MANAWATU SAND DUNE VEGETATION

A. E. ESLER

Botany Division, D.S.I.R., Auckland

INTRODUCTION

Coastal sand dunes provide a habitat for plants which can withstand:—

(i) a moving substrate which covers and uncovers their roots, has little capacity to store water and affords no encouragement for seedling establishment;

(ii) strong desiccating winds carrying large amounts of salt and driving abrasive sand;

(iii) widely- and rapidly-changing temperatures, because the sparse cover of vegetation does little to moderate the effects of the high specific heat and high reflectivity of sand.

This, perhaps the most adverse of lowland environments, supports a very limited number of plant species fitted, in various ways, to maintain themselves in such conditions. However, a few species flourish and these, by their growth form and behaviour, play a large part in shaping the topography of the sand country.

This paper examines the interplay of plants and habitat in the changing topography of a dune area north of Himatangi Beach (Fig. 1) on the west coast of the Wellington province.

THE ENVIRONMENT

Sand is brought to the Manawatu coast by a northerly drift carrying erosion debris from the Rangitikei and other rivers to the north. The sand is composed principally of grains of quartz and feldspar up to 0.5 mm. in diameter. The preponderance of these minerals, the small diameters and the shape of the grains contribute to the looseness and free mobility of the sand on the Manawatu beaches. Some other constituents are prominent but not abundant. Shell fragments up to 3 mm. in diameter scud across the sand surface and are deposited in patches with large grains of vesicular volcanic material and other dark pebbles.

Wind is the prime force which moves sand. The wind diagram in Figure 1, constructed from daily wind data for Ohakea 12 miles away and seven miles from the coast, gives some indication of the frequency of winds from different directions. The W. to N.W. winds which account for about half the frequencies are most prevalent and strongest in the spring and summer. Himatangi Beach, with only 32 in. of rain annually, is the driest part of the west coast of the Wellington province. Less than 3 in. falls on each of the windy months and its effectiveness is reduced by rapid evaporation brought about by the winds and high insolation. The direction of sand movement towards the E.S.E. reflects the potency of the prevailing wind in the formation of the dunes. Winds from other directions tend to spread sand deposits accumulated in the lee of objects in the path of the prevailing wind but have little influence on the trend of the dunes. In the exceptional southerly gale of 10 April 1968 blobs of wet sand were carried through the air and deposited several inches deep on parts of the dunes and plains.

Dry sand is moved by the wind until it meets wet sand, vegetation or calmer air in the lee of the dunes. The ability of the wind to move sand increases in wind channels and where it passes over and around solid obstacles in its path. Dunes themselves act as major obstacles and by disturbing airflow create conspicuous deflation where dry sand is exposed near the margins of dunes.

Appreciation of patterns of removal and deposition makes behaviour of sand predictable to some degree and reduces the apparent complexity. I will describe a series of phases of sand movement on an area stretching from Himatangi Beach almost two miles northwards and one mile inland (Fig. 1). In the southern section sand drifts up to half a mile from the fore dune to a tortuous plain running roughly parallel to the beach. Beyond, the dunes are stabilised with marram and the area under study is delimited on the east by plantations separating the fixed dunes from farmland. The fore dune in the northern section has a shorter landward extension and is backed by

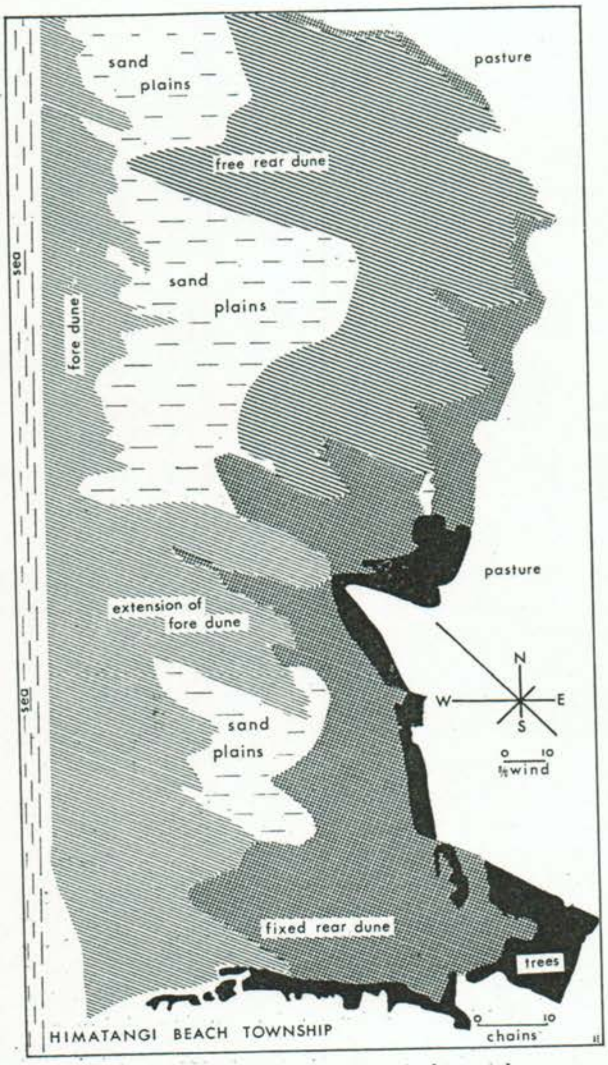

FIGURE 1. *Topographic features of the study area.*

extensive plains beyond which a free dune lying roughly north to south advances towards farmland three-quarters to one mile from the beach. Each section represents a different phase in the dynamics of sand movement.

To the natural patterns of movement and topography determined by the native plants *Spinifex hirsutus*, *Desmoschoenus spiralis* and *Carex pumila* is added the influence of marram grass (*Ammophila arenaria*) the world's best known and most widespread sand plant. Silver poplar (*Populus alba*) is not sufficiently abundant to have an influence. Plantations of pine (*Pinus radiata*) and macrocarpa (*Cupressus macrocarpa*) were established on sand already fixed and they, too, play no direct part.

PHASES OF SAND MOVEMENT

From the early days of settlement until recently sand from an irregular fore dune streamed up to two miles inland along low parallel dunes. Beyond a line now marking the boundary of the farmland (Fig. 1) sand spread in low ill-defined parabolic dunes across flat land. At present, free sand occurs on the seaward strip and a distinct basin separates a rear dune from the fore dune in a manner characteristic of dune areas on the coasts of the United States, British Isles and Europe (see Oosting and Billings 1942; Willis *et al*. 1959; Ranwell 1959; Birse 1958; Harlé 1920).

The plains on the floor of the basin are formed by deflation behind the fore dune and enlarge as the rear dune progresses inland. Initially, a series of narrow basins is created lying parallel to the prevailing wind. Later the longitudinal dunes forming the margins of the basins contract away from the fore dune. In this way basins coalesce and the apices of the incipient parabolic dunes create a single rear dune running nearly parallel to the beach. This rear dune, with an immense wind sweep, progresses inland as sand is carried from the windward face and deposited in its lee.

VEGETATION AND TOPOGRAPHY

Vegetation acts with the wind in moulding the topography of the sand country. Examination of five series of aerial photographs between 1942 and 1968 reveals changes brought about in part, at least, by vegetation. Wilson (1959) indicated that the sand country was fairly stable at the time of European settlement. Grazing of cattle, and possibly burning, caused disturbance and massive sand movement. Wilson stated that *Spinifex* was completely grazed out along the Manawatu coast but was later resown by hand, about 1930, north of Himatangi Beach. The re-establishment of *Spinifex* and the planting of marram beginning in the 1890s have done much to reshape the coastal strip. The spatial sequence of land forms and vegetation in one phase of sand movement stands out clearly in a E.S.E. traverse from the beach

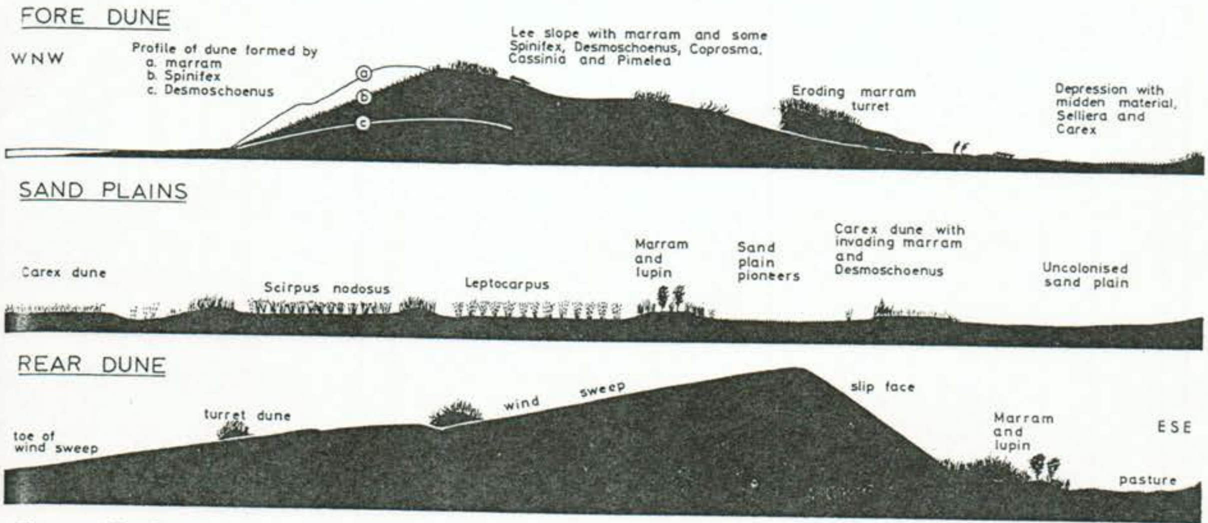

FIGURE 2. *Generalised profile of fore dune, sand plains and rear dune showing topograph and distribution of plant communities.*

to the lee of the rear dune. Figure 2 shows diagrammatically the topography along the traverse and the plant communities associated with the various habitats on the fore dune, sand plain and rear dune.

The fore dune

This has a fairly even height of 10 to 26 ft. above the strand line, a regular seaward face and a long irregular lee slope towards the plains. The profile is characteristic of sand-hills partly stabilised by vegetation but variations are imposed by the occupying species (Fig. 3). Along the Manawatu coast *Spinifex* is the dominant species on the seaward face of the fore dune. In this situation it is superior to marram as a dune builder and stabiliser because it has a greater tolerance of sea-water, provides an even cover, spreads freely down-slope in all directions and rapidly invades fresh sand deposits. The seaward face of a *Spinifex* fore dune slopes very evenly at 14–16 degrees up to a height of 20 ft. where it is frequently capped with marram. Blow-outs do not occur freely and those that do seem to originate where marram or *Desmoschoenus* grow with *Spinifex*. The tendency for *Spinifex* rhizomes to find concavities in the dunes and to gather sand helps to fill incipient channels and thus mould a more regular dune.

FIGURE 3. *Fore dune showing* Spinifex *in the foreground and distance, marram on the steep face, and* Desmoschoenus *on the low gently-sloping face.*

Marram occurs on the seaward side of the fore dune to a small extent but does not thrive in the vulnerable gap just above the strand line that is colonised by *Spinifex* and *Desmoschoenus* in New Zealand and, in the northern hemisphere, by *Agropyron junceiforme*, **Elymus arenarius*, *Fes-*

* *Elymus arenarius* was planted on the Manawatu coast but has not established (Wilson 1959).

tuca rubra var. *arenaria* and a few other species. In the few places where marram occurs alone it builds a dune that is higher and steeper (24–28 deg.) than the *Spinifex* dune. Its clumped habit causes irregular deposition of unprotected sand in its lee and this sometimes leads to wind channelling and blow-outs. As a binder of sub-surface sand it has no equal but this feature is a doubtful virtue. Normally, sand is held among its aerial parts and it is only when deflation occurs that the roots play a major role in retaining sand. If a wind channel develops, extreme coherence by the roots causes the eroding dune to stand like a pillar against the wind. Such a solid barrier accelerates a blow-out by causing deeper wind channels to form around the margins. Once started the process is irreversible. The plant loses vigour and is eroded away without opportunity of spreading into new deposits of sand. This occurs less readily with *Spinifex* because its fast-growing prostrate surface rhizomes often form the nucleus for accumulation of sand.

A fore dune newly planted with marram is very effective in gathering sand but unless tended soon becomes irregular under the influence of the strong winds of the Manawatu coast. The more regular and more stable fore dune that has developed since 1942 is probably a result of the rising ascendency of *Spinifex* over marram and *Desmoschoenus*.

Desmoschoenus is most vigorous where it receives regular additions of sand to keep its rhizomes submerged. These conditions are met on the fore dune. Like *Spinifex* it grows freely down slopes and in this way helps to prevent under-cutting by the wind. However, on deflating sand *Desmoschoenus* soon succumbs. The abundance of dead rhizomes in many places is testimony of its inability to hold sand satisfactorily. However, in such situations its rhizomes are over-represented when compared with those of marram and *Spinifex* which more readily decay and disperse. The greatest weakness of *Desmoschoenus* as a fore dune species is its inability to build a high dune. Where it dominates on the seaward face the dune may be as low as 10 ft. The slope is 8–14 degrees and the surface somewhat convex (Figs. 2 and 3).

The lee slope of the fore dune, in spite of the shelter it receives from the prevailing wind, is an inhospitable place for plants other than marram, *Spinifex* and *Desmoschoenus*, which thrive in the accumulating sand. *Cassinia leptophylla*, *Coprosma acerosa* and *Pimelea arenaria* gain a foothold near the summit but are often more abundant where the fore dune meets the sand plains.

Basins deflated to near the water table are frequent behind the fore dune. Nearly all are colonised by *Selliera radicans* and *Carex pumila*. In some, more than six chains from the beach, there are heat-fractured stones and heaps of shells. If this midden material had been deposited on the beach, say a century ago, it could provide evidence of the rate of advance of the coast which is generally considered to be two or three feet per year. However, as stated by Adkin (1949) and others, it was not customary for the Maoris to open shellfish so near the sea.

The sand plains

These are a mosaic of habitats supporting a variety of plants ranging from those of the wet plains to typical dune species. Dune plants occupy the low sandy ridges which cross the plains. The highest ridges support marram and *Desmoschoenus* but rarely *Spinifex*, which reaches its general landward limit just a few chains from the beach. *Scirpus nodosus* becomes more abundant on the low dunes at little more than a foot above the summer water table in a habitat that also favours the exotic herbs *Oenothera stricta*, *Lagurus ovatus*, *Melilotus indica*, *Medicago lupulina*, *Hypochaeris radicata* and *Leontodon taraxacoides*. Lupin (*Lupinus arboreus*) is abundant on the drier parts of the plains and dunes but has spread only slowly from those places where it appears to have been sown. On plains a little nearer the water table *Scirpus nodosus* gives way to *Leptocarpus similis* and its associated flora of *Schoenus nitens*, *Epilobium billardieranum*, *Juncus holoschoenus* and *Cortaderia toetoe*. These plains have been stable for about 30 years, those in the southern section for a further 10 to 15 years. The age difference is shown by the greater abundance of *Cortaderia toetoe* and *Cordyline australis* and the presence of manuka (*Leptospermum scoparium*) and *Olearia solandri*. It is interesting to note the presence of pampas (*Cortaderia selloana*) which, in this habitat, is the ecological equivalent of its indigenous cogener *Cortaderia toetoe*.

Near the toe of the wind sweep, sand plains of the type described by Esler (1969) develop. Each is separated by a low sandy ridge from a similar plain of greater age on the seaward side (Fig. 4). In some places a series of these occurs but drifting sand usually obscures the earlier members of the sequence. This topography is created, in part, by the removal of sand by wind and, in part, by plants preventing deflation. As the wind sweep progresses inland it leaves at the toe a shallow, damp depression or sand plain, which quickly becomes colonised with sand pioneers, principally *Myriophyllum votschii*, *Limosella lineata*, *Ranunculus acaulis* and *Selliera radicans*. When *Carex pumila* appears it forms a girdle around the depression and collects sand to form a low dune up to half a chain wide. Here marram and *Desmoschoenus* establish freely, build the dune higher and replace *Carex*. At the same time a new depression forms at the toe of the receding wind sweep and another succession of plants is begun.

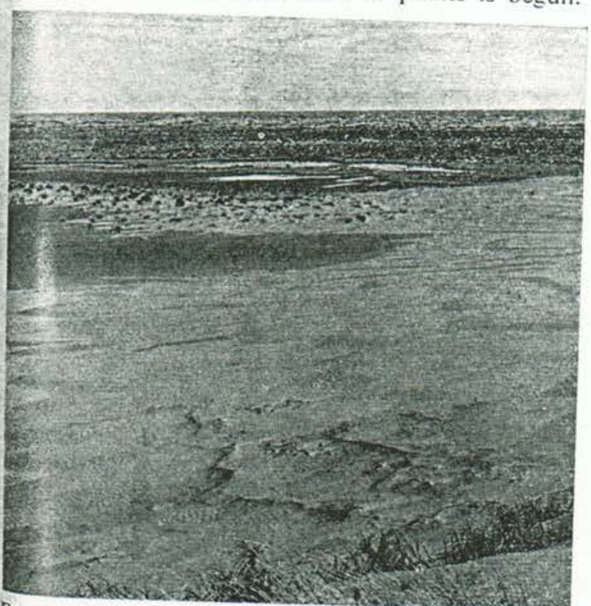

FIGURE 4. *An array of sand plains with uncolonised plain at the toe of the wind sweep in the foreground. Flooded plains with sand plain pioneers and* Leptocarpus *near the fore dune in the distance.*

Lateral sand plains along the bases of longitudinal dunes are formed in a similar manner and where a longitudinal dune is receding the plains follow it to the rear dune and become part of the sand plain at the toe of the wind sweep.

The rear dune

This rises gently from the terminal sand plain to about 30 to 40 ft at its highest points and has a form characteristic of bare or very sparsely vegetated dunes. Sand advances inland on a broad continuous front except where clumps of marram or *Desmoschoenus* divert it into channels. These entrenchments usually end in a 36-degree slip-face pouring sand onto the land beyond. In other places sand movement diminishes in the calmer atmosphere in the lee of the rear dune where it is fixed, to some extent, by marram into irregular steep-sided hills generally less than 40 ft. high. It seems that where this lee stabilisation is effective the wind sweep steepens and the dunes become more stable. This appears to have occurred on the rear dune in the southern section. This dune became fixed in the 1950s with the aid of some planted marram.

It is worthy of note that fixed rear dunes of this nature could not have developed to the same degree in the absence of marram, because the indigenous flora has no species ecologically equivalent to marram as a lee stabiliser.

This topography of basin and ridges which has developed is not permanent and could be preserved only where sand is held near the shore on a rapidly prograding coast. The fore dune in its present form does not have an infinite capacity to hold all the sand that comes ashore. The severity of the wind probably limits the height to which a fore dune can grow. Already in the southern section sand from the fore dune has advanced far across the plains. Ultimately it will reach the fixed dune and start another chaotic phase of sand movement unless steps are taken to arrest it.

There is evidence to show that, in the past, there were long periods when sand accumulated to some degree along the coast and that these were followed by short intervals when sand dispersed inland as parabolic dunes until their mass was expended across flat land in their paths. These ridges became fixed and subsequent levelling of the crests reduced their relief. Three times in 4,000 years this movement has occurred, each period giving a broad belt of dunes and plains which characterise the greater part of the Manawatu sand country (Cowie 1963).

REGIONAL DIFFERENCES

Although the Manawatu region has some patterns of deposition of sand and distribution of plant communities in common with other dune areas along the Wellington coast there are some important differences of degree:—

(i) In the Manawatu, sand plains are very extensive. This is because of a greater inherent instability of the sand, a more effective impelling force and a larger extent of flat hinterland over which sand can spread. By contrast, the plains in Horowhenua and Rangitikei are of very limited extent.

(ii) Few Manawatu dunes on the coastal strip reach higher than 50 ft. In Horowhenua and Rangitikei they are much higher.

(iii) Vegetation differences between the Manawatu and Horowhenua, in particular, are very striking. The Horowhenua sand country supported almost the whole spectrum of communities listed by Cockayne (1911) and modified fragments of most still remain. Sand grass dune, grass dune, semi-stable dune, sand hollow, shrub dune, heath and dune forests were all arrayed within two miles of the coast on surfaces up to 2,000 years old, or more. In the Manawatu the coastal strip has been stable for no more than 50 years and only the sand grass dune (fore dune) and sand hollow (sand plain) occur. Some other communities, i.e. grass dune, scrub dune and dune forest occurred up to 12 miles from the coast on older soils.

Within the Manawatu there are differences between north and south. Between Himatangi and Foxton beaches the unstable belt extends inland for two miles and there has been little artificial stabilisation. The fore dune does not differ essentially from its counterpart in the north but the other dunes tend to be more parabolic with a much less distinctive rear dune, and the sand plains are elongated parallel to the prevailing wind. The greater expanse of free sand and the sparseness of vegetation, either natural or planted, account for many of the differences.

ACKNOWLEDGMENTS

I am grateful for the assistance of Dr E. J. Godley, Mrs M. J. A. Bulfin and Mr C. W. S. Van Kraayenoord in the preparation of this paper. Mr J. M. Stewart's help in many aspects relating to the field work is appreciated.

REFERENCES

ADKIN, G. L. 1948. *Horowhenua: Its Maori place names and their topographical and historical background.* Department of Internal Affairs, Wellington, New Zealand.

BIRSE, E. M. 1958. Ecological studies on the growth-form of bryophytes. III. Relationship between the growth-form of mosses and ground-water supply. *J. Ecol.* 46: 9–27.

COCKAYNE, L. 1911. Report on the sand-dune areas of New Zealand, their geology, botany and reclamation. *Append. J. N.Z. House Repres.* C.-13.

COWIE, J. D. 1963. Dune-building phases in the Manawatu district, New Zealand. *N.Z. J. Geol. Geophys.* 6: 268–80.

ESLER, A. E. 1969. Manawatu sand plain vegetation. *Proc. N.Z. Ecol. Soc.* 16: 32–35.

HARLE, E. 1920. *The fixation of the dunes of Gascony.* Translated from the French by Ruth D. M. McIntyre and E. Phillips Turner. Government Printer, Wellington.

OOSTING, J. H., and BILLINGS, W. D. 1942. Factors affecting vegetational zonation on coastal dunes. *Ecology* 23: 131–142.

RANWELL, D. 1959. Newborough Warren, Anglesey. I. The dune system and dune slack habitat. *J. Ecol.* 47: 571–601.

WILLIS, A. J.; FOLKES, B. F.; HOPE-SIMPSON, J. F., and YEMM, E. W. 1959. Braunton Burrows: the dune system and its vegetation. *J. Ecol.* 47: 1–24.

WILSON, R. A. 1959. *Fifty years' farming on sand country.* Keeling & Mundy Ltd., Palmerston North.