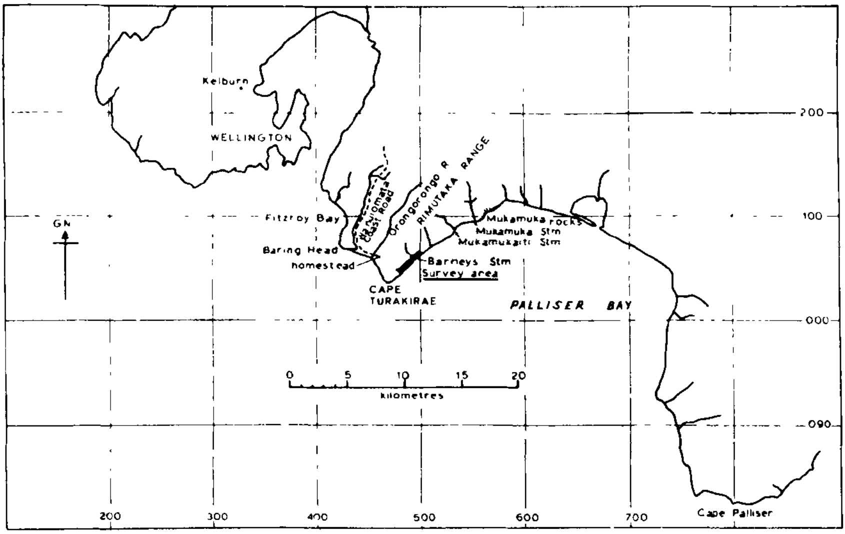


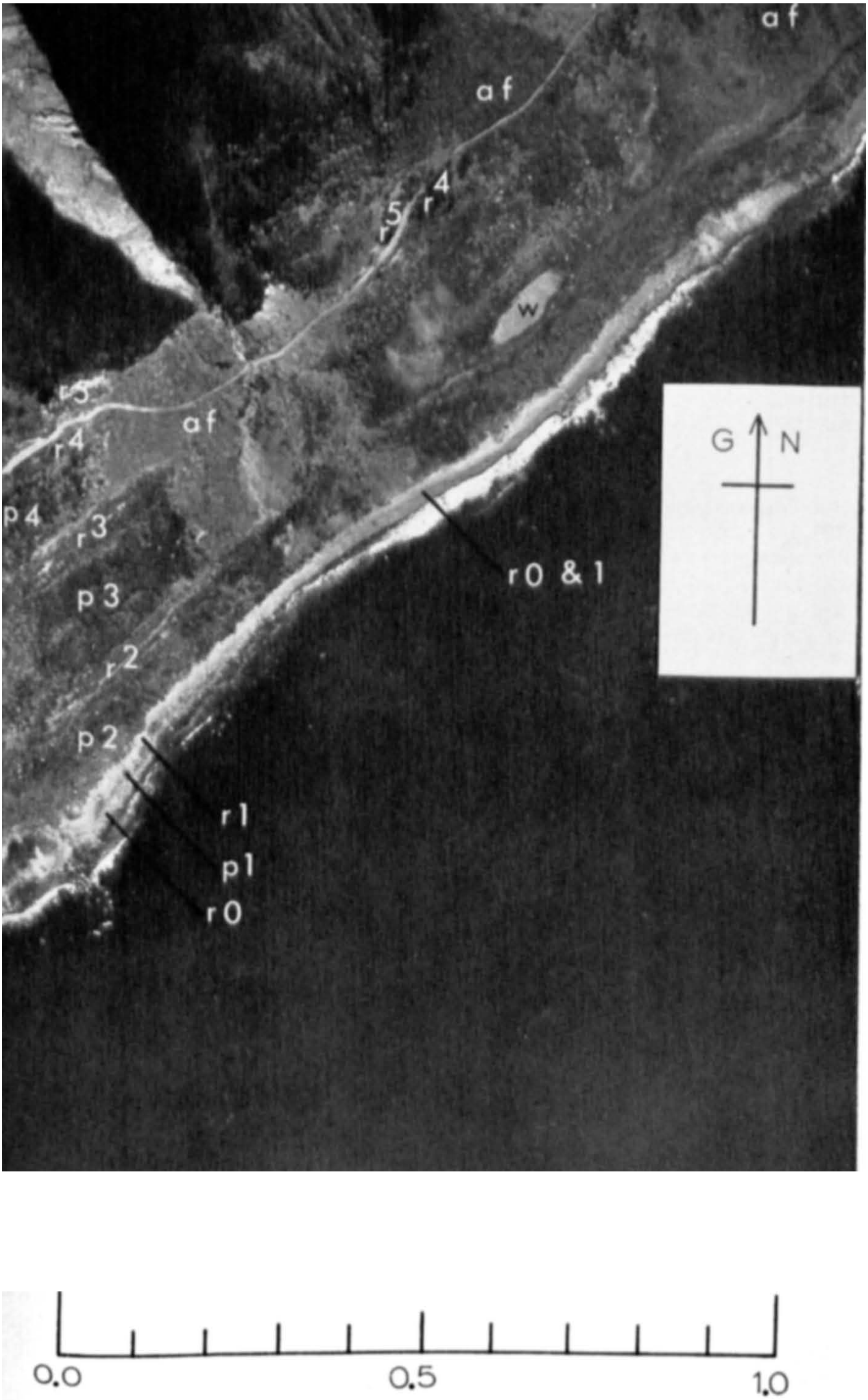
FIG. 1—Map of the general area.

Zealand Meteorological Office, pers. comm.). Wind is now recorded at Wellington Airport, where the pattern is very similar to that at Moa Point. The following are surface wind data from Wellington Airport for the daylight period (0600–1700 hr NZST) during 1953–70:
frequency % of gusts ⩾ 69 km/hr = 1.2 (0.6 N to NW; 0.6 S to SE)
frequency % of gusts ⩾ 59 km/hr = 10.0 (7.6 N to NW; 2.4 S to SE)
frequency % of gusts ⩾ 40 km/hr = 28.1 (18.7 N to NW; 9.4 S to SE)
Mean wind speed (including calms) = 30 km/hr, approximately 60% N or NW and 30% S or SE.

Important Environmental Factors

Soil moisture is potentially limiting because of frequent summer droughts. Soils over much of the platform areas are permanently saturated, whereas the beach ridges generally have rapidly draining soils in which soil moisture is likely to be frequently deficient for plant growth.

Although the area is sheltered from the direct effects of N and NW winds, very strong southerly gusts frequently move across it under these winds. Full exposure to S and SE winds severely limits plant growth on exposed hill slopes and the younger raised beaches. As the winds are largely unidirectional they allow the growth of quite salt- and wind-sensitive plants in the lee of boulders and taller vegetation. On beaches 0 and 1 and the front of platform 2, wave-washing during S or SE storms is not uncommon in winter.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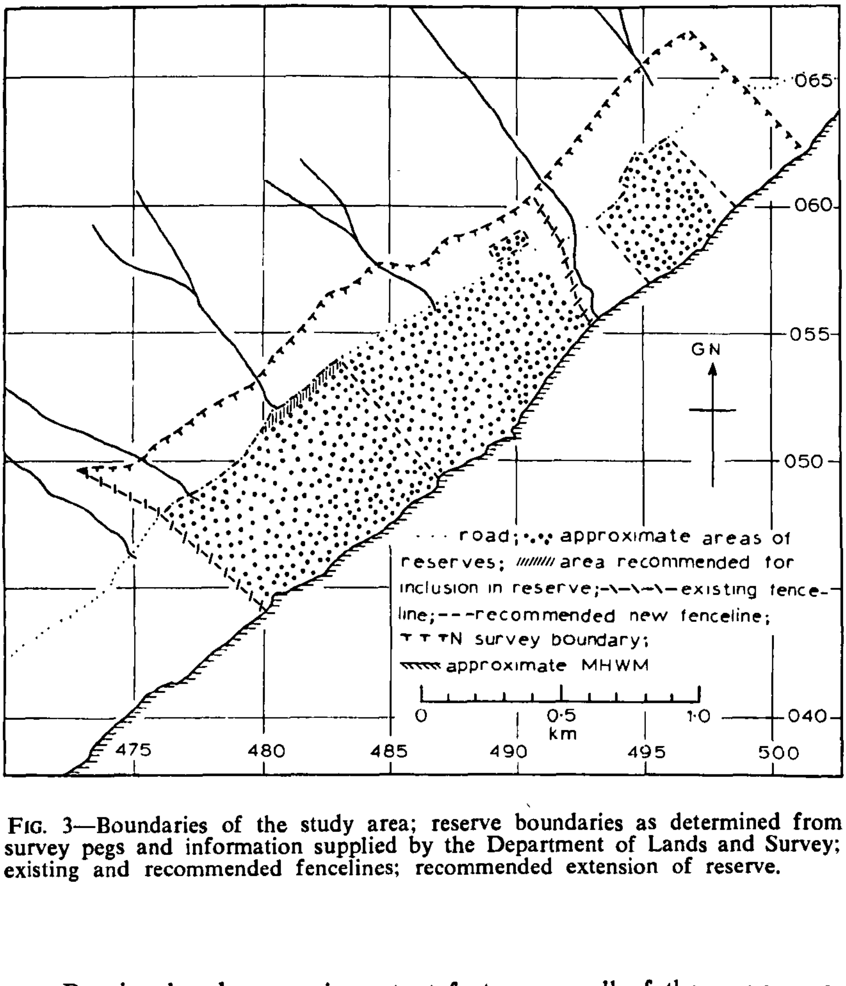

FIG. 3—Boundaries of the study area; reserve boundaries as determined from survey pegs and information supplied by the Department of Lands and Survey; existing and recommended fencelines; recommended extension of reserve.

Burning has been an important factor over all of the survey area except in the sparse vegetation on beaches 0 and 1.

Cattle and sheep have been grazed in the area since the late 1840s.

GEOLOGY

The area (Fig. 1) is situated on the west flank of the actively growing Rimutaka anticline (Wellman 1969), the crest of which is marked by the axis of the Rimutaka Range running into the sea NE of Cape Turakirae. The rocks are indurated Triassic greywacke sandstones and mudstones with small local areas of volcanic and mixed volcanic and sedimentary rocks (Stevens 1969).

Uplift of the Rimutaka anticline has occurred as a series of small sudden movements (Stevens 1969). Each uplift has raised above sea level the once actively forming marine beach and part of the adjacent lower wave-cut platform. Between each uplift a new beach ridge has formed at and above high-tide level. The platform width is dependent on the amount of initial uplift and the time between uplifts (the beach ridge growing with time). Each platform has a hard rock base with abundant overlying boulders and large emergent undercut monoliths up to about 4 m in diameter. Monoliths exist also within the beach ridges but are mostly completely buried by the gravel, stones, and boulders. The preservation of these beach sequences and the monoliths is attributed by Stevens to the very hard nature of the rock which is continuous with that forming the core of the Rimutaka Range.

The particle size of the beach ridge material has been influenced by exposure during the formation of each beach ridge. Thus the beach ridges are of gravel and small stones where there are no adjacent boulders concentrating wave action during beach formation. Where such boulders do exist the gravel is absent and only stones form the beach ridge. To the landward of large boulder complexes even the stones may be absent, leaving a ridge of boulders.

In the survey area five raised beaches are evident (Figs 2 & 7) in addition to the currently forming beach ("beach 0") and part of a higher beach ("beach 6"). Wellman (1969) has dated the approximate time and measured the vertical extent of the uplifts which have preserved each of these beaches:

"beach 1" – 2.5 m uplift, 118 years ago (1855 A.D.);
"beach 2" – 6.5 m uplift, *c.* 513 years ago (*c.* 1460 A.D.);
"beach 3" – 9.0 m uplift, *c.* 3 100 years ago;
"beach 4" – 6.0 m uplift, *c.* 4 900 years ago;
"beach 5" – 3.0 m uplift, *c.* 6 500 years ago;
"beach ridge 0" is forming about 1.0 m above mean high-water mark (M.H.W.M.).

Alluvial fans are aggrading and burying the raised beaches in places around the coast. This is occurring actively at the stream approximately 520 m NE of Barneys Stream (Fig. 7). Both of these streams have already spread alluvium across the whole series of raised beaches. Other alluvial fans in the area have now stabilised having buried only portions of beaches 4, 5, and 6. These alluvial fans and colluvium from the hill slopes have buried all of platform 6 except one area, which is not included in the reserve, at about NZMS 1, Sheet N164 480051 to 482053 (Figs 3, 7).

Bog with permanent and ephemeral pools has developed on platforms 3, 4, 5, and 6, and is developing on platforms 1 and 2. In contrast to this the beach ridges are very porous except locally where infilled with fine alluvium.

The raised beaches to the S and W of the survey area have been damaged by removal of the boulders for reclamation work in Wellington Harbour.

History

In 1846–47 Mr D. Riddiford took title to the lease on the Orongorongo Station (Anon. 1875). The present survey area was included in this station. From 1847 a vigorous programme of land clearing and development was undertaken with the early introduction of cattle. Information on the vegetation of the area before European settlement is very meagre. Bagnall (1972) notes that there is evidence of Maori occupation of the general area extending back many centuries, with more or less permanent settlements in the mid-nineteenth century at Fitzroy Bay, the Orongorongo River mouth, and the coast by the Mukamuka Stream (Fig. 1).

Travellers in the area during the nineteenth century, such as Best (Taylor 1966), Colenso (Bagnall & Petersen 1948), Weld (Lovat 1914), Carter (Carter 1866), and Government surveyors (McFadgen 1963), recorded little about the vegetation. Their records reveal that forest growth covered the hills to the NE of Barneys Stream but not to the SW where there was evidence of burning. In the only known record of vegetation on the raised beaches last century, that of Carter (1866) in 1853, vegetation apparently similar to, but taller than, that found today was mentioned.

Aston (1912) described the geology and botany of the raised beaches from the Orongorongo River to the Mukamuka Stream. There is detailed comment on Aston's work later in the present paper.

SOILS

Methods

Peat depth traverse

Tapes were laid in a straight line at right angles to the coast from about NZMS 1, Sheet N164 485048 to the edge of the road adjacent to platform 6. At each 0.3-m interval along this line the depth of the peat or peaty soil was measured using a 10-mm-diameter steel rod. Where the survey line crossed an emergent boulder the height above the surrounding peat surface was also recorded at each 0.3-m interval. The slope of the peat surface along the tape was measured using a Suunto clinometer. Except where covered by peat, no records were made on a beach ridge.

Beach ridge soils and root distribution

The soils and distribution of roots were studied in an area of beach ridge 3 at about NZMS 1, N164 471041. Soil pits were dug through the shingle to trace the root systems of the three most important shrubs growing on the beach ridges. These were: *Coprosma propinqua, Hymenanthera crassifolia,* and *Muehlenbeckia complexa.* At least four specimens of each were studied. Soil samples of about 8 kg and appropriate field data were taken from each horizon in two of the soil pits. The samples were analysed for textural composition and for organic matter content of the fine (<2.0 mm diameter) fraction by determining loss of weight on ignition. Methods used in the textural analysis followed Duchaufour (1965).

Shallow pits also were excavated in beach ridges 5 and 6 to the E of Barneys Stream. From these pits field data only were recorded.

Peats and peaty soils

A range of soil samples was studied which had been classified as "peats" or "peaty" in the vegetation descriptions. The samples were chosen to show a wide range of stream influence, from almost no included alluvial material to suspected high proportions of fine alluvium. These samples were analysed for: loss of weight on ignition; pH using a glass electrode pH meter and the method of Metson (1961); and bulk density (N.Z. Department of Scientific and Industrial Research Soil Bureau 1968).

Results

Peat depth traverse

The results are presented diagrammatically in Fig. 4. The traverses clearly revealed an accumulation of peat with time across the beaches. The maximum heights of emergent boulders crossed by the survey line (Table 1) do not give a reasonable indication of peat accumulation around the boulders. This is due to the general scarcity of large boulders and the consequent small probability of the survey line traversing the top of the largest boulder on each platform. The maximum peat depths (Table 1) do, however, fairly reflect the trend in increasing peat depth across the platforms.

Extrapolating from observation of beaches 0 and 1 it is considered that each platform base comprises a mantle, generally >1.0 m thick, of boulders overlying a seaward-sloping plateau. This plateau with its boulder mantle is continuous both under the ridges and the platforms. The boulders are buried to varying depths under the ridges by the accumulations of stones, gravels, and boulders.

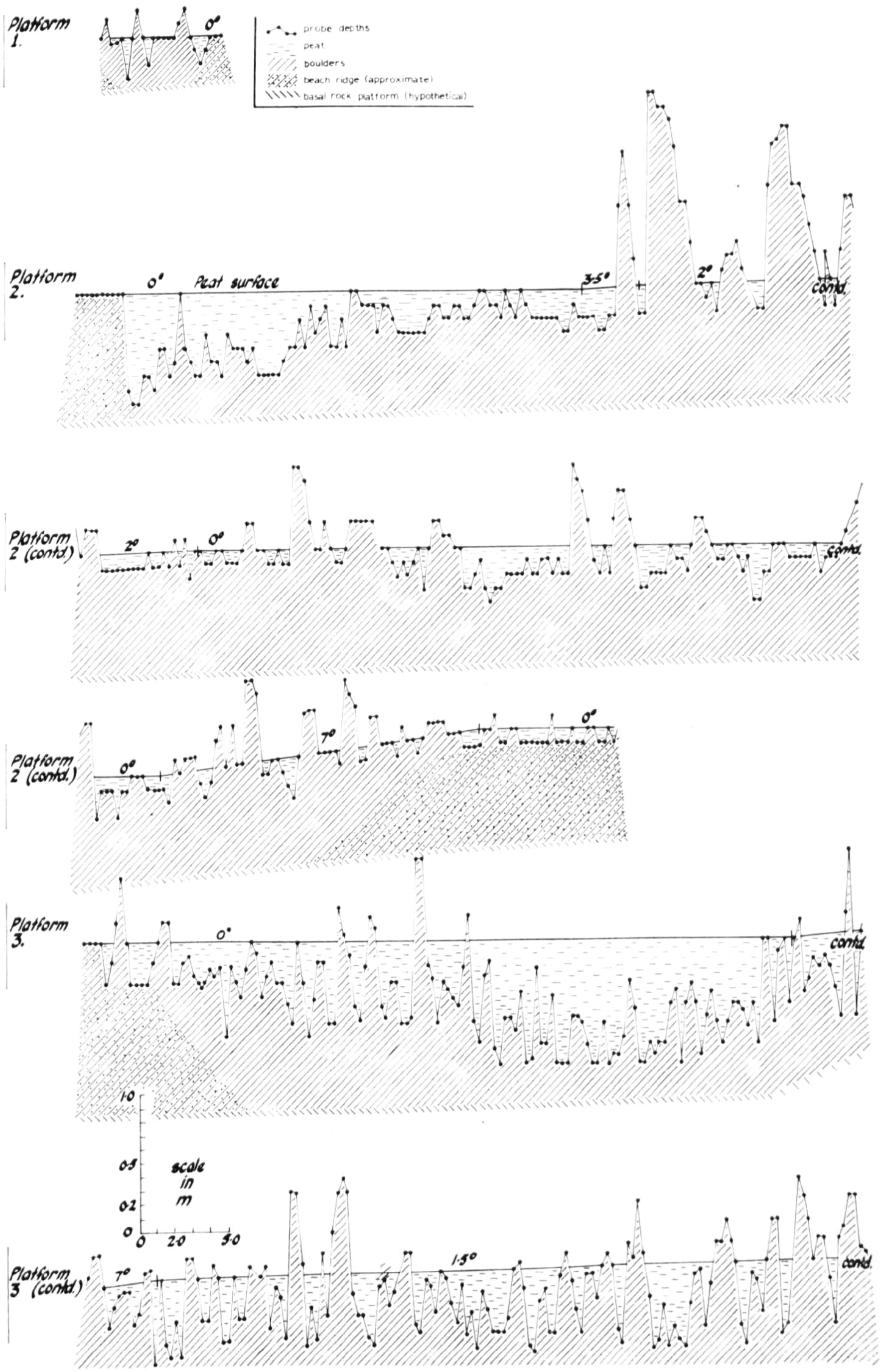

FIG. 4—Peat depth traverse. Plotted points represent peat depths (where below the abscissa) or emergent boulder heights (where above the abscissa) along the survey line. The abscissa represents the peat surface; the slope in degrees from the horizontal is shown.

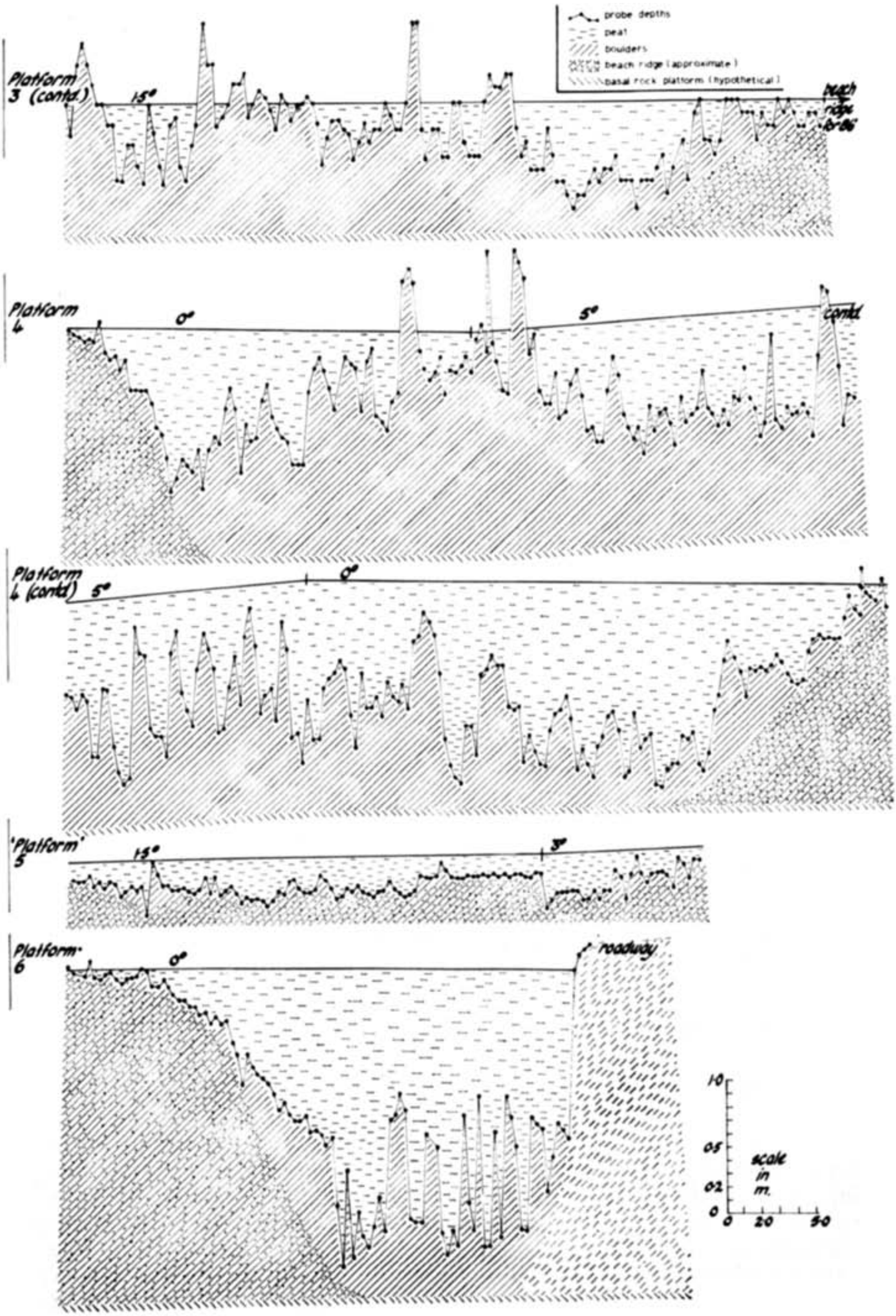
probe depths
peat
boulders
beach ridge (approximate)
basal rock platform (hypothetical)
Platform 3 (contd.)
15°
beach ridge
Platform 4
0°
5°
contd.
Platform 4 (contd.)
5°
0°
'Platform' 5
15°
3°
Platform 6
0°
roadway
1·0
0·5
0·2
0
scale in m.
0
20
50

TABLE 1— Maximum peat depths and emergent boulder heights recorded in peat depth traverse.

Platform No.	*Max. peat depth* (mm)	*Max. height of emergent boulders* (mm)
1	300	200
2	800	1 420
3	900	1 080
4	1 540	620
5	410	20
6	2 420	160

Abrupt rises in the traverse represent the positions of boulders and occasional large logs. The broader undulations represent piles of boulders. The deeper probes on each platform probably were quite close to the underlying rock plateau. This is indicated in Fig. 4.

At the front and back of each platform the peat-covered portion of the adjacent beach ridge is evident. Where the edge of a ridge rises very steeply it is bounded by partly immersed boulders. It was evident from this traverse and an examination of the areas beside Barneys Stream that the small uplift between beaches 4 and 5 (3.0 m) and the long interval between uplifts (1 600 years) had allowed the material of ridge 4 to extend back on to ridge 5, thereby burying platform 5. This has restricted the accumulation of peat over this platform area. Between ridges 0 and 1 where a similar initial uplift (2.5 m) occurred the material of ridge 0 is already covering much of platform 1, especially in the vicinity of Barneys Stream (Figs 2 & 7).

Colluvium from the adjacent hill slopes and roadway now forms the landward boundary of platform 6, so that the horizontal extent of this platform could not be determined with the techniques used.

The peat depth figures for platform 1 are unusually high because of the proximity of the recording line to a stream. On each platform, especially platform 6, buried wood was encountered during probing. It was not possible to ascertain which of this wood had been washed up by the sea and which was previously growing in or adjacent to its recorded position. The wood was always close to the bottom of the peat.

BEACH RIDGE SOILS AND ROOT DISTRIBUTION

Beach ridge 3

Excavation was very difficult because the soil fell down to form cones rather than pits. This made accurate photographic or sketch recording of each root system impossible. The general features of each root system were, however, quite apparent and are presented diagrammatically in Fig. 5. Fig. 6 gives details of the soil physical analyses. The data for boulders and stones (Fig. 6) show variation due to inadequate-sized samples; this also somewhat skews the data for finer particles. In

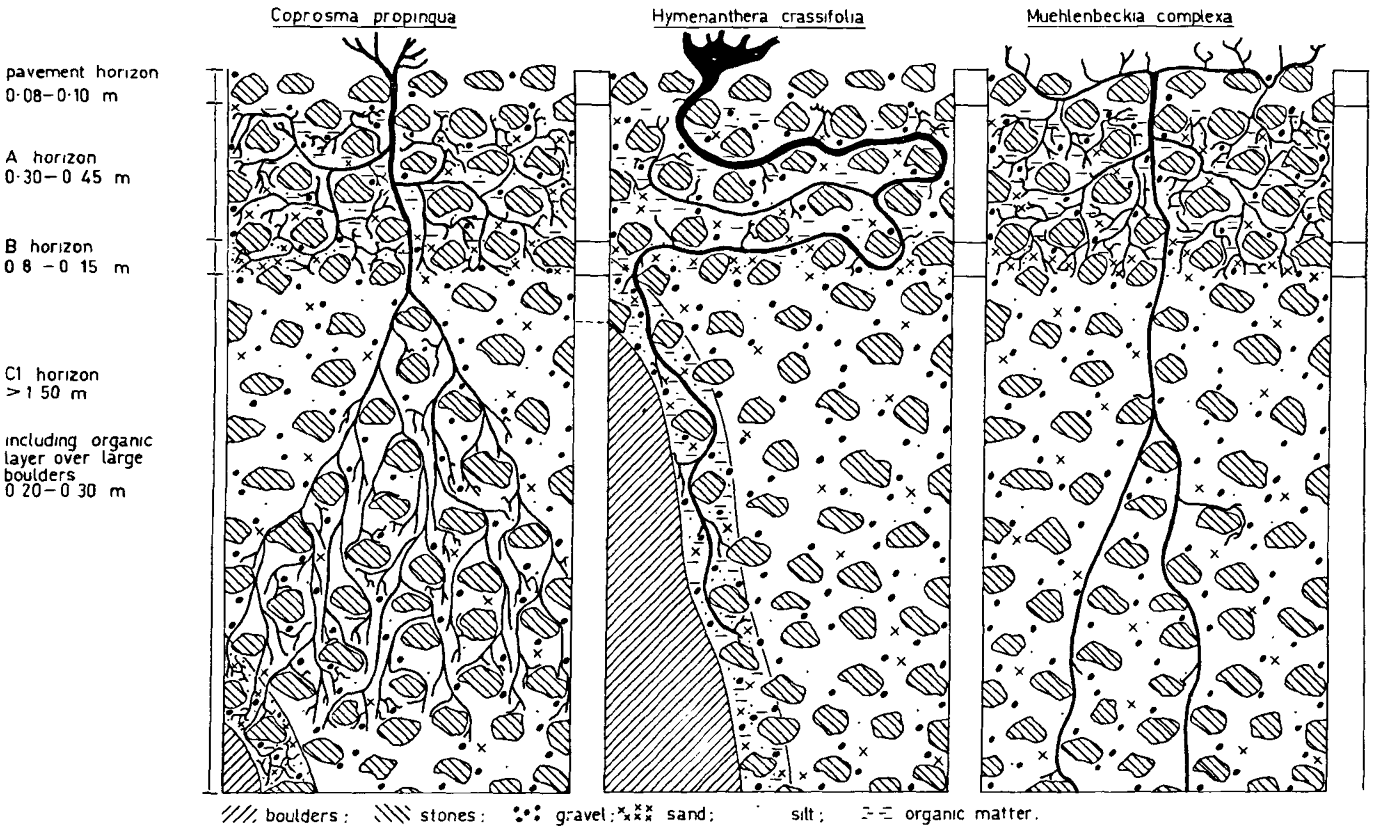

FIG. 5—Diagrammatic sketch of root-growth patterns in beach ridge 3.

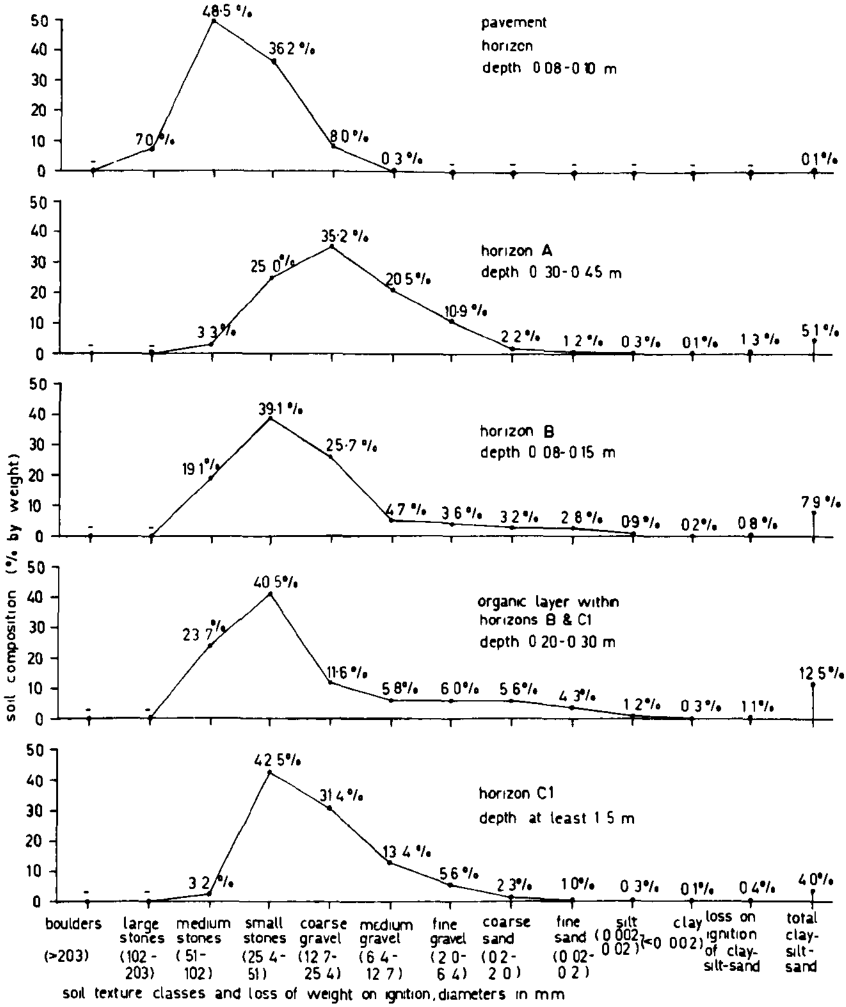

FIG. 6—Particle-size analyses of soil horizons in beach ridge 3.

all pits there were clear soil horizons (with distinct boundaries) and associated patterns of root development. Soil colours are after Oyama & Takehara (1967).

Vegetation – *Coprosma–Muehlenbeckia* grass shrubland.

Pavement horizon – Brownish grey to dull orange (5YR 6/1 to 6/3). Predominantly stones with some gravel and negligible fine material. Large pores between the stones and gravel. No feeding roots.

A horizon – Brownish black (5YR 3/1). Predominantly stones and gravel with relatively high organic matter and fine-textured material*. Very loose small crumb structure. Fragments of charcoal evident. Abundant fine feeding roots of *C. propinqua* and *M. complexa*. In *M. complexa* these arose from adventitious roots and a few strong laterals. In *C. propinqua* they arose only from a few strong laterals. *H. crassifolia* formed a generally massive tap root that divided only occasionally and twisted ± horizontally about the A and B horizons, sending off generally small and apparently short-lived laterals.

B horizon – Dull red-orange (7.5YR 6/4). Predominantly stones and gravel with sufficient fine-textured material (mostly sand) to form a moderately compact structureless soil, low in clay and silt. Fine feeding roots of all three shrub species were common.

C1 horizon – Dull brown (7.5YR 5/4). Predominantly stones and gravel with some sand but very low in silt, clay, and organic matter. An extremely loose, porous, structureless soil horizon which continued at least to the bottom of the deepest pit dug (to 2.0 m); this was also about 0.4 m below the surface of the saturated peat at 2–3 m distance on platform 4, yet the water table was not reached in the pit (in August). No *H. crassifolia* roots. *C. propinqua* formed a diffuse, inverted cone-shaped growth of roots. *M. complexa* formed almost no feeding roots, but the tap root continued ± vertically downward through this horizon, ± without dividing. Where it did divide both branches continued almost vertically downward. We were unable to completely excavate any of the older *M. complexa* tap roots.

Organic layer within the B and C1 horizons – This layer closely resembles the A horizon but is formed by accumulation of fine material as a cap over very large boulders in the B and C horizons. It is brownish black (5YR 3/1). Root growth resembles that in the A horizon.

Beach ridge 4

Vegetation – *Corynocarpus* forest.

Pavement horizon – (0)–0.1–0.15 m. Colour, texture, and roots as described for beach ridge 3.

A horizon – 0.2–0.25 m. Black (7.5YR 2/1). Stones, gravel, and organic loam; with well-developed firm crumb structure. Numerous grass and *Corynocarpus laevigatus* roots which firmly hold the soil. Grades indistinctly into the B.

B horizon – 0.1–0.15 m. Dark brown (7.5YR 3/3). Stones with sand and gravel. Roots of *C. laevigatus* common but less so than in the A. Grades diffusely into the C1.

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*see Appendix 3.

C1 horizon – At least 0.2 m (to bottom of pit). Dark reddish brown (5YR 3/4). Stones with gravel and coarse sand. Very little fine-textured material.

Beach ridge 5

Vegetation – *Myoporum* forest shrubland.

Pavement horizon – 0.5–0.8 m. Brownish grey to dull orange (5YR 6/1 to 6/3). Large stones and boulders. No fine plant roots. Separated distinctly from the A.

A horizon – At least 0.1 m (to bottom of pit). Brownish black (5YR 2/1). Large stones, boulders, and organic loam with well-developed firm crumb structure. Abundant plant roots.

Peats and peaty soils

All peats and peaty soils examined were clayey or silty peats with low sand fractions (field determinations only). The soils (Table 2) varied widely in organic matter content (5–84% loss of weight on ignition) and bulk density (0.11–1.22), reflecting a range from true peats to

TABLE 2—Analysis of selected samples of peats and peaty soils.

% loss of weight on ignition	*Bulk density*	*pH*	*Type of soil*	*Vegetation type*	*Platform no.*	*Grid ref.* (NZMS 1, N164)
84	0.11	5.8	peat	herbfield	6	480051
75	0.21	6.1	peat	herbfield	3	496059
72	0.12	6.3	peat	*Phormium–Olearia* shrub tussockland	2	492055
63	0.14	6.0	peat	*Typha* herb reedland	4	495061
61	0.27	5.7	peat	*Leptospermum* scrub	4	489057
60	0.18	5.9	peat	*Phormium–Olearia* shrub tussockland	2	497060
44	0.31	5.9	peat	*Phormium–Olearia* shrub tussockland	3	488053
36	0.32	5.5	peat, beside alluvial fan	herbfield	5	485054
34	0.40	5.8	peat, beside stream	*Phormium–Olearia* shrub tussockland	3	487054
34	0.51	5.7	peat	grass herbfield	4	489056
24	0.88	6.1	peaty, beside alluvial fan	grassland	3	491056
18	1.04	6.2	peaty	herbfield	3	496060
16	0.89	5.8	peaty	herbfield	3	497061
15	1.07	5.5	peaty, beside alluvial fan	herbfield	5	487055
11	0.98	5.7	peaty	herbfield	3	497061
5	1.22	5.1	alluvial fan	grassland	5	487056

less than slightly peaty soils (Taylor & Pohlen 1962). The soils on alluvial fans ("moist" soils), those around the bases of fans ("peaty" soils), and beside streams ("peats" or "peaty" soils) contained higher proportions of inorganic matter than did peat soils further from streams. There was no evident relationship between organic matter content and vegetation type or platform age.

The bulk densities ranged from very low to low (Taylor & Pohlen 1962) in the peats and from low to medium in the peaty and alluvial soils. There was a direct relationship between bulk density and proximity to a stream or alluvial fan but no evident association with vegetation type or platform age.

The pH of the soils varied from strongly acid to slightly acid (Taylor & Pohlen 1962), but could not be related to present vegetation type, organic matter content, bulk density, age of platform, or position in relation to streams.

VEGETATION

Methods

Description and mapping of vegetation

Areas of vegetation were plotted on enlargements of an aerial photograph (Department of Lands and Survey, 7 August 1969, 4242/4, S.N. 3185) shown reduced in Fig. 2.

The minimum mapping unit was about 500 m^2. Areas were mapped separately using one or more of the following criteria:

1. They differed in the height of any equivalent vegetation strata, such that the normal range of heights in the two areas did not overlap.

2. They showed differences in soil moisture on the following scale: ± permanent pools; ephemeral pools or ± permanently saturated; moist; droughty.

3. If the species composition of any strata differed such that the normal range of cover values in the areas did not overlap–providing that the species contributed 10% or more to the cover in the stratum. Exceptions to this 10% rule were made for species judged to be of particular ecological importance–in particular, emergent trees over scrub, and scattered shrubs over herbfield or grassland.

The floristic composition of herbfield and grasslands was so variable that they were grouped only on growth form and soil moisture.

Strata were recognised where there were clear differences in species composition at different levels of the vegetation or where the canopies of vegetation layers did not overlap. Species composition was estimated on the basis of foliage only. Specific cover differences of

<10% were not considered important unless the species concerned was absent in one of the putative vegetation strata and was judged to be of particular ecological importance.

Vegetation was mapped separately on beach ridges, platforms, hill slopes, and alluvial fans.

The following information was noted for each area plotted, using specially compiled recording sheets.

1. The normal height range of each stratum and an estimate of the total stratum cover.
2. The major species (normally those with 5% or more of the cover) in each stratum. Within each stratum the following information was recorded for each species: percentage cover range in the area, taking an approximately 25 m^2 area as the smallest unit of variation; effects of browsing, on a 5-point scale; wind damage, on a 3-point scale; and wind-shaping, on a 3-point scale.
3. An estimate of ground cover (0–0.3 m height) as: bare soil or sand; bare gravel, stones, or boulders; litter; and live vegetation.
4. A record of the soil moisture as: pool (± permanently flooded); swamp (± permanently saturated but without permanent surface water); moist; droughty; and flooded periodically.
5. An estimate of soil texture in the top 30 cm of soil, as percentage: stones; gravel; sand; clay and silt; and peat.
6. An estimate of percentage ground surface covered by vegetated and non-vegetated boulders, with the average diameter range and average height above ground.
7. Notes on any special features and a brief discussion on anticipated vegetation change.

This work was carried out by four groups, each of three persons. The author continually supervised the work of these groups and established a good degree of uniformity in the recording.

The mapped vegetation areas were subsequently grouped into vegetation types. These vegetation groupings were made in cases where different recording groups had described the same vegetation type or where two or more mapped vegetation areas were found on examination of the data to be of the same type. The vegetation types were plotted on a 0.6 × 0.6 m copy of the aerial photograph used for the survey. A description of each vegetation type was prepared using information from all relevant field recording sheets. The ages of some *Leptospermum scoparium* stands were obtained from felling and ring-counting specimens from different areas.

The group prepared a map of the major substrate features (beach platform, beach ridge, alluvial fan, etc.), using aerial photographs and field observation.

Vegetation types were named using both floristic and structural features as described by Atkinson (1962), but with the following modifications:

1. Vegetation in all strata (not only the canopy plants) was taken into account, although the soil surface was considered only when it formed part of the canopy.
2. Mean cover values were taken as the midpoint of the normal range.
3. A species was not included in the name if it was sufficiently important only locally or marginally.
4. Herbfield was taken to include low-growing (<0.3 m) sedgeland and rushland as well as herbfield *sensu stricto*.
5. Where used in a vegetation name the genera *Juncus* and *Carex* were included on the basis of generic (rather than specific) cover.
6. Grasslands and herbfields (which were very varied in species composition) were named using only structural features.

Vegetation on large boulders

The frequency of species occurring on large boulders was examined. Twenty-five boulders each >2 m in height were selected from each raised beach. All vascular plant species occurring >0.3 m above the surrounding ground level were recorded with estimates of percentage cover.

Results

Description and mapping of vegetation

The survey revealed a great range of vegetation form and species composition. Forty different vegetation types were recognised. This variety is attributable largely to the interaction of three environmental factors: the time since an area was last burned, the moisture availability, and the age of the substrate.

Vegetation on the beaches is generally quite distinct from that on the platforms. Moisture availability appears to be limiting in the deep, stony beach ridge soils which carry mostly a xeromorphic species-poor vegetation. The youngest raised ridge (number 1) supports only scattered halophytic herbs and small shrubs. Ridges 2 and 3 are characterised by dense divaricating shrublands principally of *Coprosma propinqua* and *Muehlenbeckia complexa;* locally other shrubs or grassland are important. The oldest ridges, numbers 4 and 5, show the development of coastal forest and the local growth of peat mires over the ridges from adjacent platforms.

In contrast, the platforms show a rapid development into peat mires after being uplifted. The youngest raised platform (number 1) carries a sparse growth of halophytic herbs and shrubs between the boulders. On platforms 2 and 3 peat mires are developing with the growth of tussockland, reedland, and herbfield. The reedlands on platform 2 are dominated largely by *Leptocarpus* (a halophyte), whereas on platform 3 *Typha* is dominant. Shrublands on platform 2 primarily occur in areas where peat mire as yet has not developed, but on platforms 3–5 shrubland generally is found on old peats where the water table is below the surface for most of the year. Forest occurs on platform 5 but not on any other platforms. In spite of this shrub and tree growth, mire communities, however, are still dominant over much of the area of the older platforms. Compared with the younger mires they are more variable in species composition and structure. They are mostly strongly influenced by grazing and burning.

Developing alluvial fans and colluvium from the hill slopes produce young skeletal soils with a wide range of moisture availability. They carry mostly induced grassland with varying proportions of shrub and forest elements.

Fires have been, and continue to be, a common occurrence. Each burn generally is small in area, thus superimposing a complex of secondary successions on the primary chronosequences.

The vegetation map (Fig. 8) is at the same scale as the map of substrate features (Fig. 7). The frequent coincidence of boundaries between areas on these two maps reflects the importance of soil in determining the vegetation type. The boundaries between vegetation types were considered to be quite distinct in all cases. They coincided with one or more of the following: a fire boundary; a change in moisture availability; a change in substrate age; or, occasionally, a steep gradient in stock browsing and trampling. Cartographic errors in compiling these maps are estimated to be at least as great as errors in actually recognising a boundary in the field.

The symbol used for each vegetation type is derived as follows. The initial letter or letters (A–E), whether upper or lower case, follow a classification based on the structural development of the vegetation types; thus A covers the morphologically simplest types (boulderfield, stonefield, and gravelfield) and E the most complex (forests). Where two letters are used there are two major structural components in the canopy, e.g., db7 = grass shrubland (d = shrubland, b = grassland). Where the structurally simpler component is dominant the first letter is capitalised, e.g., Bd = shrub reedland (B = reedland, d = shrubland). Where the structurally more complex component is dominant both letters are lower case, e.g., dc = tussock shrubland (d = shrubland, c = tussockland). The numbers within each morphological category very approximately rank the vegetation types according to successional sequence (1 youngest–1x oldest). The numeral sequence is not strict because: 1, two or more seral sequences are often present in a morphological category; 2, seral relationships are not elucidated in all cases; and 3, they vary with the dominant limiting factor.

Vegetation types are given descriptive titles after Atkinson (1962). There is a full description of each type in Appendix 2. A selection of vegetation types is illustrated in Figs 9 & 10.

The vegetation types are classified in Table 4. Vegetation on beach ridges, beach platforms, and other substrates is treated separately because the vegetation types on each of these are largely distinct. Under primary successions the older vegetation types should fall to the right of the table, with the younger to the left. Factors disturbing the primary successions (particularly burning, browsing, and alluvial deposition) have, however, broken this pattern. Seral relationships are discussed more fully later in this paper.

VEGETATION ON LARGE BOULDERS

The frequencies of species on large boulders are presented in Table 5. The species are grouped into four categories: those associated with younger beaches, those associated with older beaches, those not correlated with beach age, and species of low occurrence. It is probable that with a larger sample many of the species in the last category (i.e., species of low occurrence and uncertain distribution) could be placed in one of the categories which shows a particular pattern of distribution. Estimates of species cover, mostly $<5\%$, were discarded because the errors in estimating such low cover values make comparison meaningless. Grasses are not here identified because the study was made in winter when we were unable to identify many of the species.

Many species show a clear increase in frequency of occurrence with increasing age of the boulder surface. A lesser number of halophytic species are associated with the seaward boulders. These trends may be the results of either time-dependent changes such as soil accumulation or of responses to a coastal exposure gradient. All boulders, although to a lesser extent those on platform 1, were almost completely covered, except on overhanging surfaces, by crustose and occasional foliose lichens. These lichens were noticeably more luxuriant in surface depressions along which rainwater was channelled. The bryophytes (not recorded) and tracheophytes grew almost exclusively from, or on soil mats adjacent to, deep rock crevices in which wind-blown soil had presumably accumulated. Palatable plants such as *Dendrobium cunninghamii* and *Earina* spp. were growing only in places inaccessible to stock.

DISCUSSION

SOILS AND ROOT DISTRIBUTION

Further study of the soil development in beach ridges should be carried out, but some tentative conclusions can be drawn from our work. With the accumulation of organic matter and wind-blown material two moderately compact soil horizons (A and B) develop as a

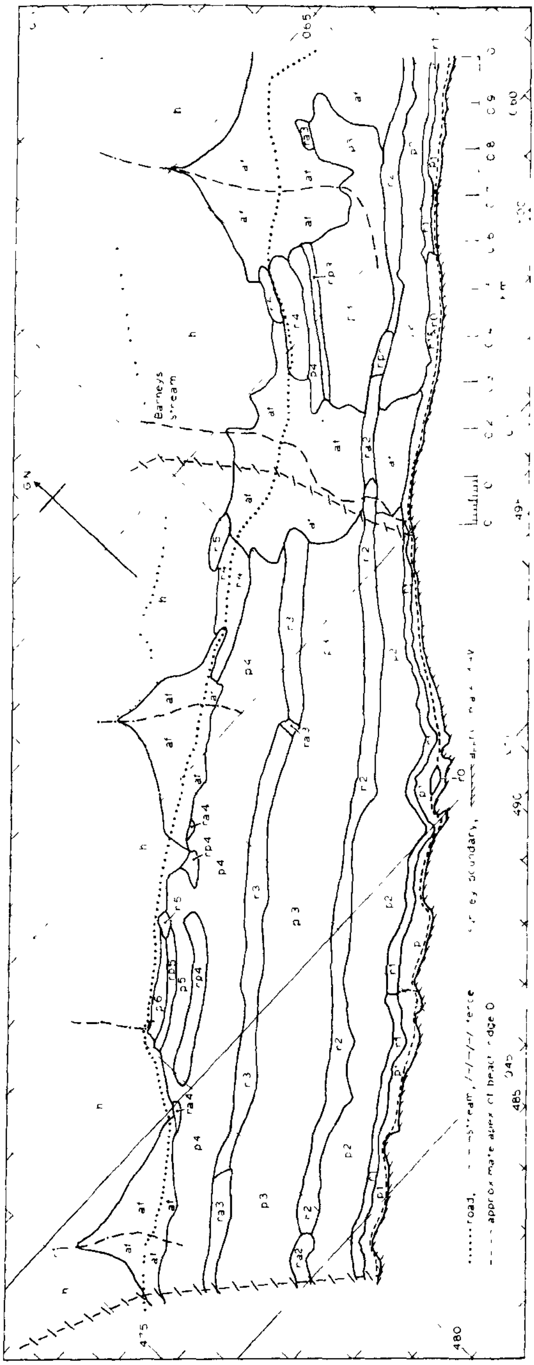

FIG. 7—Map of raised beaches and alluvial fans; af=alluvial fan; h=hill slope; p=beach platform; r=beach ridge; ra=ridge, alluvium filled; rp=ridge, peat covered; numbers 0–6 refer to the numbered beaches.

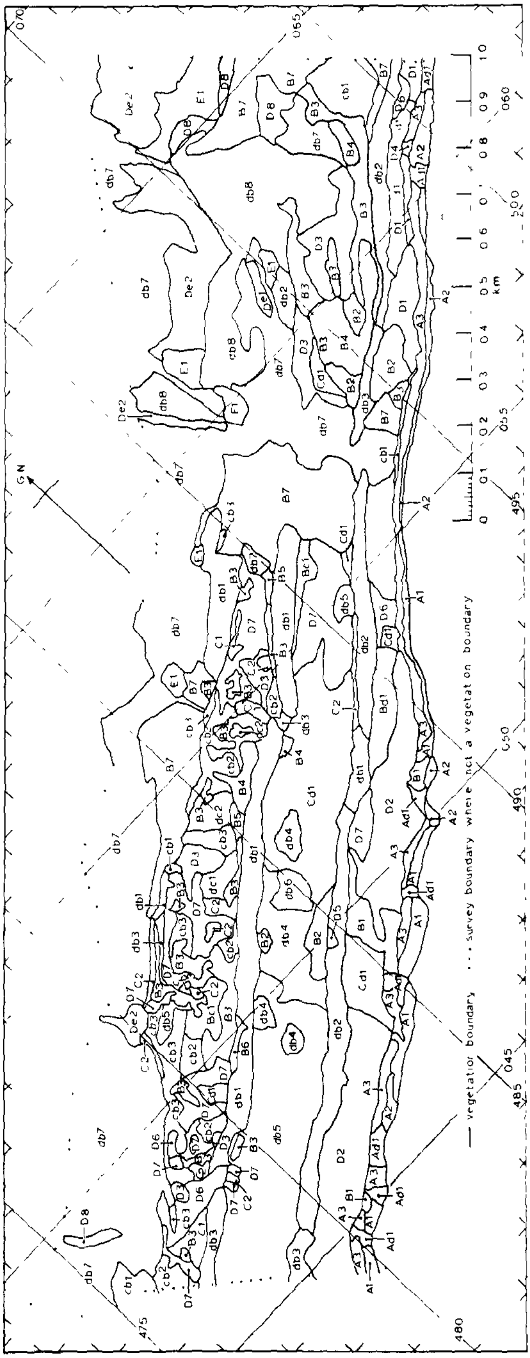

FIG. 8—*Vegetation map.* **For key to symbols *see* Table 3.**

TABLE 3—Key to vegetation types.

A		boulderfield, stonefield, gravelfield
	A1	stony boulderfield
	A2	gravel and stone field
	A3	gravel and stone field with *Glaucium* and *Plagianthus*
Ad		shrub boulderfield
	Ad1	*Plagianthus* shrub boulderfield
B		grassland, herbfield, herb reedland
	B1	*Leptocarpus/Samolus–Apium* herb reedland
	B2	*Leptocarpus–Typha* herb reedland
	B3	herbfield
	B4	*Typha* herb reedland
	B5	grass herbfield
	B6	*Silybum* herbfield
	B7	grassland
Bc		tussock herbfield
	Bc1	*Phormium* tussock herbfield with *Leptospermum*
Bd		shrub reedland
	Bd1	*Leptocarpus–Leptospermum* shrub reedland
cb		grass tussockland, herb tussockland
	cb1	*Cyperus* herb tussockland
	cb2	*Cyperus* herb tussockland with *Carex*
	cb3	*Cyperus–Juncus* grass tussockland
C		tussockland
	C1	*Phormium/Cyperus* tussockland
	C2	*Phormium* tussockland
Cd		shrub tussockland
	Cd1	*Phormium–Olearia* shrub tussockland
db		grass shrubland, herb shrubland, reed shrubland
	db1	*Coprosma–Muehlenbeckia* grass shrubland
	db2	*Coprosma–Muehlenbeckia* grass shrubland with *Olearia* and *Cassinia*
	db3	*Coprosma/Muehlenbeckia* grass shrubland
	db4	*Leptospermum/Leptocarpus* reed shrubland
	db5	*Leptospermum–Cassinia* herb shrubland with *Phormium*
	db6	*Leptospermum–Cassinia* herb shrubland
	db7	*Cassinia–Coprosma* grass shrubland
	db8	*Coprosma* grass shrubland with *Pennantia* and *Myoporum*
dc		tussock shrubland
	dc1	*Phormium/Leptospermum* tussock shrubland
	dc2	*Leptospermum/Cyperus* tussock shrubland
D		shrubland, scrub
	D1	*Plagianthus* shrubland
	D2	*Olearia/Coprosma* scrub
	D3	*Coprosma* shrubland with *Phormium*
	D4	*Ulex* shrubland
	D5	*Cassinia* scrub
	D6	*Olearia–Cassinia* shrubland
	D7	*Leptospermum* scrub
	D8	*Coprosma* shrubland with *Corynocarpus*
De		forest shrubland
	De1	*Myoporum* forest shrubland
	De2	*Corynocarpus/Cassinia* forest shrubland
E		forestland, forest
	E1	*Corynocarpus* forest

shallow band within the upper 1 m of gravel, stones, and boulders. These horizons develop closer to the surface where the original beach material is finer in texture. Examination of the vegetation suggests that the soil, at least after 5 000 years and probably sooner, will support growth of coastal forest under the present climate.

There is evidently an accumulation of organic material in horizons A and B from beach ridge 3 to ridges 4 and 5, as judged from soil colours. The *C. laevigatus* tree roots in beach ridge 4 are mainly in the upper (A and B) soil horizons. *C. laevigatus* normally develops a strong, deep tap root system (author's observation), but there is insufficient evidence of a root distribution of this type in beach ridge 4. The growth of *M. laetum* roots in beach ridge 5 was not studied.

Of the three xerophytic shrubs which cover most of the beach ridge areas, *Hymenanthera crassifolia*, with its roots restricted to the upper soil horizons, must tolerate very dry soils at least on beaches 2 and 3. *Muehlenbeckia complexa* is the first and most vigorous coloniser of the beach ridges; it has a well-adapted root system with both upper feeding roots and a rapidly growing tap root which probably penetrates to the water table. *Coprosma propinqua* appears to be less specialised with a slowly growing, branching tap root system which may also eventually reach the water table.

The contrasting vegetation between the droughty beach ridges and the boggy platforms is very marked. Vegetation on platforms 1, 2, and locally 3 shows the influence of the accumulating peat with progressive restriction and diminishing importance of stony upper soils. Within each platform the present vegetation shows considerable variation attributable, at least partly, to differences in soil moisture. However, these differences have been considerably highlighted by burning and will eventually become of small importance if further burning (and grazing) is stopped. As vegetation develops it tends to raise the peat soil surface above the water table, but this is reversed or retarded by burning or by trampling by stock.

On beach ridge 1 the influence of salt is clearly at least as important as the droughty soil in determining plant cover.

Recent Vegetation Change

It is evident that the soils and climate are capable of supporting forest growth over much of the survey area. This includes the hillslopes, stable alluvial fans, upper platforms (numbers 3–6) where not too waterlogged, and the older beach ridges (numbers 4 and 5). If forest previously covered these areas it was largely destroyed before the 1840s, probably through Maori fires. Bagnall (1972) records that since European settlement . . . ". . . the bush never grew on the steep face behind and to the east of the Orongorongo homestead where

FIG. 9—View from beach ridge 1. 1=gravel and stone field with *Glaucium* and *Plagianthus* (A3), 2=*Cyperus* herb tussockland (cb1), 3=herbfield (B3), 4=*Leptocarpus–Typha* herb reedland (B2), 5=*Coprosma/Muehlenbeckia* grass shrubland (db3), 6=*Phormium–Olearia* shrub tussockland (Cd1) above and *Typha* herb reedland (B4) below, 7=*Corynocarpus* forest (E1), 8=grassland (B7), 9=*Coprosma* grass shrubland with *Pennantia* and *Myoporum* (db8), 10=*Corynocarpus/Cassinia* forest shrubland (De2), 11=*Cassinia–Coprosma* grass shrubland (db7).

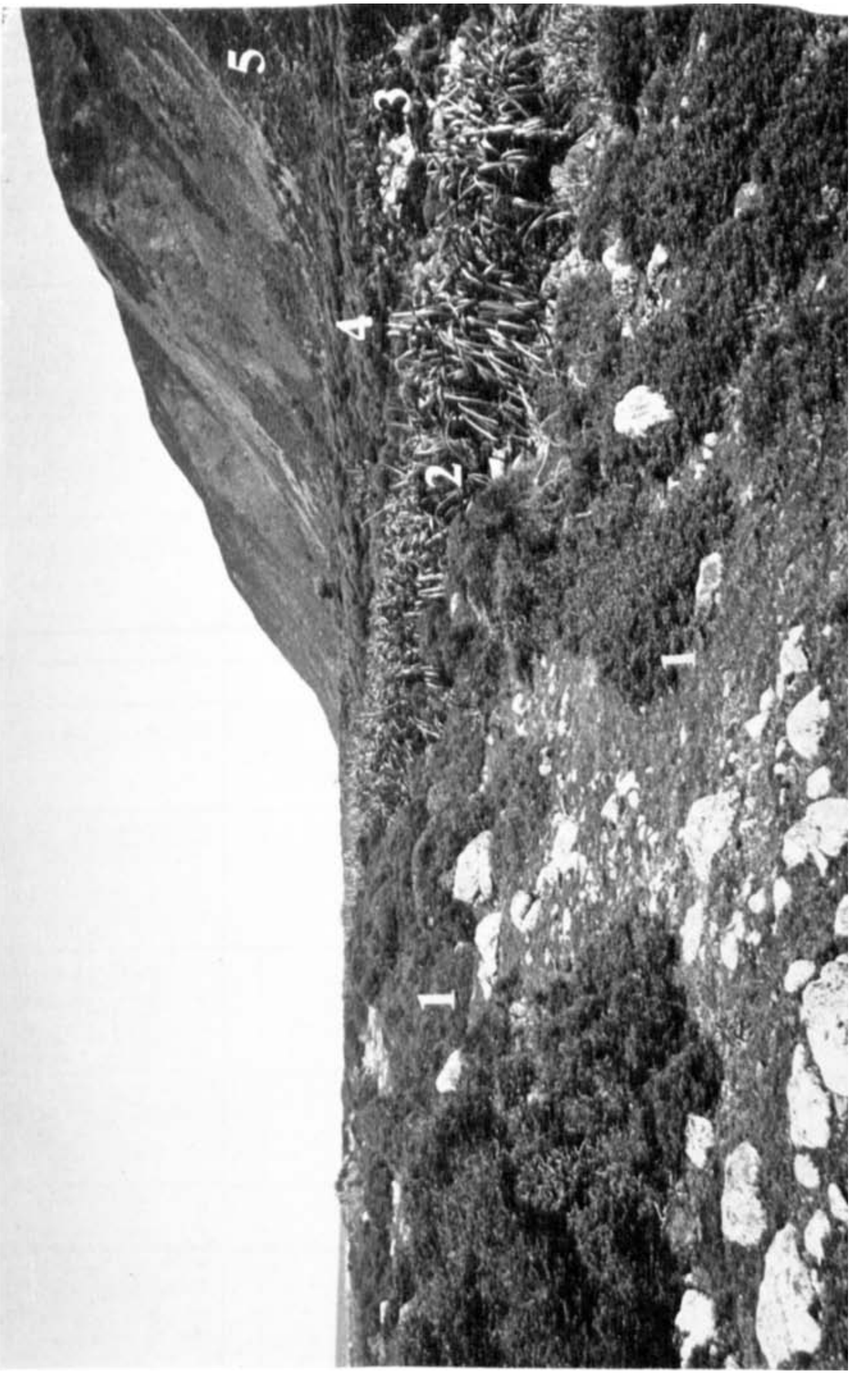

FIG. 10—View along beach ridge 2. 1=*Coprosma–Muehlenbeckia* grass shrubland with *Olearia* and *Cassinia* (db2), 2=*Phormium* tussockland (C2), 3=*Leptospermum–Cassinia* herb shrubland with *Phormium* (db5), 4=*Leptospermum* scrub (D7), 5=*Cassinia–Coprosma* grass shrubland (db7).

TABLE 4—Classification of vegetation types by growth form (columns) and presence on each raised beach sequence (rows).

	boulderfield, stonefield, gravelfield, shrub boulderfield.	grassland, herbfield, herb reedland, tussock herbfield, shrub reedland.	grass tussockland, herb tussockland, tussockland, shrub tussockland.
beach ridge 0	A2 — gravel and stone field		
beach ridge 1	A3 — gravel and stone field with Glaucium and Plagianthus Ad1 — Plagianthus shrub boulderfield		
beach ridge 2			
beach ridge 3		B3 — herbfield B6 — Silybum herbfield	Cd1 — Phormium - Olearia shrub tussockland
beach ridge 4		B3 — herbfield Bc1 — Phormium tussock herbfield with Leptospermum	cb2 — Cyperus herb tussockland with Carex cb3 — Cyperus - Juncus grass tussockland
beach ridge 5		B3 — herbfield	cb3 — Cyperus - Juncus grass tussockland
beach platform 0	A2 — gravel and stone field		
beach platform 1	A1 — stony boulderfield Ad1 — Plagianthus shrub boulderfield	B1 — Leptocarpus / Samolus - Apium herb reedland	
beach platform 2		B1 — Leptocarpus / Samolus - Apium reedland B2 — Leptocarpus - Typha herb reedland Bd1 — Leptocarpus - Leptospermum shrub reedland	Cd1 — Phormium - Olearia shrub tussockland
beach platform 3		B2 — Leptocarpus - Typha herb reedland B3 — herbfield B4 — Typha herb reedland Bc1 — Phormium tussock herbfield with Leptospermum	C2 — Phormium tussockland Cd1 — Phormium - Olearia shrub tussockland
beach platform 4		B3 — herbfield B4 — Typha herb reedland B5 — grass herbfield Bc1 — Phormium tussock herbfield with Leptospermum	cb2 — Cyperus herb tussockland with Carex cb3 — Cyperus - Juncus grass tussockland C1 — Phormium / Cyperus tussock C2 — Phormium tussockland Cd1 — Phormium - Olearia shrub tussockland
beach platform 5		B3 — herbfield	cb3 — Cyperus - Juncus grass tussockland
beach platform 6		B3 — herbfield	cb3 — Cyperus - Juncus grass tussockland C2 — Phormium tussockland
alluvium and hill slopes		B3 — herbfield B7 — grassland	cb1 — Cyperus herb tussockland cb2 — Cyperus herb tussockland with Carex cb3 — Cyperus - Juncus grass tussockland C2 — Phormium tussockland

grass shrubland, herb shrubland reed shrubland, tussock shrubland.	shrubland, scrub, forest shrubland.	forestland, forest.
db1 — *Coprosma* - *Muehlenbeckia* grass shrubland db2 — *Coprosma* - *Muehlenbeckia* grass shrubland with *Olearia* and *Cassinia* db3 — *Coprosma* / *Muehlenbeckia* grass shrubland	D5 — *Cassinia* scrub	
db1 — *Coprosma* - *Muehlenbeckia* grass shrubland db3 — *Coprosma* / *Muehlenbeckia* grass shrubland db7 — *Cassinia* - *Coprosma* grass shrubland	D3 — *Coprosma* shrubland with *Phormium*	
db1 — *Coprosma* - *Muehlenbeckia* grass shrubland db2 — *Coprosma* - *Muehlenbeckia* grass shrubland with *Olearia* and *Cassinia* db5 — *Leptospermum* - *Cassinia* herb shrubland with *Phormium*	D3 — *Coprosma* shrubland with *Phormium* D7 — *Leptospermum* scrub	E1 — *Corynocarpus* forest
db1 — *Coprosma* - *Muehlenbeckia* grass shrubland db3 — *Coprosma* / *Muehlenbeckia* grass shrubland db5 — *Leptospermum* - *Cassinia* herb shrubland with *Phormium*	D7 — *Leptospermum* scrub De1 — *Myoporum* forest shrubland	
	D1 — *Plagianthus* shrubland D2 — *Olearia* / *Coprosma* scrub D4 — *Ulex* shrubland D6 — *Olearia* - *Cassinia* shrubland D7 — *Leptospermum* scrub	
db4 — *Leptospermum* / *Leptocarpus* reed shrubland db5 — *Leptospermum* - *Cassinia* herb shrubland with *Phormium* db6 — *Leptospermum* - *Cassinia* herb shrubland db7 — *Cassinia* - *Coprosma* grass shrubland	D3 — *Coprosma* shrubland with *Phormium* D7 — *Leptospermum* scrub	
dc1 — *Phormium* - *Leptospermum* tussock shrubland dc2 — *Leptospermum* / *Cyperus* tussock shrubland	D3 — *Coprosma* shrubland with *Phormium* D6 — *Olearia* - *Cassinia* shrubland D7 — *Leptospermum* scrub	
db1 — *Coprosma* - *Muehlenbeckia* grass shrubland db5 — *Leptospermum* - *Cassinia* herb shrubland with *Phormium* db7 — *Cassinia* - *Coprosma* grass shrubland	D7 — *Leptospermum* scrub	E1 — *Corynocarpus* forest
	D7 — *Leptospermum* scrub	
db1 — *Coprosma* - *Muehlenbeckia* grass shrubland db7 — *Cassinia* - *Coprosma* grass shrubland db8 — *Coprosma* grass shrubland with *Pennantia* and *Myoporum*	D3 — *Coprosma* shrubland with *Phormium* D6 — *Olearia* - *Cassinia* shrubland D7 — *Leptospermum* scrub D8 — *Coprosma* shrubland with *Corynocarpus* De2 — *Corynocarpus* / *Cassinia* forest shrubland	E1 — *Corynocarpus* forest

TABLE 5—Presence of vascular plants over 0.3 m above ground level on 25 large boulders (>2.0 m height) on each raised beach.

	Presence on boulders on beach number:* 1	2	3	4
Species associated with younger beaches				
Coprosma repens	"	'		
Disphyma australe	"			
Senecio lautus	'	"		
Taraxacum officinale	+	'	'	
Species associated with older beaches				
Arthropodium candidum				"
Asplenium flaccidum	'	++	+	++
A. lucidum	'	+	"	"
Bulbophyllum pygmaeum			+	"
Cassinia leptophylla	"	+++	+++	++
Cerastium holosteoides		'	'	+
Coprosma propinqua	+	+++	++	++
Dendrobium cunninghamii		'	"	"
Earina autumnalis			+	+
E. mucronata		'	+	"
Galium aparine			'	"
Geranium molle		'		"
Gramineae**	"	+++	+++	+++
Hymenanthera crassifolia		+	+	"
Hypochaeris radicata		'	'	"
Leptospermum scoparium			'	+
Linum monogynum		"	'	"
Luzula banksiana		"	+	"
Muehlenbeckia complexa		+	++	+
Olearia solandri		"	"	"
Pellaea rotundifolia			"	
Phormium cookianum			"	'
P. tenax		"	'	"
Phymatodes diversifolium		+	++	++
Pyrrosia serpens	+	++	++	+++
Senecio jacobaea			"	"
Thelymitra longifolia	'	"	'	"
Trifolium spp.†			+	"
Vicia sativa				"
Wahlenbergia gracilis		'	+	+
Species not correlated with age of beach				
Scirpus nodosus	"	"	+	"
Tillaea sieberiana	++	+	+++	++
Species of low occurrence				
Acaena novae-zelandiae				'
Acianthus fornicatus				'
Aciphylla squarrosa		'	'	'
Anagallis arvensis		'		'
Asplenium flabellifolium			'	'
Astelia fragrans	'		'	
Calystegia tuguriorum				'
Cardamine debilis				'
Cirsium vulgare		'	'	'
Clematis forsteri				'
Colobanthus muelleri			'	
Craspedia uniflora		'		
Cyperus ustulatus			'	
Dichondra repens		'	'	

	2	3	4
Gnaphalium spp.	′	′	
Hymenophyllum sanguinolentum	′		
Hypolepis tenuifolia		′	
Luzula picta	′	′	
Lycopodium varium	′		
Parsonsia heterophylla	′		
Pennantia corymbosa		′	
Picris echioides	′	′	
Polycarpon tetraphyllum	′		′
Polystichum richardii	′		′
Pteridium aquilinum			′
Rhagodia triandra	′		
Sagina procumbens		′	
Scleranthus biflorus		′	
Silybum marianum	′	′	′
Solanum nigrum			′
Sonchus oleraceus	′		
Stellaria media		′	
Torilis nodosa		′	
Vicia hirsuta		′	
Vittadinia australis		′	

* present on, ′ <11%, ″ 11–25%, + 26–50%, + + 51–75%, + + + 76–100% of boulders.
** species of Gramineae were not identified in this survey.
† *Trifolium dubium*, *T. repens*, and *T. striatum*.

its seaward fringe today is very little behind its southern limit in pre-European times". An observation made by Best in 1840 strongly suggests recent burning. While walking around Cape Turakirae from the Orongorongo River mouth in December of that year Best (Taylor 1966) recorded that . . . "The first few miles of our road was very bad over stones and rocks, we kept along the sea coast and now I found out the reason why the Mauries objected so much to travelling in windy weather. The cliffs were of a loose crumbling nature and even the little wind we had today brought down showers of earth and sand and occasional large stones". Further, in January 1845 Weld (Lovat 1914) reports starting a fire which burned grassland of the Orongorongo Valley and spread over adjacent hills. Bagnall & Petersen (1948) record that in the 1840s the track around Cape Turakirae was the main highway between Wellington and the Wairarapa. Accidental fires would be most likely in the dry coastal forest. Colenso (Bagnall & Petersen 1948) notes the catching of huias in 1845 in . . . "nearby karaka trees" (i.e., 4 hours walk towards the Wairarapa from Parangarehu Pa at Fitzroy Bay). Unfortunately, although a frequent traveller around the Cape, Colenso recorded nothing of the vegetation through which he passed.

In 1853 Carter (1866), walking from the Orongorongo homestead to the Wairarapa, records after he left the homestead, "I walked on smartly . . . over stony ground overgrown with tufts of coarse grass, till I came to some flax bushes. On I went, following some cattle tracks, at first numerous, afterwards less so, the ground getting wetter and softer, till I found I was in a swamp in a mass of reeds and flax, much taller than myself. I had now lost the track, I could not see my way out, or my way in; I could not see the hills . . .". From this description Carter was walking first along a beach ridge then a platform, through vegetation similar to, but taller than, that found on platforms today. Further around the coast Carter (op. cit.) when encountering the Mukamuka rocks (Fig. 1) writes, "I turned my eyes to the hills at the back; they looked more inviting [than the rocks], there was bush on them . . . and on one of their slopes, composed of loose stones and earth, I found a fine clump of New Zealand *laurels**, not shrubs but *trees**, with umbrageous tops, foliage ever green, and with fine large leaves, of a bright dark green colour . . . ". From his site and species description I assume that Carter was referring to *Corynocarpus laevigatus* trees. Carter's failure to record any such trees earlier on this journey is probably at least partly explained by his interest in finding shelter on reaching the Mukamuka rocks.

McFadgen (1963), using old survey records, has drawn a map of forested areas and discusses some of the survey notes. He used information from surveys in 1859, 1869, and 1882. The earliest record shows the "bush" (meaning: "timber, bush, birch bush, or manuka") edge extending south-westwards along the coastal hills as far as Barneys Stream. The coastal hills SW of this point and the raised beaches are not shown to carry bush. This forest pattern is also shown on an 1895 Department of Lands and Survey map (Wellington Province, Sheet No. 3) where the forest boundary is Barneys Stream. Today, forest remnants are found only in moist valleys above the series of raised beaches and in isolated clumps on the upper raised beaches, lower hill slopes, and alluvial fans. In addition, remnants of old tree stumps are evident on the ridge to the E of Barneys Stream but have not been observed to the SW. This lends support to the forest boundaries recorded in the second half of the nineteenth century.

The many forest plant species growing in shrubland on the raised beaches and the forest epiphytes on boulders in the area suggest the close proximity of recent forest growth, at least on the hill-slopes if not the upper beaches. It is also possible that the apparent disappearance of *Drymoanthus adversus* from monoliths, since Aston (1912) recorded it, could be the result of prolonged exposure after forest clearance (Aston recorded this species on monoliths on platform 4).

Best in 1840 (Taylor 1966) describes the coastal track as following the sea coast, and Carter in 1853 (Carter 1866) started to walk along an older beach and became lost in tall vegetation. Today, one would naturally walk on any of the beach ridges. Aston (1912) described even more open vegetation on beach ridges than is found today.

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*Carter's italics.

Projected development of vegetation on beach ridges 3–5 suggests an almost impenetrable plant cover in the near future (i.e., in the absence of burning). It is thus possible that in the mid-nineteenth century the vegetation on older beach ridges was comparatively tall and dense, but was burned off by the time of Aston's survey.

From Aston's paper it is quite clear that beach ridges 2 and 3 were open and colonised almost entirely by very low-growing vegetation. Mention is made that these beach ridges. . . ". . . form natural roadways along which one may drive". Also that . . . "For the greater part the shingle [of beach ridges 2 and 3] presents an appearance differing little from that of beaches which often exist now at the ocean's marge. In many places the shingle is, however, overgrown with *Muehlenbeckia complexa*, or with grasses and other plants. The main impression left on one's mind is that marvellously little alteration has taken place in the peopling of these areas by plants . . .". The vegetation on these two beach ridges is today a much taller and denser growth mainly of *Coprosma propinqua* and *Hymenanthera crassifolia* with scrambling *M. complexa*. The road at the time of Aston's study was in approximately the same position as it is now. Aston's description and photograph of beach ridges 0 and 1 reveal a vegetation similar to that observed in the present study. The sparse vegetation and the harsh environment have minimised the direct and indirect influence of man on the vegetation of these beaches.

Aston describes beach ridges 4 and 5 as being largely buried by alluvium, but notes that the non-alluviated areas of beach 4 carried a better plant cover than did those of beach 5. Beach ridge 4 is described and pictured as carrying in places . . . "true forest . . . ", namely a nearly pure stand of *C. laevigatus* with some trees up to 1.8 m in circumference. This stand is the still extant, although smaller, remnant immediately E of Barneys Stream. It is actually growing only partly on beach ridge material, some of the stand being rooted in alluvium-filled beach ridge and the adjacent alluvial fan. Examination of the soils of beach ridges 4 and 5 in this area confirms Aston's suggestion about the grain size, namely that beach ridge 4 is finer than 5. Aston attributed the observed growth of forest on ridge 4 and not the older ridge 5 to this difference in grain size. The present study at least partly supports this conclusion. The smaller stones of ridge 4 appear to have accumulated, close to the surface, horizons of fine-textured wind-blown material from the adjacent hill slopes and alluvial fans. Beach ridge 5 has a similarly well developed soil but it is at a greater depth in the stones and boulders than it is in ridge 4. In spite of this difference, beach ridge 5 in this area now carries some tall *M. laetum* trees which appear to have established since Aston's study. The shrub growth on beach ridges 4 and 5 is described as being similar to that found in the present survey.

Aston describes the vegetation on platforms as generally more open, lower growing, less shrubby, more herbaceous, and with more water-logged soils than were recorded in the present study. Platform 1 has probably changed little but all other platforms show the above changes, which also apply to the ponds on platform 3 and to the E of Barneys Stream. Aston published a photograph of these ponds and describes them as having open, free surface water with submerged water plants. Today the "ponds" are shallower and carry a dense growth of *T. orientalis* and lower emergent bog-herbs described by Aston as growing only marginally. Other areas of the ponds have already developed into bogs. On the platforms generally, tall, dense, shrub growth (e.g., of *Leptospermum scoparium* and *Olearia solandri*) and similar growths of *Phormium tenax* have developed since Aston's study.

Aston makes particular mention of the plants on monoliths on platform 4. The growth of these appears to have been similar to that today, but grazing and burning have probably reduced the floristic richness and density of the growths. Aston records shingle fan activity and plant cover similar to that noted in the present study, although stands of *C. laevigatus* are now more restricted.

Examination of a later aerial photograph (Department of Lands and Survey, 17 April 1941, 169/4) shows shrubby vegetation on the beaches, overlying deposits, and hillslopes to be more open and lower growing than it is now. Shingle fans at that time were also noticeably more actively aggrading than they are today.

In conclusion, it is probable that before burning by Maoris the hillslopes, alluvium-filled beach ridges, peat-covered beach ridges, and older platforms (numbers 3–6), where not too waterlogged, carried a windswept coastal forest with local areas of swamp forest. The remaining areas of beach ridges 4 and 5 probably also carried coastal forest. Beach ridge 3 and to a lesser extent beach ridge 2 probably carried a dense tall shrubland of xerophytic shrubs and climbers of the same species as those recorded in the present study. Pre-European fires destroyed most of the forest. More intensive burning in the second half of the nineteenth century further reduced the vegetation cover. Burning has continued throughout the present century but fires have been less frequent and smaller in extent than previously, thus allowing a general successional progression of the vegetation. The rapid development of vegetation since the study of Aston (1912), when measured against the great ages of the colonised surfaces (up to 6 500 years), is most consistent with this hypothesis.

Effects of Salt and Wind on the Vegetation

The effects of wind in modifying plant growth form are evident throughout the survey area. Only on beaches 1 and 2 is the influence apparently strong enough to prevent the development of tall vegetation. After southerly storms, exposed young growth of all shrub and tree species in the area has been burned off. On beaches 1 and 2 whole plants of even quite resistant species such as *Olearia solandri* and *Cassinia leptophylla* were killed by such storms. In rough weather the sea sometimes washes over beach 1 onto areas of platform 2. On these beaches the emergent boulders provide shelter for shrub establishment. The height of each shrub is substantially limited by that of the windward boulders. Marginally the wave action and generally the direct effects of wind will limit growth on platform 2 to a stunted mixed shrubland.

Extreme exposure to wind-borne and wave-washed salt (as on beach 1) evidently selects for annuals (e.g., *Cirsium vulgare, Silybum marianum, Atriplex novae-zelandiae*), for resprouting semi-perennial or perennial herbs (e.g., *Glaucium flavum, Calystegia soldanella*), for deciduous shrubs (*Plagianthus divaricatus*), and for evergreen halophytic herbs and subshrubs (e.g., *Selliera radicans, Samolus repens, Triglochin striatum, Salicornia australis*). On the Trio Islands, Campbell (1967) recorded a similar pattern although deciduous shrub growth was not apparently a feature.

Effects of Fire on the Vegetation

Burning has been the principal environmental factor influencing the present vegetation pattern. Evidence of recent fires over most of the survey area includes the following: frequent burned stumps of shrubs and *Carex secta;* sunken peats; charcoal in soil pits; dense even-aged *Leptospermum scoparium* stands*; observed rapid vegetation change which is consistent only with recent dramatic environmental change; recently burned areas where burned vegetation was still standing. It was evident that burning favoured the herbaceous and pioneer shrubland types of growth. It also tended to accentuate the importance of edaphic factors in determining the vegetation pattern. Examples of this were frequently observed, e.g., the effects of burning on raised peat soils where a reversion to bog conditions frequently occurred; also the burning of shrub vegetation on old beach ridges leaving the soil-surface unprotected and less able to support seedling growth. Burning has thus tended to replace the chronosequence dependent on uplift with one related to the frequency of fires and the time elapsed since last burning. In the survey area recent fires have tended to cover small areas and this has added to the complexity of vegetation types by inducing a mosaic of variously aged stands. Cessation of burning would allow, with time, the vegetation to become more uniform along each raised beach.

**see* Appendix 2—vegetation type D7 (*Leptospermum* scrub).

Effects of Stock on the Vegetation

Both cattle and sheep have a free range of the reserve areas. Their influence on some vegetation types is dominant; particularly on grassland (B7), *Silybum* herbfield (B6), grass tussockland (cb3), and the herb tussocklands (cb1 & cb2). On other types stock influence is minor; particularly on the dense shrublands such as young *Leptospermum* scrub (D7) and *Coprosma* grass shrubland with *Pennantia* and *Myoporum* (db8). Continued grazing will destroy the few extant stands of coastal forest, in which no regeneration of the canopy species is occurring. The xerophytic beach ridge shrublands are quite browse-resistant and will continue to develop with or without stock access. Further development of these shrub communities to short-lived coastal forest communities could occur if further firing is prevented. The growth of browse-susceptible plants on monoliths is restricted by browsing. Trampling, particularly by cattle, damages the herbaceous bog and pool communities, but how much the existence of the floristically rich herbfields is dependent on grazing is not clear. Other vegetation types, although greatly modified by stock, could show continuing successional development with a preponderance of browse-resistant species such as *Cassinia leptophylla, Leptospermum scoparium, Muehlenbeckia complexa,* and *Olearia solandri.*

In areas where the climate and soils are suitable for forest growth there is evidence of cyclical patterns of vegetation change under the influence of cattle and sheep. Beginning for argument with coastal forest (e.g., *Corynocarpus* forest, E1) it is clear that stock are preventing all canopy regeneration. The canopy species in these stands are all palatable and lack resistance to browsing. Natural death of the trees opens the canopy and permits the invasion of pasture species and shade-intolerant browse-resistant shrubs. This leads to a vegetation like that of type D8 (*Coprosma* shrubland with *Corynocarpus*). Ultimate death of all trees leads to grass shrubland, e.g., *Cassinia–Coprosma* grass shrubland, db7. The grass shrubland continues to close over in the upper shrub stratum with the parallel replacement of grasses by more shade-tolerant herbs and ferns. The shrubs, being more browse-tolerant and mostly densely divaricating, progressively restrict stock movement in the vegetation. This allows the establishment and growth of browse-sensitive coastal forest tree species, leading to a vegetation like that of type db8 (*Coprosma* grass shrubland with *Pennantia* and *Myoporum*). Further trees can be expected to establish as long as the shrub stratum is impenetrable to stock. Emergence and continued growth of the young trees will reduce light to the shrub strata. Death of the shrubs from age and shading permits stock re-entry, stopping canopy regeneration, and a vegetation like the E1 type is returned.

Under continued grazing and in the absence of further burning much of the vegetation on and landward of beaches 2–6 can be expected to enter similar cyclical patterns. Edaphic factors would influence the species present, e.g., on the drier peats and peaty soils

Leptospermum scoparium shrubland develops (types db5, db6, dc1, dc2, and D7); on the stony beach ridge soils *Coprosma propinqua* and *Muehlenbeckia complexa* shrubland types are involved (types db1, db2, and db3); on hillslopes and alluvial fans *Cassinia leptophylla* and *C. propinqua* are important shrub components, but the *C. leptophylla* is short lived and dies out before trees are established (Esler 1967).

On peat bogs and pools dense *Phormium* tussockland (C2) which generally precedes major shrub growth, can exclude stock, thereby facilitating soil build-up and the growth of a partly broad-leaved shrubland. On the peats and peaty soils where *L. scoparium* is an important shrub element, forest seral stages are probably not attained. The tall fastigiate growth form of this species allows stock to under-graze mature stands before young trees have grown beyond browse reach. Because the shrubs will only regenerate after the stand has substantially died out the succession returns to grassland or, where severe trampling and peat depression occur, to herbfield.

Chronosequence

Burning and grazing have destroyed most of the vegetation chronosequence across the series of raised beaches and replaced it with secondary successions. Some trends are, however, still apparent. These are presented here by noting the major distinguishing features of the vegetation of each beach relative to each adjacent younger beach.

Beach 1 relative to 0

Ridge —The development of shrub boulderfield and of gravel and stone field with *Glaucium* and *Plagianthus*.

Platform —The development of shrub boulderfield and herb reedland.
The localised development of peat.

Beach 2 relative to 1

Ridge —The displacement of shrub boulderfield and of gravel and stone field.
The development of grass shrubland and scrub.

Platform —The displacement of gravel and stone field, stony boulderfield, and shrub boulderfield.
The development of shrub reedland, shrub tussockland, shrubland, and scrub.
The horizontal spread and increase in depth of peat.

Large boulders—The loss of *Disphyma australe*.
The lower frequency of *Coprosma repens* and *Taraxacum officinale*.
The appearance of new species (several), e.g., *Earina mucronata, Hymenanthera crassifolia, Linum monogynum*, and *Phymatodes diversifolium*.
The higher frequency of several species, e.g., *Asplenium flaccidum, Cassinia leptophylla*, and *Pyrrosia serpens*.

Beach 3 relative to 2

Ridge —The development of herbfield.

Platform —The displacement of saltmarsh herbs, e.g., *Samolus repens* and *Apium australe*, in herb reedland.

The considerable increase in the proportion of bog vegetation (e.g., *Leptospermum* scrub and *Phormium–Olearia* shrub tussockland) relative to vegetation over boulderfield (especially *Olearia–Cassinia* shrubland and *Plagianthus* shrubland).
The development of herbfield.
The increase in peat depth.

Large boulders—The loss of *Coprosma repens* and *Senecio lautus*.
The lower frequency of, e.g., *Coprosma propinqua*.
The appearance of new species (several), e.g., *Bulbophyllum pygmaeum*, *Earina autumnalis*, and *Leptospermum scoparium*.
The higher frequency of several species, e.g., *Olearia solandri*, *Pyrrosia serpens*, and *Wahlenbergia gracilis*.

Beach 4 relative to 3

Ridge —The development of forest growth.
Platform —The displacement of *Leptocarpus* vegetation types.
The increase in peat depth.
Large boulders—The loss of *Taraxacum officinale*, *Phormium cookianum*, and *Pellaea rotundifolia*.
The lower frequency of, e.g., *Cassinia leptophylla*.
The appearance of new species: *Vicia sativa* and *Arthropodium candidum*.
The higher frequency of, e.g., *Galium aparine* and *Pyrrosia serpens*.

Beach 5 relative to 4

Ridge —No change.
Platform —The development of forest.

Beach 6 relative to 5

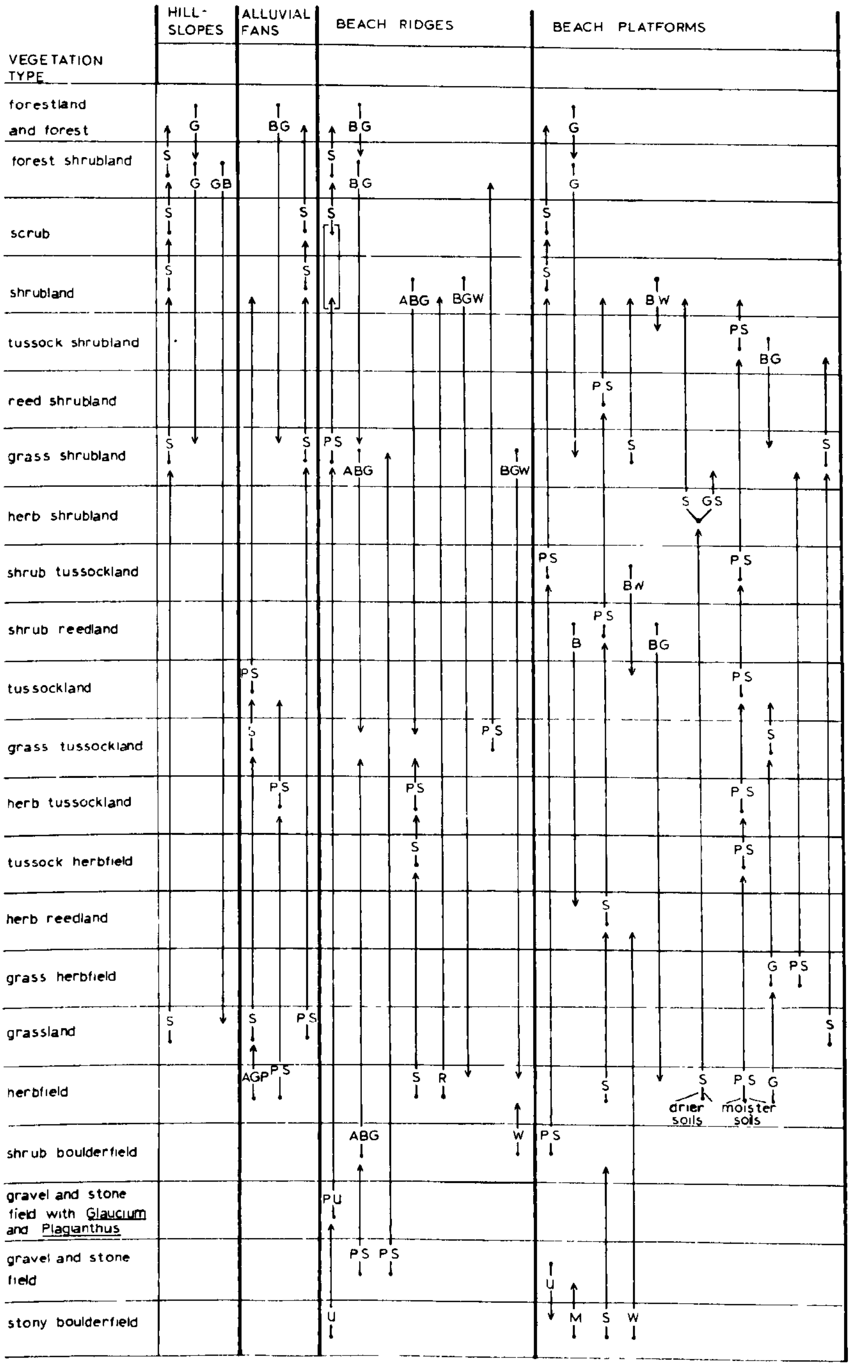
Ridge —No change.
Platform —The increase in peat depth (compared with all other beaches).

The study of beach ridge soils indicated that further work on these would be likely to reveal a strongly time-dependent pattern of development.

Seral Relationships and Projected Patterns of Vegetation Change

Projected patterns of change are presented in Fig. 11. These are based on recorded vegetation types and their inferred inter-relationships. The continuation of both present management regimes and climate are assumed except where otherwise specified. Where controlling factors of change are noted it is understood that other factors will change in parallel.

FIG. 11—Flow chart of hypothesised vegetation change. Arrowheads show the direction of change. The symbols indicate the principal controlling factors in each change, as follows: A=alluviation, B=burning, G=grazing and browsing, M=gravel and stone accumulation, P=soil profile development, R=change would occur only if stock were removed, S=seral change, U=uplift, W=waterlogging.


HILL-SLOPES
ALLUVIAL FANS
BEACH RIDGES
BEACH PLATFORMS
VEGETATION TYPE
forestland and forest
forest shrubland
scrub
shrubland
tussock shrubland
reed shrubland
grass shrubland
herb shrubland
shrub tussockland
shrub reedland
tussockland
grass tussockland
herb tussockland
tussock herbfield
herb reedland
grass herbfield
grassland
herbfield
shrub boulderfield
gravel and stone field with Glaucium and Plagianthus
gravel and stone field
stony boulderfield
drier soils
moister soils

Vegetation development on beaches 1 and 2 is restricted by proximity to the sea. Older beaches, the hillslopes, and alluvial fans are more strongly influenced by browsing and burning. In the survey area, where most of the vegetation has a history of burning, further fires tend to push the development backwards on each occasion. Browsing by stock, on the other hand, tends to impose a selective influence on species development and consequently to modify the course of a succession.

After uplift the beach platforms rapidly develop into peat mires, often with pools. Thus, <10% of platform 1 is mire, but platform 2 is about 50% and platform 3 about 70% mire. With seral advance to shrubland there is a general tendency for old peats to become drier by peat accumulation and alluviation. However, bogs and pools were observed to be present on all platforms. On the older platforms their presence could be explained by proximity to streams, but rejuvenating influences. particularly grazing, burning, and ponding by alluvial fans may have caused the reversion of older, previously moist, raised peat soils. Pollen studies of the peat profiles should elucidate this.

Platform areas which are not close to a stream are much slower to become boggy, e.g., the N end of beaches 2 and 3 where *Olearia/Coprosma* scrub (D2) covers platform 2 and *Leptospermum–Cassinia* herb shrubland with *Phormium* (db5) covers platform 3. The *Phormium* on the older platform reflects some mire development. The N end of platform 4 is almost entirely boggy with only small areas of drier *Olearia–Cassinia* shrubland (D6).

Associated with the seral changes shown in Fig. 11 there occurs a general displacement of halophytes by less salt-tolerant species, e.g., from *Leptocarpus/Samolus–Apium* herb reedland (B1) to *Leptocarpus–Typha* herb reedland (B2) to *Typha* herb reedland (B4); and from *Plagianthus* shrub boulderfield (Ad1) to *Phormium–Olearia* shrub tussockland (Cd1).

Cyclical seral patterns under stock influence were discussed earlier. Linear seres may enter these cycles, e.g., on moist platforms from herbfield to tussock herbfield to herb tussockland to tussockland to shrub tussockland to tussock shrubland to shrubland; and on beach ridges from stony boulderfield to gravel and stone field to grass shrubland to shrubland. Some vegetation types, e.g., *Silybum* herbfield (B6) are under such heavy grazing pressure that major change is unlikely.

The *Myoporum* forest shrubland (Del) on beach ridge 5 was not evident at the time of Aston's study (Aston 1912). This is an unusual vegetation type in that both trees and shrubs are widely spaced because of the very coarse upper soil horizon.

The growth of shrubs in bog herbfield and tussocklands begins on raised peat lips around emergent boulders and the bog margin. In many tussocklands the raised *Carex secta* clumps also support shrub growth.

The *Cyperus* herb tussocklands, cb1 and cb2, are soil-controlled vegetation types, owing their presence to the continuing deposition of fine alluvium at the bases of active fans. Large areas of *Cassinia–Coprosma* grass shrubland (db7) are growing on unstable stony alluvial and colluvial soils. Sporadic substrate rejuvenation plays a similar role in their maintenance.

There is a small area of *Ulex* shrubland (D4) on platform 2. This exotic species is an aggressive pioneer on drier soils and builds up a very inflammable litter. Its continued spread in the area, although difficult to control, is not desirable.

Continued land management similar to that of the last century will probably not allow much change in the types of vegetation present. On the other hand, the relative cover of each type and its distribution are likely to change. To alter the management by removing stock and preventing further fires would almost certainly allow most of the vegetation on all but beaches 1 and 2 to change into a simpler pattern of coastal forest types. In its mature state this vegetation may not outwardly show as strong a contrast between platforms and ridges as does the present cover. Although some of the described vegetation types may disappear from the area it is unlikely that this would happen to any species because the range of habitats would probably be increased rather than diminished.

The linear patterns of vegetation change on mire soils described here are generally similar to those described by Moar (1949, 1950, 1953) for other similarly grazed mires in the Wellington area. Neither Moar's nor the present study have revealed lowland mire vegetation which has not been greatly modified. There is a need for stock exclosures to provide more information about the effects of grazing on vegetation change in mires.

To preserve the few remaining areas of beaches 4 and 5 it would appear to be essential that the catchments of all streams flowing onto the reserved areas are managed to develop rapidly a stabilising forest cover. Any widening of the existing road would have most unfortunate results in further reducing the few remaining areas of beaches 4 and 5. Also, for future scientific study, the one peat-filled area of platform 6 should be preserved at any cost; preservation will require the exclusion of stock, reservation of the area, and the prevention of further infilling with spoil from the adjacent roadway.

If the reserves are to be managed purely as scenic attractions it is probably of small consequence whether or not grazing and burning continue. For future scientific studies, however, this would be most undesirable. The stock are disturbing the peat soils, and grazing and burning are continuing to impose an artificial vegetation pattern on an area which would otherwise reveal the influence on vegetation of a fascinating, valuable, and unique interplay of contrasting environmental factors.

Except on limited areas, like platform 6 adjacent to the access road, any problems resulting from greatly increased numbers of tourists are likely to be minimal. If grazing is not increased in intensity and burning is stopped the area will become fairly impenetrable to all but the most enthusiastic.

RECOMMENDATIONS ON RESERVE MANAGEMENT

The following actions are recommended if the reserves are to be maintained as useful scientific and cultural assets:

1. Forest growth should be allowed to develop in the catchments of all streams flowing onto the reserves. This could be achieved by planting appropriate indigenous trees and continuing grazing or by fencing the catchments off and allowing regrowth of coastal forest.

2. The main reserve should be extended to include the whole of the remaining area of platform 6 (*c.* NZMS 1, Sheet N164 480051 to 482053 and adjacent to the road–Figs 3 & 7).

3. Burning of the reserve vegetation should be actively discouraged.

4. Part of the main reserve should be fenced from grazing. It is recommended that this area (Fig. 3) should extend from the existing SW boundary fence to a boundary running to the sea from the NE end of platform 6. A fence should also follow the boundary adjacent to the road.

5. All the reserve around the ponds to the E of Barneys Stream (Fig. 3) should be fenced off.

6. The reserve area around beach ridge 5 and the adjacent area of beach ridge 4 to the W or to the E of Barneys Stream should be fenced off.

7. Apart from the above areas, grazing at the present level of intensity could continue.

8. Upgrading and increased use of the existing road must not encroach across any of the remaining areas of beaches 4, 5, or 6.

9. No attempt should be made to encourage public access to any part of the reserves not already accessible from the road. Vehicles should be excluded from all reserve areas.

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Appendix 1—List of Vascular Plant Species at Cape Turakirae

Except where authorities are cited, nomenclature is after the following authors: exotic species, New Zealand Weed and Pest Control Society (1969); indigenous Araliaceae, Philipson (1965); indigenous Arundinoideae, Zotov (1963); other indigenous Gramineae, Zotov (1943), or where not superseded, Cheeseman (1925); other indigenous Monocotyledonae, Moore & Edgar (1970);

other indigenous species, Allan (1961). Herbarium specimens are deposited in the Department of Botany herbarium, Victoria University of Wellington (WELTU). Symbols used: * exotic species; ** indigenous species recorded by Druce (1972) and not noted in this study; † species recorded only from hill slopes or alluvial fans; × no herbarium specimen collected; — rare; I frequent (scattered widely spaced plants or clumps, or confined to restricted areas); + common-abundant (scattered ± throughout or abundant over considerable areas).

PTERIDOPHYTA
Adiantum cunninghamii I
Asplenium bulbiferum †—
A. flabellifolium —
A. flaccidum agg. (coastal and forest forms) I
A. hookerianum †I
A. lucidum —
Azolla rubra I
Belchnum capense agg. +
B. filiforme I
B. lanceolatum I
B. penna-marina I
Cyathea dealbata —×
C. medullaris —
Grammitis heterophylla —
Histiopteris incisa I
Hymenophyllum sanguinolentum —
H. rarum —
Hypolepis tenuifolia I
Lastreopsis glabella —, hillslopes I
L. microsora †I
Lycopodium varium — only on monoliths
Ophioglossum sp. (aff. *O. coriaceum*) —
Paesia scaberula I
Pellaea rotundifolia I
Phymatodes diversifolium I
Polystichum richardii I, hillslopes +
Pteridium aquilinum var. *esculentum* —, hillslopes +
Pteris macilenta I
P. tremula —
Pyrrosia serpens I
Thelypteris pennigera I

GYMNOSPERMAE
Cupressus macrocarpa *—

MONOCOTYLEDONES
Acianthus fornicatus — only on monoliths
Agropyron scabrum agg. I
Aira caryophyllea *I
A. praecox *—
Anthoxanthum odoratum *+
Arthropodium candidum I
Astelia fragrans —
Baumea juncea I
B. rubiginosa I
Briza maxima *—
B. minor *—
Bromus mollis *I
Bulbophyllum pygmaeum I only on monoliths
Caladenia carnea — only on monoliths
Carex flagellifera +
C. flaviformis I
C. germinata I
C. pumila I
C. secta var. *secta* +
C. solandri †—
C. virgata I
Catapodium rigidum *—
Cordyline australis —×
Cortaderia toetoe I
Corybas orbiculatus —
Cynosurus cristatus *I
C. echinatus *—
Cyperus eragrostis *I
C. ustulatus +
Dactylus glomerata *+
Dendrobium cunninghamii I only on monoliths
Deyeuxia crinita +
Earina autumnalis I primarily on monoliths
E. mucronata I primarily on monoliths
Echinopogon ovatus I
Eleocharis acuta I
E. gracilis I
Festuca multinodis I
Glyceria declinata *I
Hierochloe sp. **—×
Holcus lanatus *+

Hordeum murinum *+
Juncus acutus *I
J. articulatus *+
J. australis I
J. bufonius *+
J. caespiticius I
J. distegus I
J. effusus *I
J. gregiflorus I
J. holoschoenus I
J. maritimus var. *australiensis* I
J. pallidus −
J. planifolius I
J. sarophorus +
Lachnagrostis richardii **−×
Lagurus ovatus *I
Lepidosperma australe −
Leptocarpus similis +
Libertia ixioides †−
Lolium perenne *+
Luzula banksiana s.s. I
L. picta s.s. −
Microlaena stipoides +
Microtis unifolia I especially on monoliths
Notodanthonia gracilis I
N. racemosa +
N. unarede +
Phormium cookianum I×
P. tenax +
Poa anceps var. *anceps* +×
P. anceps var. *condensata* I
P. annua *+
P. infirma H.B.K. *I
P. laevis I
P. pratensis *+
P. trivialis *I
Potamogeton cheesemanii I
Prasophyllum colensoi −
Pterostylis banksii −
Schoenus maschalinus I
Scirpus americanus −
S. cernuus +
S. lacustris −
S. nodosus +
S. prolifer +
Sisyrinchium bermudiana L. *+
Thelymitra longifolia I× especially on monoliths
Triglochin striatum I
Trisetum antarcticum s.s. I
Trisetum sp. (aff. *T. antarcticum*) **−×
Typha orientalis +
Uncinia leptostachya †−
Vulpia bromoides *I
Zoysia minima −

DICOTYLEDONES

Acaena ovina *+
A. novae-zelandiae I
Aciphylla squarrosa I
Alectryon excelsus †−×
Anagallis arvensis *I
Apium australe I
Atriplex novae-zelandiae I
A. patula *−
Bellis perennis *I
Brachyglottis repanda var. *repanda* −
Callitriche stagnalis *+
Calystegia soldanella I
C. sylvatica (Kit.) Griseb. *−
C. tuguriorum +
Capsella bursa-pastoris *I
Cardamine debilis ("narrow petal" of Pritchard 1957) −
C. debilis ("corymbosa" of Pritchard 1957) I
Carmichaelia sp. (Subgen. *Carmichaelia*) †−
Cassinia leptophylla +
Centaurium erythraea *+
Centella uniflora +
Centunculus minimus L. *−
Cerastium holosteoides *+
Chenopodium pumilio *−
Cirsium vulgare *I
Clematis forsteri I
C. paniculata −
Colobanthus muelleri −
Coprosma crassifolia I
C. propinqua var. *latiuscula* +×
C. repens −×
C. rhamnoides I
C. robusta I
C. propinqua var. *latiuscula* × *C. robusta* −
C. virescens −
Corynocarpus laevigatus I
Cotula australis I
C. coronopifolia I
C. squalida I
Craspedia uniflora var. *grandis* I
Crepis capillaris *+
Cyathodes juniperina −×
Dichondra brevifolia I
D. repens +
Digitalis purpurea *I× mainly on hillslopes
Disphyma australe I×
Drosera binata −
Epilobium alsinoides s.s. **−×
E. atriplicifolium A. Cunn. **−×
E. billardierianum I
E. brunnescens (Cockayne) Raven & Engelhorn **−×
E. chionanthum I
E. insulare +

E. nerterioides var. *nerterioides* I
E. microphyllum **–×
E. nummularifolium I
E. pallidiflorum I
E. rotundifolium I
Erechtites atkinsoniae *–
E. minima var. *heterophylla* –
E. scaberula –
Erica lusitanica *–
Erigeron canadensis *I×
Erodium cicutarium *I
Euphorbia glauca –
E. peplus *–
Euphrasia cuneata I
Fumaria muralis *+
Galium aparine *I
G. parisiense *I mainly on hillslopes beside streams
G. propinquum I
G. tenuicaule **–×
Gaultheria antipoda –
Geranium microphyllum var. *microphyllum* I
G. molle *+
G. robertianum *†–
G. sessiliflorum s.sp. *novae-zealandiae* Carolin –
Glaucium flavum *I
Glossostigma elatinoides *–×
Gnaphalium audax s.s. Drury –
G. collinum I
G. gymnocephalum DC –
G. limosum Drury **–×
G. luteo-album agg. I
G. spicatum Lam. *I
G. trinerve **–×
Gnaphalium sp. (aff. *G. luteo-album*) –
Gratiola sexdentata –
Griselinia lucida †–
Gunnera prorepens –
Haloragis depressa I
H. erecta I
Hebe stricta var. *atkinsonii* I
Hedycarya arborea †I
Helichrysum aggregatum P. F. Yeo I
Hydrocotyle americana +
Hydrocotyle sp. (*H. novae-zelandiae* agg.) two forms +
Hymenanthera crassifolia +×
Hypericum japonicum I
Hypochaeris glabra *+
H. radicata *+
Knightia excelsa –
Korthalsella lindsayi –
Lagenophora sp. (*L. pumila* agg.) I
Lemna minor I
Leontodon taraxacoides *I
Leptospermum ericoides †–
L. scoparium +
Lilaeopsis sp. (coastal sp.) –
Limosella lineata **–×
Linum marginale *–
L. marginale × *monogynum* –
L. monogynum +
Lobelia anceps +
Ludwigia palustris *I
Lythrum hyssopifolia *–
Macropiper excelsum –×
Marrubium vulgare *†–
Mazus pumilio –
Medicago lupulina *I
Melicope ternata –
Melicytus ramiflorus –, hillslopes I, ×
Melilotus indica *I
Mentha pulegium *I
Metrosideros diffusa –
M. robusta –
Mimulus guttatus *I
Montia fontana I
Muehlenbeckia australis I, hillslopes +
M. complexa +
M. australis × *complexa* †I×
Mycelus muralis *–
Myoporum laetum –, hillslopes I, ×
Myosotis caespitosa *I
M. scorpioides *I
Myriophyllum elatinoides I
M. propinquum I
Myrsine australis –
Nasturtium officinale *+
Nertera cunninghamii +
N. setulosa –
Olearia paniculata +
O. solandri +
Onopordum acanthium *I
Oxalis sp. (aff. *O. corniculata*) small flowered *+
Oxalis sp. (aff. *O. corniculata*) large flowered *I
O. lactea –
Parentucellia viscosa I
Parietaria debilis I
Parsonsia capsularis I
P. heterophylla +
P. capsularis × *heterophylla* **–×
Pennantia corymbosa +
Picris echioides *I
Pittosporum tenuifolium –
Plagianthus divaricatus +
Plantago coronopus *I
P. lanceolata *I
P. major *I
P. raoulii –
Polycarpon tetraphyllum *+
Polygonum aviculare agg. *I
P. persicaria *I
Polygonum sp. (*P. decipiens* auct. N.Z.) I
Potentilla anserinoides –
Pratia angulata +

Prunella vulgaris *+
Pseudopanax arboreus −
Ranunculus acaulis I
R. fluitans *I
R. hirtus I
R. repens *+
R. rivularis +
R. sardous *I
Raoulia glabra −×
Rhagodia triandra I
Rosa rubiginosa *−
Rubus squarrosus −
Rumex acetosella *+
R. brownii *−
R. conglomeratus *I
Sagina procumbens *+
Salicornia australis I
Samolus repens I
Scleranthus biflorus I
Selliera radicans I
Senecio jacobaea *I
S. lautus s.sp. *lautus* I
Silybum marianum *+
Sisymbrium orientale *I
Solanum aviculare −
S. nigrum *−
Sonchus asper *−
S. littoralis −
S. oleraceus *I
Sophora microphylla −, hillslopes I
Stellaria media *+
Taraxacum officinale *+
Tillaea kirkii **−×
T. moschata −×
T. sieberiana +
Torilis nodosa *I
Trifolium dubium *+
T. glomeratum *+
T. micranthum *I
T. repens *+
T. striatum *I
T. subterraneum *+
Ulex europaeus *−
Urtica ferox +
Veronica arborea Buchan. −
V. serpyllifolia *−
Vicia angustifolia *−
V. hirsuta *−
V. sativa *+
Viola cunninghamii −
Vittadinia australis I
Wahlenbergia gracilis s.s. +

APPENDIX 2—DESCRIPTION OF VEGETATION TYPES

NOTES ON THE DESCRIPTIONS

SOILS. Diameters of boulders are given as the most common size range; the sizes of unusually large and unusually small boulders were not recorded. Cover percentages given for boulders refer to the percentage of ground surface covered by all emergent boulders; a range of cover percentage is normally given which includes the values from all areas of the vegtation type; unusual extreme values are given as a third and a fourth figure in parentheses. Percentages given for other texture size classes are field estimates by volume in the top 0.3 m of soil.

VEGETATION. Each stratum is described. These are numbered from the uppermost downwards, with the data arranged in the following order: the usual height range of the stratum canopy; the major component species each with its estimated cover range; estimated total vegetation cover for all species in the stratum. Important observations on distribution and environmental factors are noted.

A1—Stony boulderfield

SOILS—Droughty, locally and sporadically wave-washed during storms; 70% cover of boulders 1.2–2.4 m diam, emergent over a shifting soil of stones (80%), gravel (15%), and finer material (5%).

VEGETATION—Less than 2% of the ground is covered by isolated plants (especially *Salicornia australis*) or small clumps of vegetation on accumulated patches of fine-textured soil where the main species are: *Selliera radicans, Salicornia australis, Atriplex novae-zelandiae, Juncus maritimus, Scirpus nodosus, Triglochin striatum, Apium australe,* and *Samolus repens.*

Included in this vegetation type are areas of platform 1 which are not yet covered in deep gravel and stones. With strong salt influence and a very mobile coarse substrate there is unlikely to be much development of this vegetation.

However, the substrate of this vegetation type is probably being buried under wave-thrown gravel and stones which will result in an edaphically induced seral change to gravel and stone field.

A2—Gravel and stone field

SOILS—Droughty soils of stones and gravel with emergent boulders 0.9–2.4 m diam.

VEGETATION—Less than 1 % of the total area is vegetation-covered, with a variety of salt-tolerant species, especially: *Apium australe, Atriplex novae-zelandiae, Juncus maritimus, Salicornia australis, Samolus repens, Scirpus nodosus, Selliera radicans,* and *Triglochin striatum.*

This vegetation covers gravelly and stony areas of the currently forming beach (beach ridge 0 and some areas of platform 1). The substrate is very unstable and is frequently shifted and wave-washed during heavy seas. Compared with the older raised beach ridges, beach ridge 0 is very poorly developed, suggesting that the general trend is likely to be a continuing build-up of gravel and stones. This accumulation will probably extend over platform 1 to meet beach ridge 1 as has already occurred at the northern end of the survey area between these beaches, and as occurred between beaches 4 and 5 with a similar range of uplift. As the build-up proceeds more stable conditions may prevail for periods, thus possibly allowing greater vegetation development.

A3—Gravel and stone field with *Glaucium* and *Plagianthus*

SOILS—Over 95 % of the area is covered with coarse material: boulders 0.3–0.6 m diam. (10% cover), emergent over stones (80%), and gravel (5%).

VEGETATION—Total cover is <5%. Local patches of *Glaucium flavum* or *Plagianthus divaricatus* cover up to 10 % of the ground surface. Other locally important species are: *Cassinia leptophylla, Cirsium vulgare, Cyperus ustulatus, Muehlenbeckia complexa,* and *Silybum marianum.*

This vegetation occurs on areas of beach 1 where there is a deep accumulation of gravel and stones. Without or until further geologic uplift, development of this vegetation will be very restricted by extreme exposure to salt spray and occasionally to wave-wash.

Ad1—*Plagianthus* shrub boulderfield

SOILS—Predominantly boulders with smaller proportions of stones and shingle, the relative proportions of these texture categories varying with the situation. A 60–90% cover of emergent boulders.

VEGETATION—This shows a general gradation from that on the adjacent platform 2 to that on platform 1 (stony boulderfield, A1). *Plagianthus divaricatus* predominates, in places forming an almost complete cover between the boulders.

Vegetation of this type is found where large seaward boulders have greatly retarded or prevented the build-up of stones and gravel on beach ridge 1. Exposure and skeletal soils are probably the most important factors limiting vegetation change, making this virtually a climax vegetation type under the prevailing conditions.

B1—*Leptocarpus/Samolus – Apium* herb reedland

SOILS—Peaty with local pools, both permanent and seasonal; 50 % cover of boulders 1.0–1.2 m diam., partly buried in fine-textured soil with 10–20 % gravel and stones.

VEGETATION—

1. 0.6–1.5 m; *Cortaderia toetoe* (5 %) and *Phormium tenax* (2 %).
2. Up to 0.9 m; *Leptocarpus similis* (80 %), *Plagianthus divaricatus* (5 %), and *Olearia solandri* (2 %); 80–90 % total cover.
3. Up to 0.2 m; *Samolus repens* (50 %) and *Apium australe* (20 %); 70–80 % total cover.

This is a young community (being on the platform raised from the sea in 1855) strongly influenced by salt spray and water-logged soils.

B2—*Leptocarpus–Typha* herb reedland

SOILS—Boggy, periodically flooded peats and peaty soils with emergent boulders –up to 30 % cover, 1.0–2.0 m diam.

VEGETATION—
1. 0.3–1.2 m; *Leptocarpus similis* ((15)–40–75%) and *Typha orientalis* ((5)–25–30 %); *Leptospermum scoparium* growing peripheral to emergent boulders on slightly raised peat (5–10% overall); locally: *Phormium tenax* (up to 5 %) and *Cyperus ustulatus* (up to 10 %); (30)–80–100 % total cover.
2. Bog-herbs (*see* vegetation type B3), 20–90 % cover, with the greatest development where the upper stratum is poorly developed.

B3—Herbfield

SOILS—Bogs and pools; peats and peaty soils with varying proportions of fine-textured alluvium, the proportion depending primarily on the proximity of streams. Boulders are locally emergent but not covering more than 5 % of the surface because the presence of boulders tends to encourage the growth of tussocks and shrubs. In some areas more or less permanent pools exist, but most of this vegetation does not carry surface water except after rain and during winter.

VEGETATION—
1. Marginally and around emergent boulders, scattered small *Phormium tenax, Leptospermum scoparium, Cassinia leptophylla, Carex secta,* and *Juncus* spp.
2. A great variety of species forming a low-growing tight mat of herbaceous vegetation on the bog areas. Locally the vegetation may be dominated by one species, e.g., *Centella uniflora, Eleocharis* spp., *Hydrocotyle americana,* small *Juncus* spp., *Marchantia polymorpa* (Hepaticae), *Nertera cunninghamii, Schoenus* spp., *Scirpus prolifer,* and other *Scirpus* spp.

In the pools true aquatic plants are found, these include: *Azolla rubra, Callitriche stagnalis, Lemna minor, Ludwigia palustris, Myriophyllum elatinoides, Nasturtium officinale, Polygonum persicaria, Potamogeton cheesemanii, Ranunculus fluitans,* and *R. rivularis.*

Total vegetation cover is approximately 90–100% with bare peat areas covering up to 10 %.

Trampling by cattle seriously breaks up the vegetation mat and grazing probably affects the species composition. If stock were removed this vegetation type could be short lived with invasion of shrubs and tussocks.

The pools are being infilled with fine alluvium and the accumulation of peat. This is accompanied by invasion by *Typha orientalis* (vegetation type B4) or the progressive replacement of aquatic plants by bog-herbs.

B4—*Typha* herb reedland

SOILS—Mires with more or less permanent surface water. Peats with or without occasional emergent apices of boulders.

VEGETATION—
1. Up to 2.0 m; summer-green dense growth of *Typha orientalis.*
2. Bog-herbs (*see* vegetation type B3) forming a complete cover between the *T. orientalis* bases, except where the surface mat of vegetation is broken by cattle trampling.

The margins of *T. orientalis* swamps are favoured feeding areas of cattle which heavily graze and trample the vegetation mat.

B5—Grass herbfield

Soils—Boggy to moist peaty soils. Scattered emergent small boulders.

Vegetation—

1. 0.3–1.0 m; *Cyperus ustulatus*, *Carex* spp., and *Juncus* spp. (each about 5 % cover).
2. Mixed grassland species (vegetation type B7) and bog-herbs (vegetation type B3), total cover about 80 %.

This vegetation type is found on areas of reasonably firm substrate where alluviation and peat accumulation have raised the soil surface above the water table. Proximity to grassland areas provides a high stock influence favouring pasture development.

B6—*Silybum* herbfield

Soils—Gravel and stones with moist, black, friable, peaty soil filling the interstices.

Vegetation—*Silybum marianum*, about 50 % cover, with bare soil between the *S. marianum* clumps. The soil is superficially cultivated by hooves of stock (mainly sheep).

This is an area of beach ridge margin which is used by stock as a camp.

B7—Grassland

Soils—Skeletal or young soils of recently deposited alluvium varying from silt and clay around the fan margin to deep gravels and stone beds (with little fine-textured material) towards the upper fan areas.

Vegetation—

1. 0.3–1.2 m; scattered plants of *Coprosma propinqua*, *Muehlenbeckia complexa*, and *Cassinia leptophylla* (each with up to 5 % cover); other more restricted species are *Hymenanthera crassifolia*, *Leptospermum scoparium*, *Ulex europaeus*, and *Urtica ferox*.
2. $<$0.2 m; mixed grassland normally close-cropped, 60–100 % cover (the lower values on more stony soils where there is more bare rock and soil). Species composition varies considerably with the following being of major importance: *Acaena ovina*, *Anthoxanthum odoratum*, *Dactylis glomerata*, *Lolium perenne*, *Notodanthonia unarede*, *Silybum marianum*, exotic *Poa* spp.*, and *Trifolium* spp.*. Other locally important species: *Aira caryophyllea*, *Bromus mollis*, *Cirsium vulgare*, *Erodium cicutarium*, *Geranium molle*, *Holcus lanatus*, *Hordeum murinum*, *Hypochaeris glabra*, *Lagurus ovatus*, *Leontodon taraxacoides*, *Oxalis* aff. *corniculata*, *Rumex acetosella*, *Sagina procumbens*, and *Taraxacum officinale*. Indigenous grasses (except the widespread *N. unarede*) are important mostly in areas of boulders and stones.

It is evident from an examination of early aerial photographs (1941) that this vegetation type has decreased considerably in extent with the invasion of browse-tolerant shrubs, especially *Coprosma propinqua*, *Muehlenbeckia complexa*, and *Cassinia leptophylla*. This leads to vegetation type db7. Pasture growing under tussocks and shrubs in other vegetation types is similar to the above in composition but herbs tend to be of greater importance. Herbs that are common in these situations include *Centella uniflora*, *Dichondra repens*, *Hydrocotyle* spp., *Nertera cunninghamii*, and *Prunella vulgaris*. In other cases, where soils tend to be boggy, the grassland species are mixed with bog-herbs (*see* vegetation type B3).

**see* Appendix 1.

Bc1—*Phormium* tussock herbfield with *Leptospermum*

SOILS—Boggy, peats or peaty soils with few emergent boulders -5-20-(70)% cover, 0.5-3.0 m diam.

VEGETATION—

1. 1.0-3.0 m; *Phormium tenax* (15-30%) and *Leptospermum scoparium* (approximately 5%) 5-10 years old; scattered *Cortaderia toetoe* and *Cassinia leptophylla;* 20-40% total cover.
2. 0.6-1.0 m; *Cyperus ustulatus* (5%) and *Typha orientalis* (5-10%); local areas of *Leptocarpus similis* (up to 15%) and scattered *Carex* spp., 10-20% total cover.
3. Bog-herbs, 40-60% cover.

Bd1—*Leptocarpus*- *Leptospermum* shrub reedland

SOILS—Boggy to moist peats and peaty soils with emergent boulders—up to 20% cover, 0.6-1.0 m diam.

VEGETATION—

1. 0.3-0 6 m; *Leptocarpus similis* (90%) *Leptospermum scoparium* (60%); 100% total cover.
2. Poorly developed bog-herb stratum; particularly *Blechnum capense,* bryophytes, *Centella uniflora,* and *Nertera cunninghamii;* up to 50% cover locally.

cb1—*Cyperus* herb tussockland

SOILS—Moist, fine-textured alluvial material which has buried most of the boulders, stones, and gravel of the raised beaches.

VEGETATION—

1. 0.5-1.0 m; *Cyperus ustulatus* (50-95%), *Carex* spp. (up to 10%), and *Juncus* spp. (up to 10%); scattered *Cassinia leptophylla, Coprosma propinqua,* and *Olearia solandri;* 60-100% total cover.
2. Shade-tolerant herbfield particularly of more or less etiolated *Hydrocotyle americana* and *Silybum marianum.*

This vegetation grows at the toe of each recently or currently active alluvial fan. It is a soil-controlled vegetation type.

cb2—*Cyperus* herb tussockland with *Carex*

SOILS—Mires, some seasonally dry, peat or peaty with varying proportions of fine-textured alluvium. Boulders mostly buried, but tops (0.5-1.0 m diam.) are locally emergent and cover 1-5-(50)% of the area.

VEGETATION—

1. 0.6-0.9 m; *Cyperus ustulatus* ((5)-20-50%), *Carex* spp. (5-20%), *Juncus* spp. ((0)-3-10%), and *Leptospermum scoparium* ((0)-5-10%); locally *Phormium tenax* (to 2.0 m) and *Cassinia leptophylla* occur; 20-70% total cover.
2. Bog-herbs of mixed species, 10-70% total cover.

cb3—*Cyperus*-*Juncus* grass tussockland

SOILS—Moist, boggy during winter, peaty with a high proportion of fine-textured alluvium. Locally the tops of boulders are emergent-up to 20% cover, 0.3-0.9 m diam.

VEGETATION—

1. 0.6-1.0 m; *Cyperus ustulatus* ((5)-20-40%), *Carex* spp. (5-20%), and *Juncus* spp. ((0)-10-30%); scattered *Cassinia leptophylla, Leptospermum scoparium,* and *Olearia solandri* are present in some areas; 20-60% total cover.
2. Grassland, (15)-40-80% cover, best developed where upper stratum is absent.

C1—*Phormium/Cyperus* tussockland

SOILS—Wet peats with local drier peaty areas. Emergent boulders-30 % cover, 1.5-1.8 m diam.

VEGETATION—

1. Up to 2.0 m; *Phormium tenax*, badly damaged by stock, 10–30 % cover.
2. 0.3–1.2 m; *Cyperus ustulatus* (20 %), *Carex* spp. (5 %), *Coprosma propinqua* (5%), *Olearia solandri* (5%), 30–40% total cover.
3. Bog-herbs and boggy grassland, 10–20% cover.

This is vegetation growing in peaty soils developed superficially over a gravelly and stony substrate, with some xerophytic species still present.

C2—*Phormium* tussockland

SOILS—Boggy peats or peaty soils surrounding emergent boulders (up to 50 % cover).

VEGETATION—

1. 1.8–2.7 m; *Phormium tenax*, 70–100 % cover.
2. 0.3–1.0 m; *Carex* spp. (up to 20 %), *Cyperus ustulatus* in canopy gaps (up to 20 %).

Cd1—*Phormium–Olearia* shrub tussockland

SOILS—Boggy, peats or peaty soils with few emergent boulders-5–20-(70) % cover, 0.5–3.0 m diam.

VEGETATION—

1. 2.5–4.0 m; isolated *Coprosma repens* and *Cordyline australis*.
2. 1.2–2.5 m; *Phormium tenax* (20–60 %), *Olearia solandri* (15–30 %), *Cassinia leptophylla* (10–25 %), and *Leptospermum scoparium* ((5)-15–30 %); scattered *Cortaderia toetoe* (up to 10 %); 60–100 % total cover.
3. 0.3–1.2 m; local areas of: *Coprosma propinqua* (up to 10 %), *Cyperus ustulatus*, and *Carex* spp. (up to 15 %), *Juncus* spp. (up to 10 %), and *Plagianthus divaricatus* (up to 5 %); 0–20 % total cover.
4. Local areas of bog-herbs where the canopy of higher strata is broken.

db1—*Coprosma–Muehlenbeckia* grass shrubland

SOILS—Boulders buried in a droughty, gravelly, and stony soil with only occasional tips of boulders (0.2–0.4 m diam.) emergent above the soil surface. For physical analyses of this soil type *see* the section on beach ridge soils and root distribution.

VEGETATION—

1. 0.3–1.2 m; *Coprosma propinqua* (20–50 %), *Muehlenbeckia complexa* (20–40 %), and *Hymenanthera crassifolia* (10–20 %); 70–80 % total cover; other locally important species are: *Calystegia tuguriorum, Clematis forsteri, Coprosma crassifolia, Rubus squarrosus*, and *Urtica ferox*.
2. Mossy, weedy grassland (20–40%) and lichen- or bryophyte-covered stones (60–80 %); composition of the grassland very variable (*see* vegetation type B7).

db2—*Coprosma–Muehlenbeckia* grass shrubland with *Olearia* and *Cassinia*

SOILS—Closely resembling those under the db1 vegetation type but with a greater build-up of organic and fine-textured material in the upper layers of gravel, especially over buried boulders. The soils, however, are still very droughty.

VEGETATION—

1. 0.3–0.9–(1.3) m; *Coprosma propinqua* (20–40%), *Muehlenbeckia complexa* (20–40–(60) %), *Hymenanthera crassifolia* (10–15–(20) %), *Cassinia leptophylla* ((0)-5–15 %), and *Olearia solandri* (5–15 %); additional species

locally important: *Pennantia corymbosa, Plagianthus divaricatus,* and *Urtica ferox;* 65–95% total cover.
2. Mossy pasture of mixed species (70–80–(90)%) and bryophyte- or lichen-covered boulders ((10)-20–30%).

db3—*Coprosma/Muehlenbeckia* grass shrubland

SOILS—Alluvium-filled beach ridges. Scattered boulders–0.3-1.5 m diam. and 5–10–(30)% cover, emergent from gravelly and stony soils with interstices filled with fine-textured alluvium locally capped with thin layers of peat.

VEGETATION—
1. 2.0–2.7 m; *Leptospermum scoparium* (0–5%).
2. 0.6–1.8 m; *Olearia solandri* (0–10%), *Phormium tenax* (0–5%), and *Coprosma propinqua* (0–30%); 5–30% total cover.
3. 0 3–1.0 m; *Cyperus ustulatus* (5–10%), *Muehlenbeckia complexa* (0–30%), *Plagianthus divaricatus* (0–20%), *Cassinia leptophylla* (0–10%), and *Carex* spp. (0–5%); 10–30–(60)% total cover.
4. Mixed grassland and herbfield, 30–90% cover.

This is a rather variable vegetation type characterised by soil development through alluvial deposition of fine material in raised beach ridges.

db4—*Leptospermum/Leptocarpus* reed shrubland

SOILS—As described for vegetation type Bd1.

VEGETATION—
1. 1.0–2.4 m; *Leptospermum scoparium* (80%), *Phormium tenax* (15%); 90% total cover.
2. Up to 1.0 m; *Leptocarpus similis* (5–50%), *Olearia solandri* (up to 5%), and *Cassinia leptophylla* (up to 5%); 10–50% total cover.
3. Poorly developed bog-herb stratum, as described for vegetation type Bd1; up to 50% cover locally.

db5—*Leptospermum–Cassinia* herb shrubland with *Phormium*

SOILS—Wet peats and peaty soils with ephemeral pools and local raised dry areas. With or without emergent boulders–up to 50% cover, 0.6-3.0 m diam.

VEGETATION—
1. 1.8–2.7 m; *Phormium tenax*, local patches, 5–10% cover.
2. 0.6–1.8 m; *Leptospermum scoparium* (20–50%) 5–9 years old, *Cassinia leptophylla* ((10)-30–60%), *Olearia solandri* (up to 5%); 30–70% total cover.
3. 0.3–1.0 m; *Leptocarpus similis* (up to 10%), *Carex* spp. (up to 5%), *Cyperus ustulatus* (up to 5%), *Juncus* spp. (up to 5%).
4. Bog-herbs and boggy grassland, (5)–20–50% cover.

db6—*Leptospermum–Cassinia* herb shrubland

SOILS—As for vegetation type db5.

VEGETATION—
1. Up to 0.6 m; *Leptospermum scoparium* (30%), *Cassinia leptophylla* (30%), *Carex* spp. (5%), *Cyperus ustulatus* (5%), *Juncus* spp. (5%), marginal patches of *Olearia solandri* (5%); 70–80% total cover.
2. Bog-herbs and boggy grassland, 30% cover.

This is an area of vegetation type db5 which has been burned recently.

db7—*Cassinia–Coprosma* grass shrubland

SOILS—Young or skeletal soils on recently deposited alluvium and talus. The alluvial soils range from silts and clays around the margins of alluvial fans to deep gravels and stone beds (with little fine-textured material) towards the upper fan areas. Hill slope soils are of boulders, stones, and gravels with interstices filled with sandy loam; locally, on the steeper gully slopes (up to 45°), there is an unstable superficial layer of boulders and stones.

VEGETATION—

1. 0.3–1.2–(2.0) m; *Cassinia leptophylla* (10–50 %), *Coprosma propinqua* (5–40 %), *Muehlenbeckia complexa* (locally up to 30 %), *Urtica ferox* (5%); locally: *Coprosma crassifolia, Coprosma rhamnoides, Olearia solandri,* and *Pennantia corymbosa* (each up to 5 %); 30–70 % total cover.
2. Grassland, locally with abundant *Silybum marianum* and on hill slopes *Polystichum richardii;* (5)–40–90% cover with lower values on stony or gravelly soils and under dense upper vegetation stratum.

db8—*Coprosma* grass shrubland with *Pennantia* and *Myoporum*

SOILS—As described for vegetation type db7.

VEGETATION—

1. 1.0–4.0 m; *Pennantia corymbosa* (5–10%), *Myoporum laetum* (up to 5%); locally, scattered: *Cordyline australis, Melicytus ramiflorus, Olearia paniculata,* and *Sophora microphylla;* occasional *Corynocarpus laevigatus* relict from previous coastal forest also occur; locally heavily covered by *Muehlenbeckia australis* and *Parsonsia heterophylla;* 5–10 % total cover.
2. 0.9–2.1 m; *Coprosma propinqua* ((10)–50–80%), *Cassinia leptophylla* ((0)–5–25 %), *Urtica ferox* (up to 20 % cover); 50–90 % total cover; climbers are abundant, especially *Calystegia tuguriorum, Parsonsia capsularis, P. heterophylla, Muehlenbeckia complexa,* and *M. australis.*
3. Shade-tolerant herbfield, with grassland relict species and forest or shrubland elements such as: *Asplenium* spp., *Dichondra repens, Galium* spp., *Hydrocotyle* spp., *Polystichum richardii,* and *Gnaphalium* spp.; where inaccessible to stock, seedlings of forest trees such as *Hedycarya arborea, M. ramiflorus,* and *Alectryon excelsum* are surviving; local patches of grassland also occur; 10–50 % total cover.

dc1—*Phormium/Leptospermum* tussock shrubland

SOILS—Boggy, peats or peaty soils with few emergent boulders—5–20–(70) % cover, 0.5–3.0 m diam.

VEGETATION—

1. 1.8–3.0 m; *Phormium tenax,* 30–40 % cover.
2. 1.5–1.8 m; *Leptospermum scoparium,* approximately 50 % cover.
3. Bog-herbs (10 %) with litter from *L. scoparium* and *P. tenax.*

dc2—*Leptospermum/Cyperus* tussock shrubland

SOILS—Platforms with emergent apices of boulders (0.3–1.0 m diam.) covering 20–50 % of the boggy to seasonally boggy soil. Soil between boulders is peat with varying proportions of fine-textured alluvium (peaty soils).

VEGETATION—

1. 1.2–1.8 m; *Leptospermum scoparium* (approximately 20 %) and *Cassinia leptophylla* (approximately 10 %); approximately 30 % total cover.
2. 0.6–0.9 m; *Cyperus ustulatus* (approximately 20 %), *Carex* spp. (approximately 15 %), and *Juncus* spp. (approximately 5 %); 20–25 % total cover.
3. Mixed bog-herbs covering 5–10 % of the soil surface.

D1—*Plagianthus* shrubland

SOILS—Boulders, 0.9–1.5 m diam.; up to 60% cover emergent over droughty soil of stones (85 %) and gravel (10 %).

VEGETATION—

Up to 0 8 m; dominated by *Plagianthus divaricatus* (20 %), *Coprosma propinqua* (15–20 %), *Olearia solandri* (10 %), and *Cassinia leptophylla* (15 %).

This vegetation occurs on gravelly and stony areas of platform 2.

D2—*Olearia/Coprosma* scrub

SOILS—Boulders (1.0–2.0 m diam., up to 50 % cover) emergent over a gravelly and stony soil with the interstices well filled with fine-textured material. Locally there are areas of drier gravel and areas of boggy soil with a thin layer of peat accumulation.

VEGETATION—
1. 0.6–1.5 m; *Olearia solandri* (10–40 %), *Cassinia leptophylla* (15 %), *Olearia paniculata* (<5 %) and *Phormium tenax* (5–10 %); 30–60 % total cover.
2. Up to 0.6 m; *Coprosma propinqua* (40 %), *Hymenanthera crassifolia* (<5 %), *Muehlenbeckia complexa* (up to 40 %), *Plagianthus divaricatus* (<5 %), and *Aciphylla squarrosa* (<2 %); 40–90 % total cover. On local drier gravel patches *P. divaricatus* predominates.

Local swampy areas differ from the above:
1. 0.7–1.0 m; *Leptospermum scoparium* (40 %), *Leptocarpus similis* (50 %), and *C. leptophylla* (5 %).
2. Mat of saltmarsh and bog-herb species especially *Blechnum capense, Centella uniflora, Samolus repens, Selliera radicans,* and *Triglochin striatum.*

D3—*Coprosma* shrubland with *Phormium*

SOILS—Boggy to moist peaty soils generally with a high content of fine-textured alluvium. Emergent boulders-(5)-20–50-(80)% cover, 0.3–2.5 m diam.

VEGETATION—
1. Up to 2.4 m; *Phormium tenax* (5–10 %), *Pennantia corymbosa* (up to 5 %), locally *Melicytus ramiflorus* (up to 5 %); 10–20 % total cover.
2. 1.2–1.5–(1.8) m; *Coprosma propinqua* (10–40%), *Olearia solandri* (up to 10%) important where the cover of *C. propinqua* is low; locally *Coprosma crassifolia* (up to 20 %), *Leptospermum scoparium* (up to 5 %); 30–50 % total cover.
3. 0.6–1.0 m; *Cyperus ustulatus* (10 %), *Carex* spp. (up to 5 %).

D4—*Ulex* shrubland

SOILS—Emergent boulders-0.9–1.2 m diam., and approximately 70 % cover, over a coarse soil of stones (20%) with gravel and sand (70%). The area is low-lying and periodically flooded.

VEGETATION—
1. 0.9–1.2 m; *Ulex europaeus* (70 %) and *Cassinia leptophylla* (<5 %).
2. 0.6–1.0 m; *Cyperus ustulatus,* <5 % cover.

D5—*Cassinia* scrub

SOILS—Small boulders 0.2–0.5 m diam. (50 % cover) emergent from stony (20%) and gravelly (5%) soil with the interstices well filled with fine-textured material.

VEGETATION—
1. 1.2–1.5 m; *Cassinia leptophylla,* 60 % cover.
2. 0.1–0.3 m; *Muehlenbeckia complexa* (10%), *Olearia solandri* (2%), *Coprosma propinqua* (2 %), and *Hymenanthera crassifolia* (2 %); 15–20 % total cover.
3. <0.3 m; grassland (10 %) and litter (20 %).

D6—*Olearia–Cassinia* shrubland

SOILS—Moist, peaty, locally boggy and with ephemeral pools, mostly fine-textured alluvium deposited in previously accumulating peat. With or without emergent boulders–up to 20 % cover, 0.6–2.0 m diam.

VEGETATION—
1. 1.0–2.0 m; *Olearia solandri* ((0)-25–40 %) and/or *Cassinia leptophylla*

((0)–20–30 %); scattered *Coprosma crassifolia, C. propinqua, Leptospermum scoparium,* or *Phormium tenax* are locally present; 20–50 % total cover.
2. <0.3 m; mossy grassland, 10–20 % cover.

D7—*Leptospermum* scrub

SOILS—Boggy to moist peats or peaty soils generally with a thick layer of *Leptospermum* litter, especially in older stands. Scattered emergent boulders, up to 30 % cover; 0.5–1.0 m diam.

VEGETATION—

1. (1.0)–2.0–3.6 m; *Leptospermum scoparium* (80–95 %), (10)–22–34 years old; scattered etiolated *Phormium tenax,* well developed in canopy gaps. Stands selected to represent the range of canopy heights were aged by felling and ring-counting two specimens from each stand. The ages were as follows (plant heights in parentheses): 12(2.7 m), 15(2.1 m), 22 (1.8 m), 27(2.7 m), 28(2.6 m), 34(2.6 m), 34(3.0 m) years old.
2. 0.2–0.6 m; *Hypolepis tenuifolia* and *Pteris macilenta;* up to 10 % total cover. In canopy gaps *Carex* spp., *Juncus* spp., and *Cyperus ustulatus* form a stratum of up to 60 % cover with a lower stratum (up to 30 % cover) of shade-tolerant bog-herbs such as *Centella uniflora, Blechnum capense,* and *Prunella vulgaris.* In some areas dead plants of *Carex* spp., *P. tenax,* and *Cortaderia toetoe* remain under the dense *L. scoparium* cover.
3. A well developed bog-herb stratum; under young (recently burned) stands; cover up to 80 %.

Under tall stands, seedlings of coastal forest trees establish but appear to be too heavily browsed to develop beyond the seedling stage. The *L. scoparium* is not browsed by the sheep and cattle and young dense stands are not frequented by stock. In older stands, however, after the *L. scoparium* has become greatly thinned and the canopy is opening, stock are entering and trampling the peat soils, leaving the surviving trees raised on pedestals of peat. Tree seedlings are browsed, preventing successional advance. The browse-resistant plants such as *L. scoparium, Cassinia leptophylla,* and *Olearia solandri* are all shade-intolerant and so will not regenerate in these areas until the old *L. scoparium* canopy has largely died.

D8—*Coprosma* shrubland with *Corynocarpus*

SOILS—Superficially of moving stones and gravel with scattered small angular boulders–0.6–0.9 m diameter. More-stable, coarse, moist soils of balanced texture below approximately 0.3 m depth.

VEGETATION—

1. 4.6–8.0 m; *Corynocarpus laevigatus,* approximately 5 % cover.
2. 1.0–1.5 m; *Coprosma propinqua* (30 %), *Muehlenbeckia complexa* (10 %), and *Urtica ferox* (5 %); adjacent to streams, *Cyperus ustulatus* (where up to 10 %); 40–50 % total cover.
3. Mossy grassland, 10 % cover.

This is *C. laevigatus* forest at an advanced stage of degeneration with few trees and a developing lower growth of browse-resistant shrubs.

De1—*Myoporum* forest shrubland

SOILS—The soil is described in the section on beach ridge soils and root distribution.

VEGETATION—

1. 6.0–9.0 m; scattered *Myoporum laetum,* approximately 20 % cover.
2. 1.2–3.0–(4.5) m; *Pennantia corymbosa* (5%) with *Muehlenbeckia complexa* and *Muehlenbeckia australis* climbing over crowns.
3. 0.6–1.5 m; *Coprosma propinqua* (10 %) and *Urtica ferox* (5–10 %) covered by *M. complexa* and *M. australis;* 15–20 % total cover.
4. To 0.5 m; *M. complexa* and *M. australis* scrambling over boulders.

This vegetation is growing on an area of beach ridge 5. The tall *M. laetum* trees have grown since Aston's study (Aston 1912).

De2—*Corynocarpus/Cassinia* forest shrubland

SOILS—As described for vegetation type D8.

VEGETATION—
1. 4.5–6.0 m; *Corynocarpus laevigatus* (20–30 %), *Pennantia corymbosa* (5–10%), *Melicytus ramiflorus* (5%), and scattered *Leptospermum scoparium*; up to 40% total cover.
2. 1.0–1.5 m; *Cassinia leptophylla* (20–50%), *Coprosma propinqua* (10%), *Urtica ferox* (up to 10%), and *Olearia solandri* (up to 5%); 20–60% total cover.
3. Sparse herb growth (up to 30 %) in areas of stable soil; important species: *Parietaria debilis, Hydrocotyle americana, Polystichum richardii, Lolium perenne,* and *Anthoxanthum odoratum.*
   The *C. laevigatus* trees appear to be dying without regenerating.

E1—*Corynocarpus* forest

SOILS—As described for vegetation type D8.

VEGETATION—
1. 6.0–9.0 m; *Corynocarpus laevigatus* (80–100 %); scattered *Myoporum laetum, Hedycarya arborea, Alectryon excelsus* (each up to 5 %); occasional *Metrosideros robusta;* about 100 % total cover.
2. 4.6–6.0 m; marginal growth of: *Melicytus ramiflorus* (up to 60 %), *Pennantia corymbosa* (up to 30 %), and *Olearia paniculata* (up to 10 %); 30–90 % total cover in marginal areas.
3. 1.0–1.5 m; *Urtica ferox,* 5 % cover.
4. On hill slopes the ground surface is kept bare by grazing stock, excepting a few scattered herbs or shrubs of, e.g., *Parietaria debilis, Marrubium vulgare,* and seedling *Urtica ferox. Arthropodium candidum* grows between bryophyte-covered stones and boulders where these are stable. On alluvium and areas of beach ridge 4 where the A1 horizon is poorly developed sparse grassland is growing.

APPENDIX 3—DEFINITIONS OF SOME TERMS USED

absolute drought (Bondy 1950): at least 15 consecutive days, to none of which is credited 0.01 in. (0.25 mm) or more of rain.

bog: mire with soil saturated but the whole surface not permanently water-covered (Cockayne 1967).

bog-herbs: species characteristic of vegetation type B3 (herbfield).

fine-textured: fine sand, silt, and clay.

mire: soils where excessive water is the major influence (Burrows & Dobson 1972); including bogs and pools.

moist soils: not saturated or droughty, generally loams, or with a high organic matter content.

partial drought (Bondy 1950): a period of at least 29 consecutive days, during which the mean daily rainfall does not exceed 0.01 in. (0.25 mm) per day.

peats & peaty soils: soils with a high organic matter content (*see* Table 2).

tussock: tall-growing tufted monocotyledons, e.g., *Carex secta, Cyperus ustulatus, Juncus australis, Phormium tenax.*