COASTAL DUNE VEGETATION NETWORK

COASTAL SAND DUNES

FORM AND FUNCTION

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Form and Function

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INTRODUCTION

Sand, surf and fun, beach holidays, beach BBQs, beach cricket, beach volleyball, beach baches, a day at the beach, a walk on the beach...all these phrases conjure up thoughts of summer and winter pleasure in one of our most accessible natural assets, the New Zealand coastline. We take our sandy beaches and dunes for granted, but few of us understand the coastal dynamics and the wind and wave forces that can shift huge quantities of sand into the sea or on to the land, often over a short time period.

Sand dunes are valued for many reasons. The landforms have significant intrinsic value and their various forms demonstrate a variety of wind, wave and vegetational processes. They are the natural habitat for specially-adapted plants and animals including indigenous species, several of which are now rare or endangered. Because coastal zones have been favoured for settlement since the earliest human occupation of New Zealand, dune areas contain some of the oldest and most significant evidence of our cultural heritage. They are the present sites of holiday resorts and desirable development areas. A large proportion of New Zealanders live within 10 km of the coastline and many of us have holiday homes there. During the last 80 years more than 115 000 hectares of drifting dunes have been reclaimed for forestry and agricultural purposes. Although there have been obvious gains to the national economy, there has been significant loss of natural coastal habitat and widespread introduction of exotic species. Rapid inventories of nearly all beaches by Partridge (1992) in the North Island and Johnson (1992) in the South Island indicate the high degree of modification to New Zealand sand dunes.

Our beach and dune systems have been significantly changed in the past and different forms of modification will continue into the future. Many areas are currently under tremendous pressure, particularly from recreation and development. If our dunes are to be managed in a responsible way, it is important that we have a full understanding of how dunes function and only then can the possible consequences of human activity be taken into account.

This bulletin aims to provide information on the nature of our coastal sand dunes. It describes the range of dune types, how they form and evolve, and discusses their importance as a significant feature of our national environment.

Terms in bold print are defined in the Glossary.

WHAT IS SAND?

Sand is formed during the erosion of hard rock. It predominantly consists of single grains of minerals such as quartz (siliceous sediment) and may include various other minerals (e.g. feldspar, hypersthene, augite, hornblende, titanomagnetite [ironsand]), and often minor to considerable quantities of calcareous sea shell and rock fragments. Coarse sand has a particle size range of 2.0–0.2 mm diameter; fine sand a diameter range of 0.2–0.02 mm. The physical and chemical nature of coastal sand depends largely on the composition of the rock from which it was derived. Most of the material (such as seaweed) mixed with sand decomposes rapidly and is leached out by sea or rain water. Sand near the coast therefore contains little or no organic matter. Compared with most soils it has very low levels of nitrogen compounds which are essential for plant nutrition. Other plant nutrients may also be in short supply (Carter, 1988; Hesp, 1991).

WHAT IS A SAND DUNE?

Sand dunes are a distinctive feature of about 1100km of the New Zealand coastline. They range in size from small dunes less than 1 metre in height and width, to massive undulating dunefields. All dunes have been formed by wind action resulting in the lifting, transport and deposition of sand grains. They may be a single vegetated ridge at the rear of the beach, or a dune system that extends inland for many kilometres. All dunes are termed **'aeolian'** (wind formed) landforms; the term aeolian is derived from the Greek word Aeolus for the God of Wind.

Dunes are regarded as active or mobile if there is any possibility that exposed, dry (usually unvegetated) sand will be susceptible to further wind action. Highly specialised pioneer plant species, able to withstand drought, high surface temperature, salt winds, sand-blasting and low nutrient availability, are responsible for the commencement of the sand stabilisation process. Fixed or relict dunes are covered by vegetation and can be relatively stable landforms.

WHAT USE ARE SAND DUNES?

Coastal sand dunes

- act as an essential store of sediment protecting the hinterland from storm erosion and potential sea level rise;
- with vegetation, trap wind blown sand and stabilise beaches and dunes;
- provide specialised habitats for plants, birds and animals;
- along with beaches, represent one of the most dynamic natural ecosystems in our environment;
- provide us with a range of unique landforms and ecosystems which have high natural character value;
- act as a filter for rainwater and groundwater, and provide a range of aquatic habitats (e.g. dune lakes);
- if utilised wisely, provide recreational and living space.

WHERE DOES COASTAL SAND COME FROM ?

To understand the formation of the present New Zealand coastline it is necessary to trace events that have occurred over the last three million years. This era has been characterised by alternating cold Glacial periods (ice ages) and warmer Interglacial periods (such as the one we are experiencing now). Interglacial peaks have occurred at approximately 100 000 year intervals. During Glacial periods, the continental and polar ice sheets expand and the sea level falls. The last low sea level, about 120 metres below present sea level, occurred 18 000 years ago in the last Glacial period. Subsequently, the ice caps melted, and the sea level rose, attaining its present position about 7000 to 6000 years ago (Figure 1).

Coastal landforms such as estuaries, cliffs and dunes, which existed when the sea was at its lowest level during the last Glacial period, were eroded by the rising sea (termed a **sea level transgresssion**). Materials eroded from them, together with other sediments from the sea floor and those supplied by rivers, were transported landwards and reworked into new landforms. Thus, the latest sea level transgression provided a major forcing function which drove sediments up the former continental shelf, forming the first, generally most landward portions of the **Holocene** beaches and dunes we now see at, or near the coast (Figure 2). At the same time, the sea flooded river valleys and glacial troughs, forming estuaries, coastal lakes and fiords. Where the slope of the land/seafloor was steep and sediment supply limited, cliff formation typically occurred. Note that there are older **Pleistocene** dunes present on the NZ coast. These were formed during earlier (Pleistocene) glacial and interglacial periods.

Ever since the formation of our oldest Holocene dunes, 10 000–6000 years ago, a variety of factors have been influencing the nature and distribution of sediments and the evolution of the coast. These include: volcanic and tectonic processes (eruptions, earthquakes, uplift and downwarping); the geological structure and mineralogy of eroded rock types; river dynamics and sediment supply; variations in sediment supply; and the force of wind, waves, tides and currents. The influence of each of these factors varies from place to place; in various combinations they have influenced the distribution of sediments and the evolution of the coast to the present day.

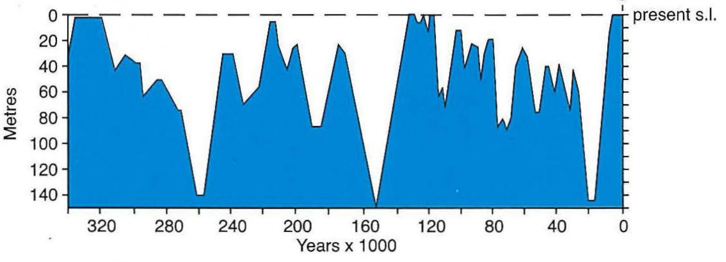


Figure 1. Sea level variation during the Holocene (0–10 000 years) and late Pleistocene.

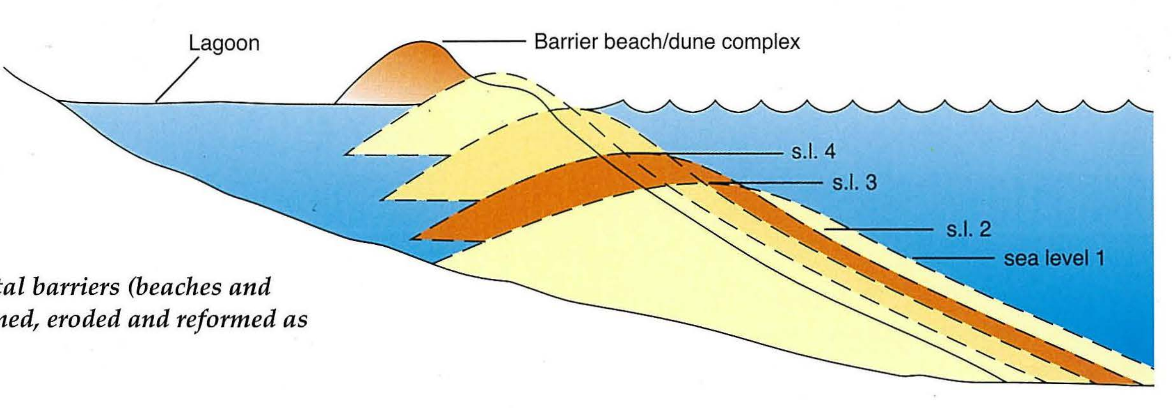


Figure 2. Coastal barriers (beaches and dunes) are formed, eroded and reformed as sea level rises

FEATURES OF A SANDY COAST

Surf Zones and Beaches

The factors listed above govern the way in which sand accumulates on the sea floor or becomes part of the surf zone, beach and dune system. The processes operating in the surf zone and on the beach have a major influence on sand dune formation and dynamics.

Figure 3 illustrates the main features of the beach system. The **nearshore zone** extends from the point where waves first interact with, or 'feel' the sea bottom to the **breakpoint** where waves first break (Figure 3). The **surf zone** is the zone of breaking waves and extends from the landward edge of the nearshore zone to the intertidal area or **swash zone**. The surf zone may contain bars, troughs and rip channels. The upper part of the intertidal area is the swash zone which reaches up to the **swash limit** which is also sometimes referred to as the **wrack** or **drift line**. The **beach** lies between the low tide line and the swash limit. Usually this is the next landward geomorphic feature (usually a sand dune or cliff). It is subject to periods of surface drying which are more frequent on the upper beach or backshore (Figure 3).

Beaches can be classified according to the way in which wave energy is reduced (or diminished) in the surf zone. The interaction between waves, currents and the sea floor slope determines the amount of sand available for both beach and dune formation. **Reflective beaches** (Figure 4a) form where wave energy is low, where coarse sediments predominate and / or where the nearshore zone is relatively deep (e.g. Marine Parade, Napier; several of the northshore beaches of Auckland). Most of the wave energy is reflected back to sea. The beaches are typically narrow and steep. There are no **bars** in the surf zone. Waves typically break as surging or plunging breakers and there can be significant **swash** and backswash. **Dissipative beaches** (Figure 4c) occur on coasts with high-energy waves, fine sediment, or a large sediment supply (e.g. Manawatu beaches, Muriwai Beach). Much of the incoming wave energy is dissipated by repeated wave breaking in an extensive surf zone which usually contains one to several parallel bars and troughs. Dissipative beaches are typically flat and wide and characterised by spilling breakers. **Intermediate beaches** (Figure 4b) lie between the two extremes of dissipative and reflective. They display a combination of wave energy dissipation and reflection, plus rip currents. Bars are commonly transverse (bar lobes that are formed at right angles to the beach), crescentic, or rhythmic (bars forming linked crescents or half-moon shapes alongshore). Intermediate beaches range from

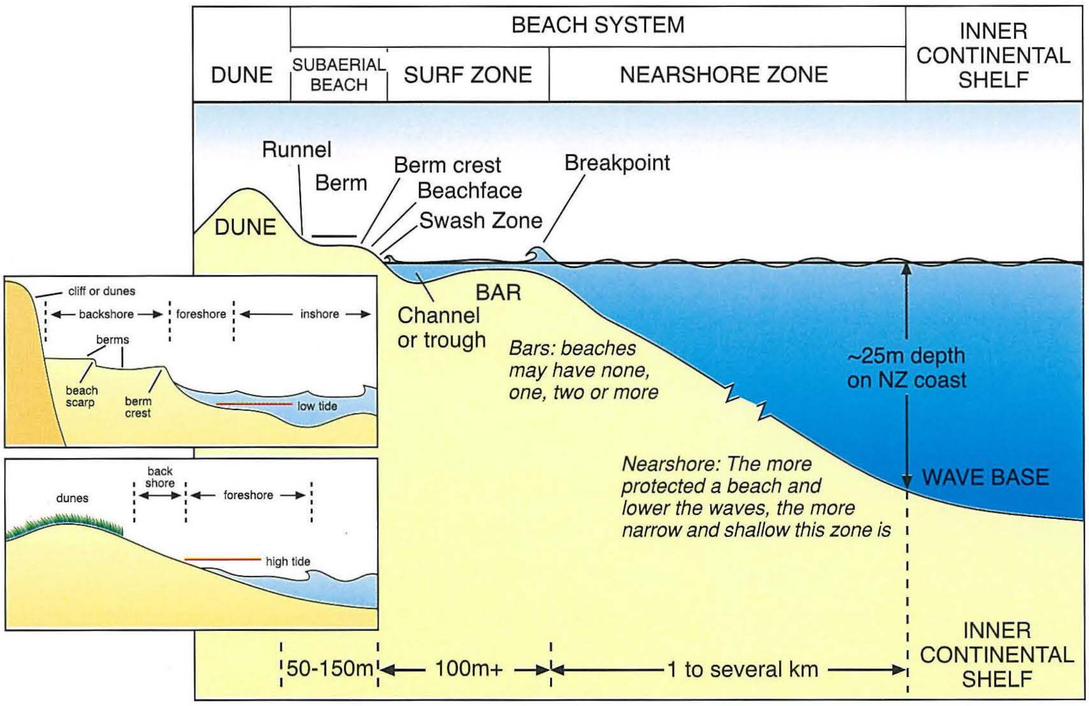


Figure 3. Schematic diagram of the beach, surf zone and nearshore system (© P. Hesp).

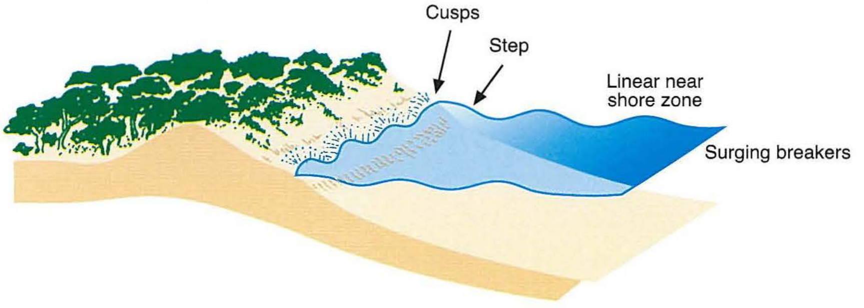


Figure 4a. Schematic diagram of a typical reflective beach (©P. Hesp).

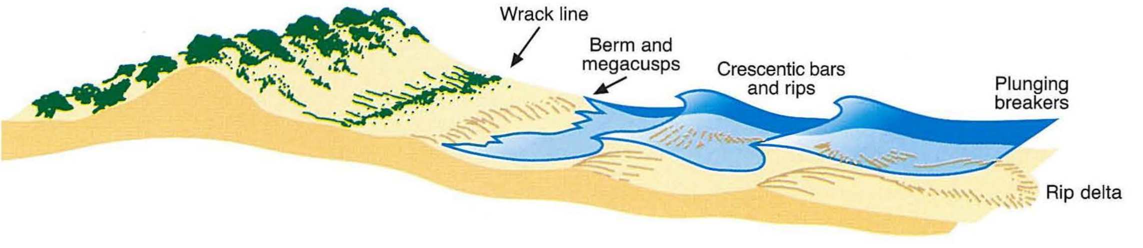


Figure 4b. Schematic diagram of a typical intermediate beach (©P. Hesp).

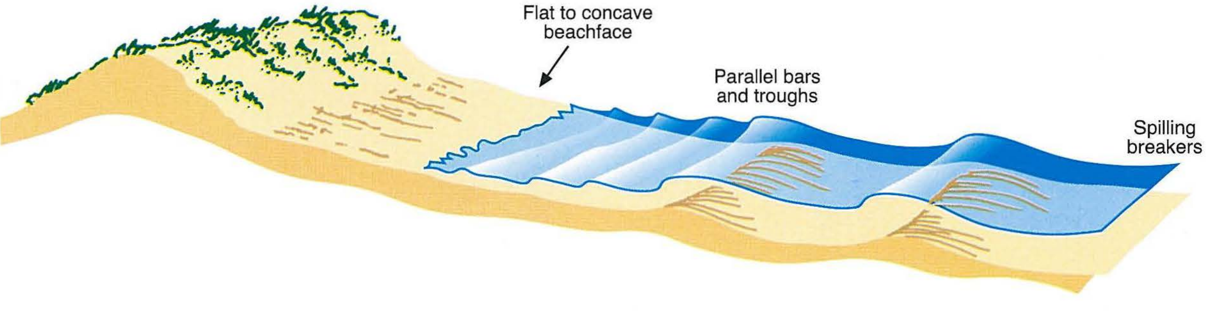
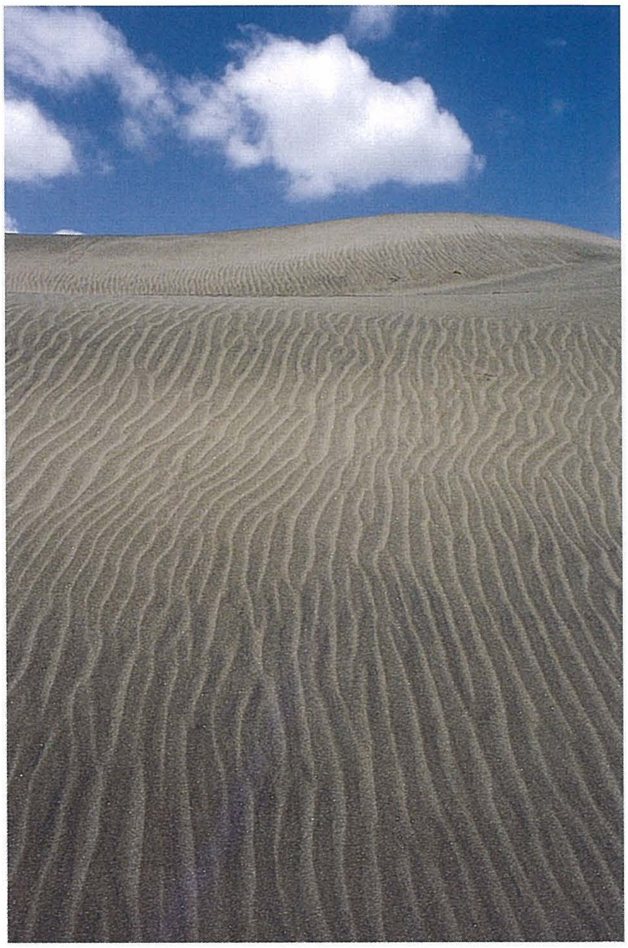


Figure 4c. Schematic diagram of a typical dissipative beach (©P. Hesp).

relatively flat and wide, to relatively steep and narrow. Many of the North and South Island east coast beaches are intermediate beaches (e.g. Wainui Beach, Gisborne; Tairua and many Coromandel beaches; New Plymouth beaches; Christchurch and Dunedin beaches). The intertidal beach and **backshore** may be relatively flat, or may have a **'berm'** (Figure 3). A berm is a wave built terrace landform comprising a seaward swash slope, a crest, and a flat to concave landward terrace slope. Berms may be very pronounced in some cases (e.g. **microtidal** intermediate beaches), subtle forms on some beaches, and generally absent on others (e.g. dissipative beaches).

SAND DUNE FORMATION



Dunes develop at the landward margin of a beach, wherever dry sand is in sufficient supply and onshore winds above a minimum velocity occur. Sand from the dry portion of the beach is blown landwards until either wind energy is dissipated or a physical barrier (such as vegetation) causes the grains to be deposited. Wind strength and direction determine how much sand is transported from the beach. Beach width and the rate of sediment supply determine sand availability. Wave energy, and the form of the beach and surf zone determine the amount of sand delivered from the surf zone and nearshore to the beach. Dissipative beaches tend to have large dunes while reflective beaches are associated with smaller dunes. The frequency and magnitude of storm wind and wave action may also have a significant influence on dune development.

Wind transport of dry sand (aeolian transport)

Sand is transported by wind in two ways: creep (a shuffling or rolling motion) and saltation. The coarsest grains are dislodged once the wind exceeds a minimum threshold velocity and **creep** or roll along the ground. Finer grains are raised above the surface briefly, and then fall in a long descending arc, a process known as **saltation**. When saltating grains collide with the sand surface they push other grains along thereby continuing the creep or rolling motion, and eject other grains into the air, thereby continuing the saltation process. The process of sand removal is known as **erosion**. The process of sand deposition is known as **accretion**.

Patterns of sand deposition and erosion are very strongly influenced by windspeed and surface topography. On average, sand grains start to be moved by the wind when the velocity exceeds around 5 metres per second at a height of about one metre above the sand surface. At low windspeeds, only fine particles are dislodged, but as windspeed increases larger particles are moved, and any displaced particle is carried for a longer distance. As windspeed decreases, larger particles will be dropped first. The wind speed near the surface changes whenever there are changes in topography, vegetation present or some other barrier to sand transport. Flow acceleration occurs as air passes up slopes, or through narrow gaps. Any irregularity or barrier will cause turbulence and potentially result in deposition of transported sand grains. Plant stems and leaves are very effective in modifying wind flow, reducing wind speed and causing sand deposition.

SAND DUNE MORPHOLOGY AND DYNAMICS

Sand deposition, accretion and erosion processes result in the development of a variety of dune forms. There are four major coastal dune types: foredunes, blowouts, parabolic dunes and transgressive dunefields.

Foredunes

Foredunes originate at the landward edge of the beach, parallel to the shoreline. They are formed by wind blown (aeolian) sand deposition within vegetation (Hesp, 1988; 1989; 1999). Actively forming foredunes occupy a foremost seaward position. However, not all foremost dunes are foredunes as other dune types may occupy a foremost position on eroding coasts or on beaches where foredunes are unable to form.

Foredunes generally fall into two main types, **incipient** and **established foredunes**. Foredunes have also been termed 'frontal dunes', 'primary dunes', 'embryo dunes', and, incorrectly, '**berms**' and '**beach ridges**'. Berms and beach ridges are ridges formed by waves, rather than wind, at the limit of storm wave and swash runup. Terms such as **'back dunes'** or **'rear dunes'** are sometimes incorrectly used to describe parts of a foredune such as the crest or lee slope of a foredune. Such terms are colloquial expressions which may be used to generally describe dunes that occur landwards of the foredune (see **glossary**).

Incipient foredunes

Incipient foredunes are newly developing foredunes. Incipient foredunes are initiated where wind-blown sand is trapped by pioneer vegetation on the beach. Sand trapping may be aided by the presence of driftwood. They may be initiated in three ways: within discrete clumps of vegetation; within a community of plant seedlings; and seaward growth of plants (Hesp, 1989).

Incipient foredunes may be formed by sand deposition within relatively discrete clumps of vegetation. This may occur, for example, where spinifex seeds have been buried on the beach and germinate. Such incipient foredunes may be seasonal if formed in **annual plants** (e.g. Cakile species, beach rocket) and require invasion by **perennial plants** (e.g. spinifex; pingao) in order to survive.

Pingao forming on incipient foredune (P. Hesp photo).

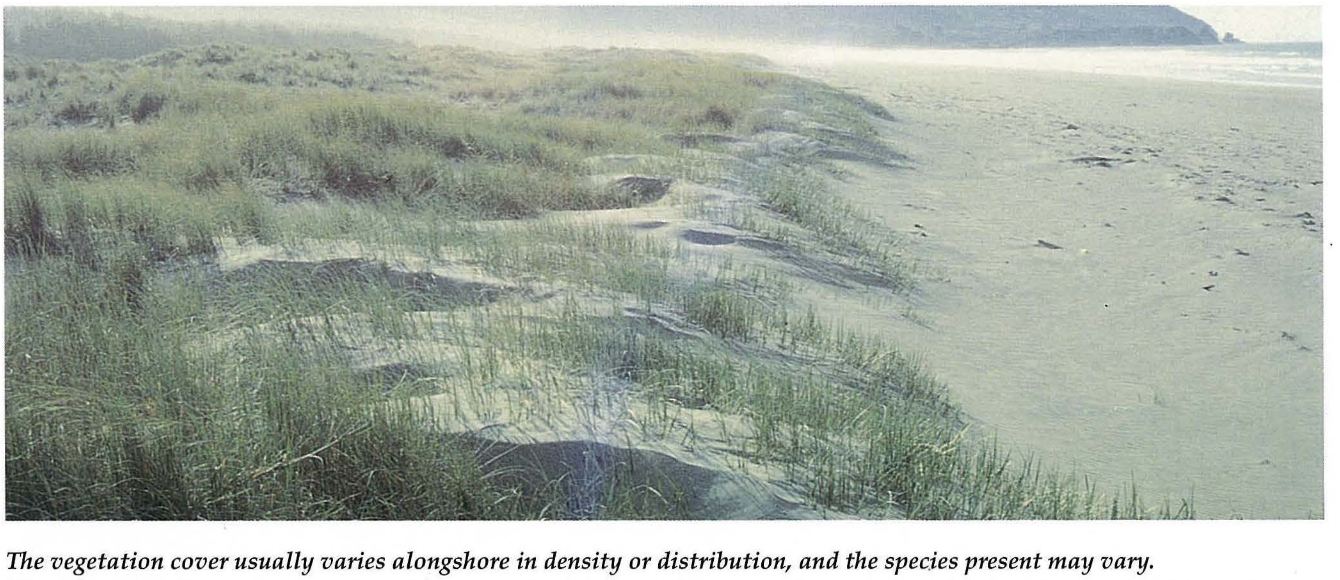
Incipient foredunes may also form on the backshore by either (i) the growth of pioneer plant seedlings in the wrack line (debris line) or spring high tide region, or (ii) by the seaward spread of pioneer vegetation from more landward dunes. The two dominant pioneer native species in New Zealand are *Spinifex sericeus* (spinifex) and *Desmochoenus spiralis* (pingao) while the dominant introduced species is marram grass (*Ammophila arenaria*). These species are characterised by well developed root systems so they bind sand as well as trap sand. Their growth is actually stimulated by sand deposition (Ranwell, 1972; Hesp, 1989; Willis, 1989; Bergin, 1999).

A spinifex incipient foredune terrace initiated by the germination of seeds above the high tide line (P. Hesp photo).

Plant species type is important in determining **morphology** or form of the dune. Species such as the introduced tall, dense marram grass (*Ammophila arenaria*) tend to produce higher, more hummocky peaked dune forms than lower, more spreading, **rhizomatous** and **stoloniferous** plants such as spinifex and pingao which produce lower, less hummocky, more regular dune forms (Esler, 1978).

Incipient foredunes form because the presence of vegetation acts to rapidly reduce wind flow velocities. Sand transported by the wind is gradually deposited and trapped by plants as the wind flow moves across the vegetation (Hesp, 1999). Incipient foredunes generally display one of three forms (or morphological types): ramps, terraces and ridges (Hesp, 1989). The development and form of an incipient foredune principally depends on where it was initiated, plant density, height and cover, wind velocity, rates of sand transport and rates of **beach progradation**. Secondary factors such as the presence of beach debris, rate of occurrence of swash inundation, storm wave erosion, **overwash** incidence, and wind direction can also be important in determining subsequent dune evolution.

Spinifex runners colonising a sand ramp formed against a former foredune scarp (P. Hesp photo).



The vegetation cover usually varies alongshore in density or distribution, and the species present may vary. These factors will determine the morphology of the foredune. The greater the variations in plant density or distribution, and sand supply, the greater the morphological variation. As plant density increases, dunes become higher and shorter (more asymmetric) (P. Hesp photo).

Swales (lee dune depressions) are generally created by the seaward growth (or accretion) of a foredune. They develop as low to limited sand deposition zones behind the foredune, and become more pronounced (in effect, deeper) as seaward incipient foredunes become higher.

An incipient foredune ridge and swale (P. Hesp photo).

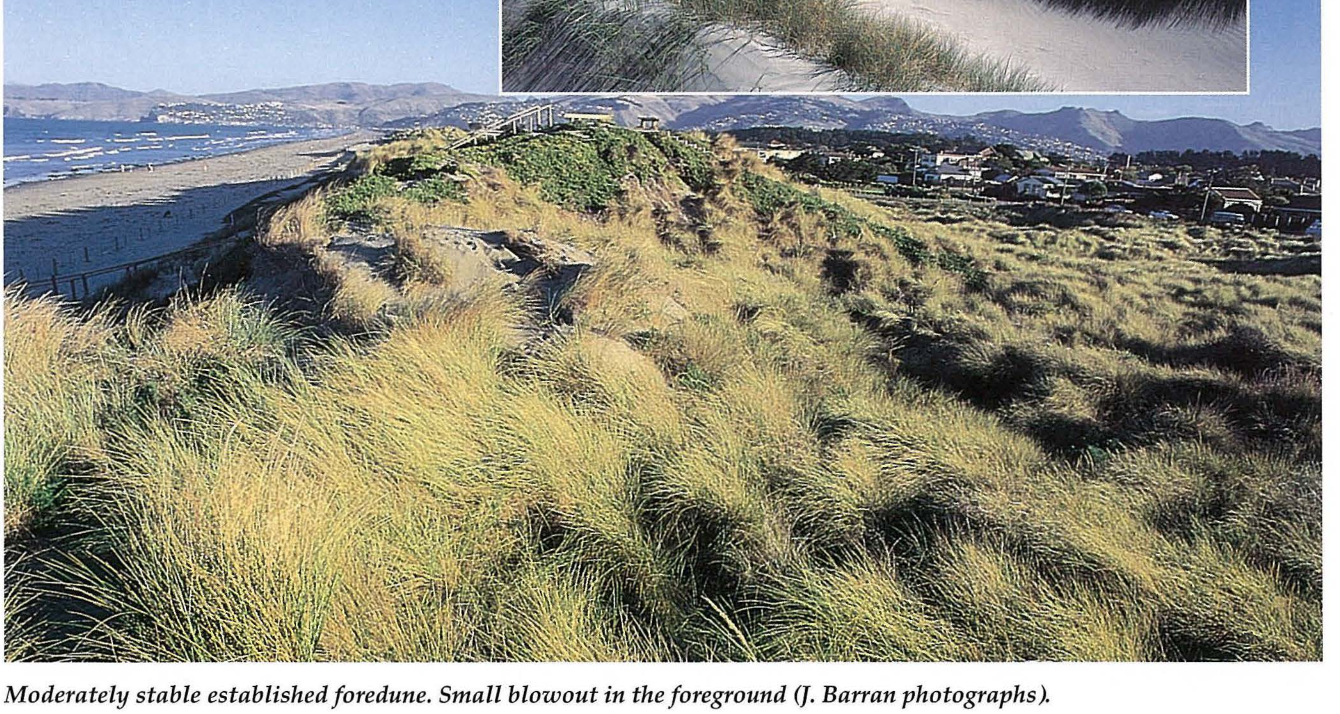
On stable shores, incipient foredunes have an episodic life, tending to be eroded or completely removed by severe storm events. They are commonly scarped by minor to moderate erosion, and grow to the high tide swash limit during periods of sand **accretion**. Sand binding, pioneer plants thrive in this region (and not in more stable dune areas) because they are adapted to the ephemeral and highly dynamic environment of the backshore.

Established foredunes

Established foredunes develop from incipient foredunes and are distinguished by the growth of intermediate, often woody plant species, and commonly by their greater complexity of form, height and width.

As an incipient foredune builds up and out, the landward (or lee) slope becomes more stable, nutrient levels increase, and sand inundation and salt spray levels

Right: ***Highly erosional established foredune.***



Moderately stable established foredune. Small blowout in the foreground (J. Barran photographs).

decrease. The lee slope is gradually colonised by a range of "intermediate" plant species that tolerate somewhat more stable conditions. Sand is gradually deposited on the seaward slope and sometimes the crest of the dune and it slowly becomes larger forming an established foredune.

The development and evolution of established foredunes depends on a number of factors including sand supply, the degree of vegetation cover, plant species present, the rate of wind blown (aeolian) sand accretion and erosion, the frequency and magnitude of wave and wind forces and erosion, dune scarping and overwash processes, beach-surfzone type, the medium to long term beach state (stable, accreting or eroding), and increasingly, the extent of human interference and use.

Established foredunes range from very low dunes a metre or so in height on some coasts dominated by overwash and in areas of limited sediment supply, to up to 30+m in height in some instances. Foredunes may be very well vegetated and stable to poorly vegetated and highly unstable (Figure 5).

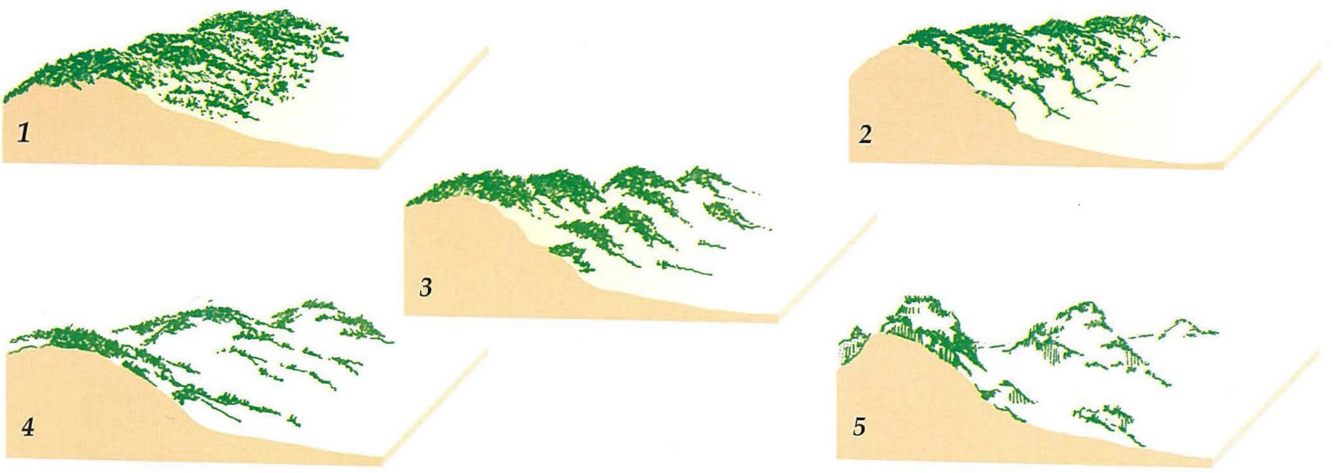


Figure 5. Established foredune types range from well vegetated and stable (type 1) to highly erosional (type 5) (© P. Hesp).

Left: ***Stable, well vegetated type 2 established foredune.***
Centre: ***Hummocky type 3 established foredune.***
Right: ***Highly erosional type 5 established foredune .***
(P. Hesp photos)

Wind flow over foredunes

The wind flow is accelerated over foredunes, particularly up windward slopes and over crests. However, the variable vegetation cover of foredunes and their topographic variability leads to localised variations in wind velocity along, and across foredunes. Such variations become more pronounced as the three-dimensional form of the foredune becomes more complex and the vegetation cover becomes highly variable. Patterns of sand deposition and erosion are very strongly influenced by wind velocity, foredune topography and vegetation cover (Arens *et al.*, 1995; Hesp, 1988). During low wind speeds, deposition on the lower, seawardmost portion of the dune **stoss face** (or dune toe) is most common where the toe is relatively well vegetated. As the vegetation density decreases, sand is transported further up seaward slopes, and this can increase as foredune height and / or steepness increases. High wind speeds may combine with topographic acceleration of wind over dunes to suspend sand grains and transport sediment far across dunes to lee slopes.

Offshore winds may also be important (especially on New Zealand east coasts), resulting in the transport of sediment from dune crests back to the seaward face and beach. Such offshore winds may also result in the closure of blowouts and increase the complexity of foredunes.

Beach and foredune dynamics

Beaches and coastal dunes (especially the foredune) are a dynamic system. The height (and often the width) of the active foredune will continue to increase as long as sand is available and net erosion of the dune by wind or storm waves does not occur. If the shoreline is prograding, the foredune may become isolated from sand deposition by the formation of a new foredune.

High wave energy events and storm surge (an elevation of the mean water level) are natural occurrences and may occur at any time. If storm waves are large enough, or the storm is prolonged, the beach may be significantly eroded and the seaward face of the foredune can be severely cut back (scarped). Subsequently, as sand is again returned to the beach by low energy waves, the eroded beach builds up, sand is blown landwards against the dune scarp and a ramp of sand eventually builds up against the eroded dune face (Figure 6). Plants grow down the eroded dune face and sand ramp and trap and bind the sand, and the eroded dune is gradually repaired. This cycle of dune erosion, dune re-building and stabilisation is quite normal and maintains the foredune as a barrier to the incursion of both sea and sand on most sandy beaches. Disturbance or destruction of sand-binding plants resulting from wave and wind erosion or human activity disrupts the process. Further wind erosion of the scarp and other areas of bare sand leads to the development of blowouts and loss of the natural protective function of the foredune.

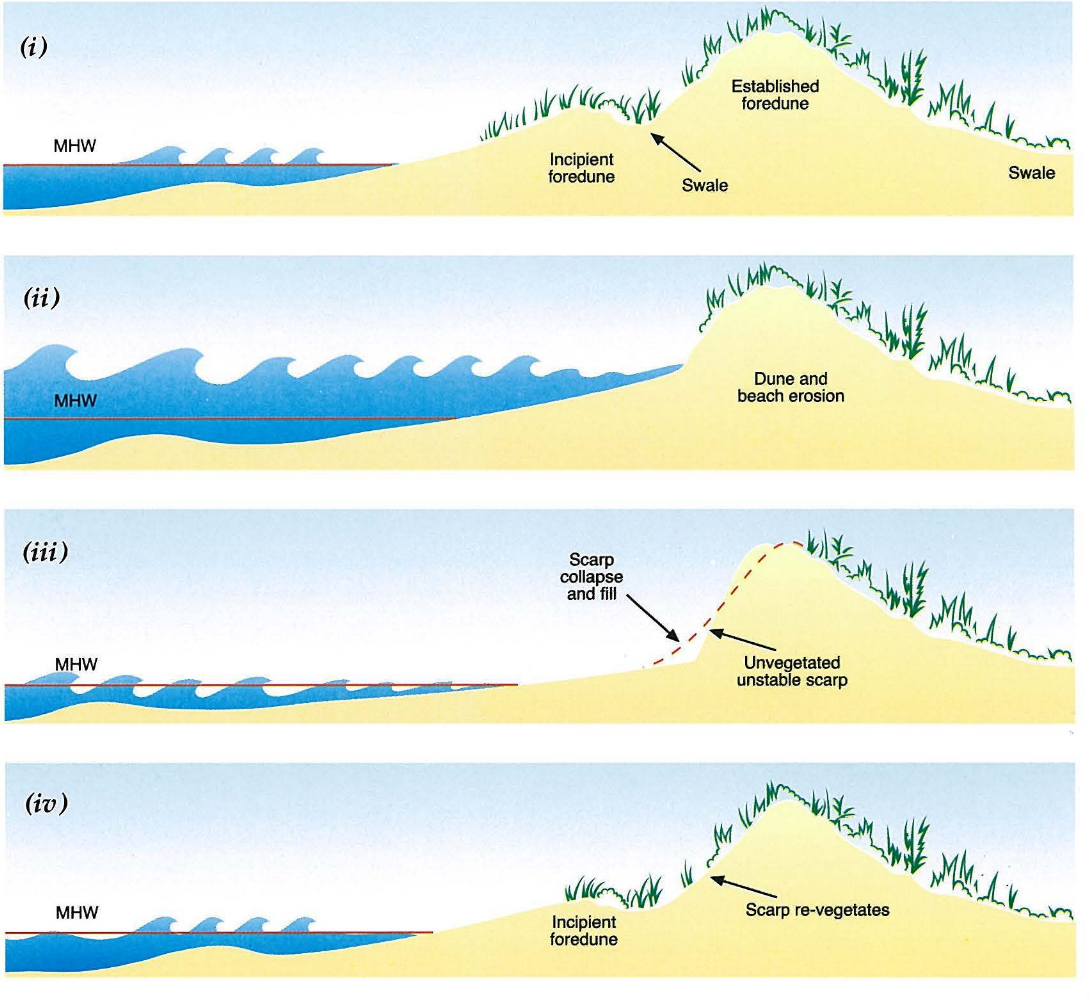


Figure 6. The dynamic beach-dune system:

(i) In good weather (low to moderate waves) waves break on the bar and across the surf zone. An incipient foredune and established foredune are present.

(ii) During storms the entire incipient foredune may be removed, the established foredune scarped and sediment moved seawards to re-establish equilibrium.

(iii) Calm weather returns, waves slowly transport sediment back to the beach. The foredune scarp slope is reduced by slumping and winds transport sand to the scarp base and over the foredune crest.

(iv) Over time the foredune stoss (seaward) slope may re-vegetate and an incipient foredune form. (MHW = Mean High Water) (© P. Hesp).

Vegetation trends on foredunes

Plant successional trends and species richness on foredunes varies as a function of the seasonal or annual volume of sand deposition, the amount of salt spray, and other factors such as nutrient availability, soil development, moisture availability, and age of the dunes. Pioneer species occupy the seawardmost slopes. Further back from the sea, the environmental conditions on established foredunes become less harsh and over time some organic development or soil is established. Shrubs ("intermediate" species) and trees will start to appear, the species present determined by regional climate, local soil and moisture factors, and dune stability. Further inland on landward, lee slopes, again depending on the regional location, coastal and other forest ecosystems existed, but are now rare.

Pioneer plant species give way landwards to intermediate shrubs as nutrient conditions improve and salt spray and sand inundation decreases (P. Hesp photo).

A foredune plain on the lower west coast, South Island (L. Homer, IGNS, photo).

Foredune plains

Foredunes may become isolated from accretion and erosion processes by the development of a new incipient foredune which itself may evolve into an established foredune. The original foredune then becomes a relict foredune as it is largely or wholly removed from a foremost beach position. Systematic beach **progradation** over time frames of tens to thousands of years may lead to the development of wide **foredune plains**. Examples include Matakana Island and the Bay of Plenty coastal plain; Waikanae Beach, Gisborne; north Canterbury coastal plain; and much of the west coast of the South Island.

BLOWOUTS

Blowouts are erosional dune landforms. They are typically saucer-, cup- or trough-shaped depressions or hollows formed by wind erosion of a pre-existing sandy substrate or dune.

Blowouts are characterised by a deflation (or erosional) basin, floor or depression, lateral erosional walls, and a downwind depositional lobe. The sand eroded by wind from the deflation basin and the adjacent walls is deposited immediately downwind to form the depositional lobe (Hesp and Hyde, 1996).

Blowouts may be highly variable in shape, but many can be classified into one of two types: **saucer** and **trough blowouts** (Figure 7). Saucer blowouts are semi-circular or saucer-shaped and often appear as shallow dishes. They develop on relatively flat dune terrain, low slopes or on the crests of dunes. Deeper cup- or bowl-shaped blowouts may evolve from these. Trough blowouts are generally more elongate, with deeper deflation floors and basins, and with steeper, longer erosional lateral walls or slopes.

Above: A deep, narrow trough blowout (P. Hesp photo).

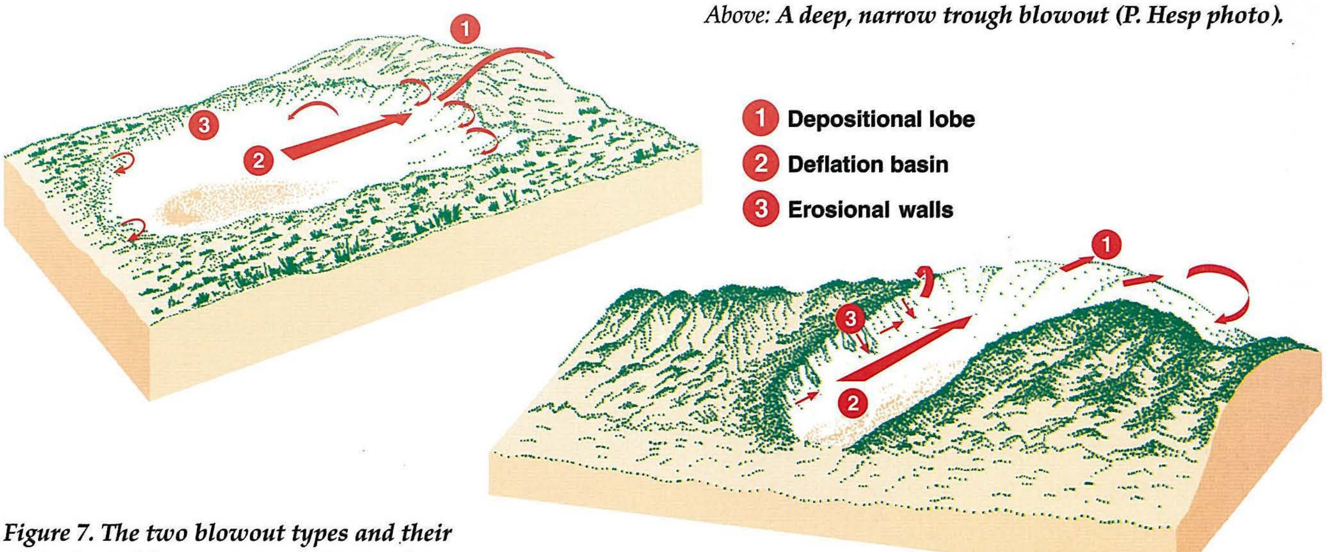


Figure 7. The two blowout types and their typical windflow patterns (© P. Hesp).

Blowouts are common in coastal dune environments, particularly on established foredunes where beaches are eroding and/or receding, but also in high energy wind and wave environments.

Blowouts are likely to be initiated wherever there is a reduction in the vegetation cover and subsequent wind erosion. Rabbits, domesticated and feral animals, 4WD vehicles, dune buggies, motorbikes, horses and pedestrian activity can all lead to a reduction in the vegetation cover of dunes and erosion of dunes (e.g. by the formation of deep tracks). Natural causes include:

(i) wave erosion of the foredune during storm events followed by destabilisation and wind erosion of bare areas and dune scarps;

(ii) wind erosion, particularly during high wind events, of naturally bare or sparsely vegetated parts of the foredune or dune;

(iii) water erosion of sparsely vegetated dunes; and

Top left: ***Slope failure of a foredune following storm erosion may lead to vegetation dieback and subsequent wind erosion (P. Hesp photo).***

Above: ***Naturally less vegetated portions of a foredune can be eroded by storm winds and blowouts may develop (P. Hesp photo).***

Top right: ***A shallow saucer blowout (P. Hesp photo).***

(iv) sand inundation and burial of the vegetation during wind storms and subsequent death of the plant cover.

Once initiated, the subsequent development depends on the size of the initial constriction, the height and width of the dune in which the blowout is developing, the degree and type of vegetation cover, the magnitude of regional winds, and the degree of exposure to winds from various directions.

Wind flow, sand transport and blowout development

The wind flow structure in a blowout may be very complex and highly turbulent. Rapid development of blowouts occurs because the wind flow is locally accelerated through the blowout and a high speed jet is formed. Thus, wind speeds in the blowout are significantly greater than outside the blowout and this leads to high rates of sand transport and erosion (Figure 7). Winds remove sand from the deflation basin and the lateral walls and transport it downwind. The erosional walls are then oversteepened, slumping occurs and the wall retreats. The wind flow accelerates up the over the depositional lobe face and experiences rapid flow deceleration over the lobe crest. Sand transport is maximised up the axis of the blowout, that is, the middle of the deflation basin, and decreases in a radial fashion away from the centreline, and particularly over the depositional lobe. This leads to the development of arcuate- or parabolic-shaped depositional lobes.

In trough, and many saucer blowouts, deflation basins tend to continue to erode until a base level such as the seasonally lowest water table level, or a more consolidated or armoured surface is reached. Such surfaces may be an old soil or carbonate (or other cemented/indurated) layer, or an armoured surface such as a pebble, shell, pumice or artifact surface.

Evolution

Blowouts may evolve in various ways. Many blowouts become larger over time and may evolve into parabolic dunes (see below). Blowouts typically advance through evolutionary stages from erosional notches and hollows, to incipient blowouts, to large blowouts, to revegetating and stabilised blowouts. Incipient foredunes commonly form across the throat or entrances of blowouts eliminating through-flow of beach sand. Subsequent dune erosion and removal of incipient foredunes can lead to re-activation of the blowouts.

Disturbance can open up the foredune to wind erosion (J. Barran photo).

The base level of a saucer or trough blowout is usually reached when the water table or a pebble, pumice or shell layer is reached. In this trough blowout at Himatangi Beach the sand has been removed leaving a concentrated shell layer (or lag) behind protecting the surface from further erosion (J. Barran photo).

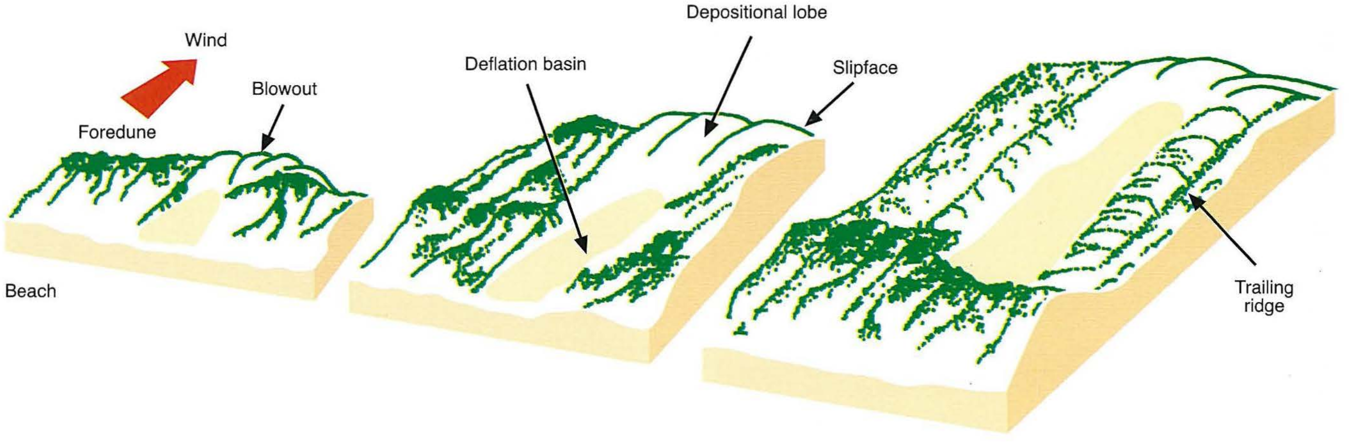
PARABOLIC DUNES

Parabolic dunes (also termed U-dunes, upsiloidal dunes, hairpin dunes) are U-shaped dunes which roughly describe a parabola or inverted U-shape when viewed from above. They are characterised by short to elongate trailing ridges which terminate downwind in U-, or V-shaped (i.e. parabolic) depositional lobes. The depositional lobes may be simple, relatively featureless sand sheets, or textured with a variety of dune forms (e.g. **transverse dunes**, **barchanoidal dunes** etc). **Deflation basins**, **slacks**, seasonal wetlands, ponds, and occasionally lagoons occupy the area between the trailing ridges (Hesp, 1999).

Initiation

Parabolic dunes typically evolve from blowouts. Blowouts continue to enlarge laterally and elongate downwind as wind erosion proceeds. In many cases the depositional lobe of a blowout continues to advance downwind regardless of what processes occur in the rest of the blowout (e.g. a foredune may reform across the front of the blowout and parts of the blowout basin may re-vegetate). Where the lobe migrates in this way, a parabolic dune evolves (Figure 8). A **parabolic dune** is typically distinguished from a blowout by the presence of trailing ridges.

Parabolic dunes on the Manawatu-Wanganui coast (L. Homer, IGNS, photo).



(i) The foredune vegetaion is reduced by storm wave erosion.

(ii) Erosion continues, the deflation basin expands, the depositional lobe advances downwind, and a parabolic dune develops.

(iii) The foredune reforms across the parabolic dune throat. The parabolic dune continues to advance downwind forming elongated trailing ridges.

Figure 8. The evolution of a parabolic dune from a blowout (©P. Hesp).

Parabolic dunes may also be initiated, and evolve from the landward and downwind margins of **transgressive sand sheets** and **dunefields**. As the mobile sands migrate into vegetation, discrete lobes may migrate ahead of the advancing dunefield forming parabolic dunes. This process seems to occur particularly where transgressive dunefields are stabilising and revegetating. Examples may be seen on the NZ North Island west coast (e.g. Manawatu region; Aupouri Peninsula; 90 Mile Beach; Mason Bay, Stewart Island).

Climbing and clifftop parabolic dunes may be formed (i) during low sea levels, (ii) during present sea levels where steep terrain lies adjacent to the beach, and (iii) where rapid erosion of unconsolidated to poorly consolidated cliffed coasts is occurring (e.g. the cliffs along the Awhitu Peninsula). Parabolic dunes are often formed on the cliff tops and downwind areas as the climbing dunes migrate into vegetated terrain.

Right: ***Blowouts, parabolic dunes and transgressive dunefields often form on highly erosional coasts. Awhitu Peninsula (P. Hesp photo).***

Left: ***A parabolic dune which has migrated across a headland (P. Hesp photo).***

Active parabolic dunes with flat floored, wet deflation basins, u-shaped depositional lobes and trailing ridges (L. Homer, IGNS, photo).

Vegetated (relict) long-walled, nested parabolic dunes. Manawatu dunefield

Parabolic dune morphology

Two principal sub-types of parabolic dune are common; **long walled types** and **squat, elliptical types**. The multiple development of these leads to there being two principal sub-types of parabolic dunefields: long walled types and imbricate types. However, as with blowouts, different shapes are possible, and some dunes may be very large (megadunes) and very complex.

Long walled parabolic dunes display long trailing ridges and extensive deflation basins. The trailing ridges may range from hundreds of metres long to several kilometers long. They are particularly well developed on relatively flat terrain, in regions of low heath or shrubland, high sand supply and strong winds (e.g. the Manawatu, N.Z. dunefields).

Depositional lobe of a climbing and clifftop parabolic dune, Awhitu Penninsula (P. Hesp photo).

Some parabolic dunes display a shorter form, often with more semi-circular or elliptical deflation basins. Multiple development results in the dunes overlapping each other in an imbricate fashion (stacked like roof tiles). They develop in a range of situations. This includes in wetter areas, on flat terrain where deflation depths are limited, where wind speeds are relatively low, on hummocky or relatively steeper terrain where significant downwind migration is impeded, in multi-directional wind regimes, and/or in dense, tall vegetation where the rate of advance is low and migration is impeded.

Dune dynamics

The parabolic dune shape results from two processes acting contemporaneously. First, sand is eroded off the windward face of the depositional lobe, transported across the lobe and deposited on the downwind **slipface** (Figure 8). As the lobe advances a deflation or erosion plain or basin is formed on the upwind side. Second,

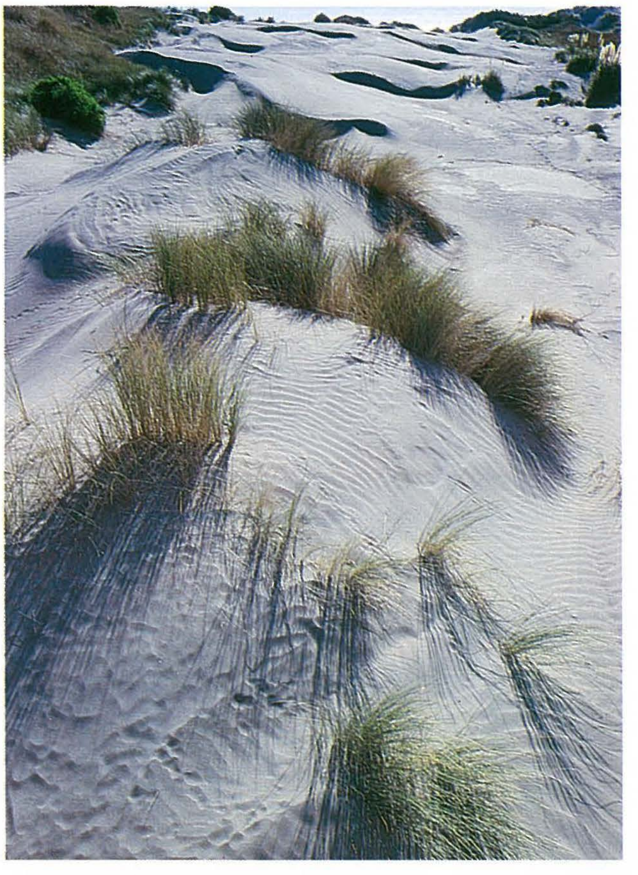
Imbricate and long-walled vegetated parabolic dunes, Horowhenua (P. Hesp photo).

sand is deposited into vegetation around the margins of the depositional lobe and some sand is trapped. As the depositional lobe advances downwind, the trapped sand remains behind forming the trailing ridges.

Deflation basins continue to erode until a base level is reached such as the seasonally lowest water table level, a calcrete (or other cemented or resistant) layer, an armoured surface such as a pebble, shell, pumice, artifact, or buried soil surface.

Rates of parabolic dune advance or migration vary considerably depending on the morphology, slope and type (e.g. sandy vs. rocky) of terrain the dunes are moving across. Other factors that may influence the rate or parabolic dune migration include the vegetation cover, species and type (e.g. woodland vs. grassland), wind velocities and directional variability of the wind, and dune size. For example, on the high wind energy North Island lower west coast dunefields, rates of dune migration vary from around 1–2 metres per year when large dunes are advancing into tall forest, 2–5 m / year over shrubs, and on rare occasions up to 100–200m / year when low dunes are migrating over short grasses and herbs (Muckersie and Shepherd, 1995; Shepherd and Hesp, in press).

A long-walled parabolic dune with deflation plain (middle), depositional lobe (bare sand) and trailing ridges (S. Chape photo).



A low parabolic dune migrating rapidly over dune grasses (J. Barran photo).

Parabolic dune migrating into forest (J. Barran photo).

TRANSGRESSIVE DUNEFIELDS

Transgressive dunefields are relatively large-scale aeolian sand deposits formed by the downwind and / or alongshore movement (or transgression) of sand over vegetated to semi-vegetated terrain. **Transgressive dunefields** have also been termed mobile dunes, sand drifts and migratory dunes. Such dunefields may range from quite small (hundreds of metres in alongshore and landward extent) to very large (many kilometres in extent). They may be largely unvegetated, partially vegetated, or completely vegetated (relict).

An active transgressive dunefield dominated by sinuous transverse dunes and occasional bush pockets (W. Illenberger photo).

Initiation of transgressive dunefields

Transgressive dunefields may form, or have formed:

- as a response to rising sea level and / or climatic change, particularly in the period, 10 000 to 7000 years ago;
- in regions of high alongshore and onshore sediment supply, usually with strong onshore winds;
- on coasts experiencing erosion, both natural and human induced.

The Postglacial sea level transgression (rising sea level), which occurred from around 18 000 years ago and ceased about 7000 years ago would have resulted in large scale shoreline erosion as the sea level rose. On high wind energy coasts with a significant sediment supply, transgressive dunefields would have been initiated by the rising sea due to this shoreline erosion and continual destabilisation of dunes. The dunefields would have migrated landwards, in some cases well ahead of the rising sea. Relict (stabilised) transgressive dunefields may now be found on clifftops completely isolated from any modern source of sand (e.g. the Wanganui-Taranaki coast; the Awhitu Peninsula). These were formed at lower sea levels when the dunes climbed up the cliff faces. Subsequent wave erosion of the climbing dune ramp and cliff erosion resulted in the stranding of the dunefields on the clifftops.

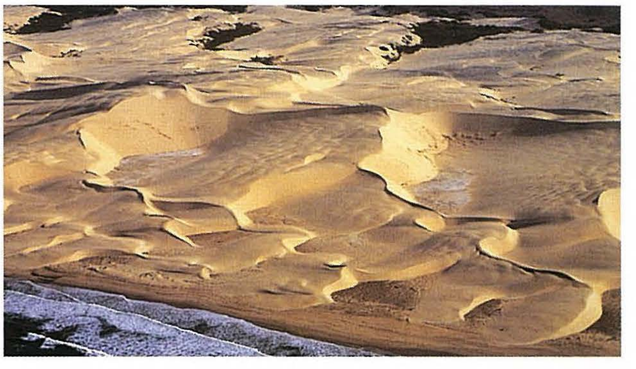
Many North Island west coast transgressive dunefields were probably initiated by the rising sea prior to sea level reaching the present position around 7000 years ago. They continued to form after that as large quantities of sediment were delivered to beaches and transported landwards by high energy westerly winds. While foredunes may have formed in some areas, the volume of sand available, the strong winds, occasional storms and significant dune scarping, meant that foredunes, where they existed, were highly erosional or temporary and mobile dunefields resulted.

A large transgressive dunefield on the northern west coast, North Island, New Zealand. Two active phases are separated by a narrow deflation basin (L. Homer, IGNS, photo).

A large-scale active transgressive dunefield with transverse and aklé (fish scale pattern) dunes (P. Hesp photo).

Location of transgressive dunefields

Transgressive dunefields are best developed on west and south coasts in high wind and wave energy environments, and more particularly so where there is, or, has been in the past, a moderate to high sand supply (e.g. the Manawatu-Wanganui coast; west coast Northland region; Farewell Spit; Mason Bay, Stewart Island), or significant coastal erosion (e.g. the North Island west coast from Manukau Harbour to Raglan). Many of the best transgressive dunefields in New Zealand have been artificially stabilised with marram grass and pine forests.



Transgressive dunefield migrating alongshore and landwards (W. Illenberger photo).

Relict (vegetated) transgressive dunefield located on a clifftop, Taranaki coast (L. Homer, IGNS, photo).

Morphology

An active transgressive dunefield consists of a mobile or partially-vegetated sand sheet or dunefield with a long-walled and often sinuous **slipface** (or **precipitation ridge**) on the landward side. A shore-parallel deflation basin or relatively continuous series of **slacks** may be found on the windward side. Transgressive dunefields may comprise relatively featureless sand sheets, or a variety of dune types ranging from simple **transverse dunes** (dunes formed at right angles to the wind) to various complex dune forms. The dunes, which may be ephemeral or permanent, migrate downwind and landwards at various rates. They may even climb up the slopes of older terrain or across headlands. Precipitation ridges form along the landward and downwind margins of the dunefields. These are typically steep lee slopes, lying at the angle of repose of sand (around 32 to 34 degrees) or at steeper angles where there is dense vegetation (up to 50 degrees). They form as the landward margin of the dunefield advances into surrounding vegetation.

Deflation plains, **basins** and **slacks** are commonly present on the seaward margin of, or within, an active

A slipface (~30 m high) of a large transverse dune, Te Paki dunefield (P. Hesp photo).

dunefield. They are often laterally extensive alongshore, and are erosional hollows and broad shallow basins in which the water table often reaches or approaches the surface at some time during the year. They tend to lie parallel to the shore and are the most common erosional feature. They form as the seaward margin of the dunefield or sand sheet is eroded by wind. Landform units associated with deflation areas include isolated conical dunes formed within vegetation (**coppice dunes**), **shadow dunes** (pyramidal dunes formed in the lee of vegetation), and eroded dune remnants (**remnant knobs**). Indurated (cemented) older dunes may outcrop within the dunefields. These may be Holocene or Pleistocene in age.

Shadow dunes and coppice dunes (P. Hesp photo).

A climbing transgressive dunefield at Castlepoint (P. Hesp photo).

An erosional remnant knob (P. Hesp photo).

The long-walled, sinuous precipitation ridge formed on the downwind margin of a transgressive dunefield (P. Hesp photo).

DUNEFIELD PHASES AND STABILISATION

Development of dune phases

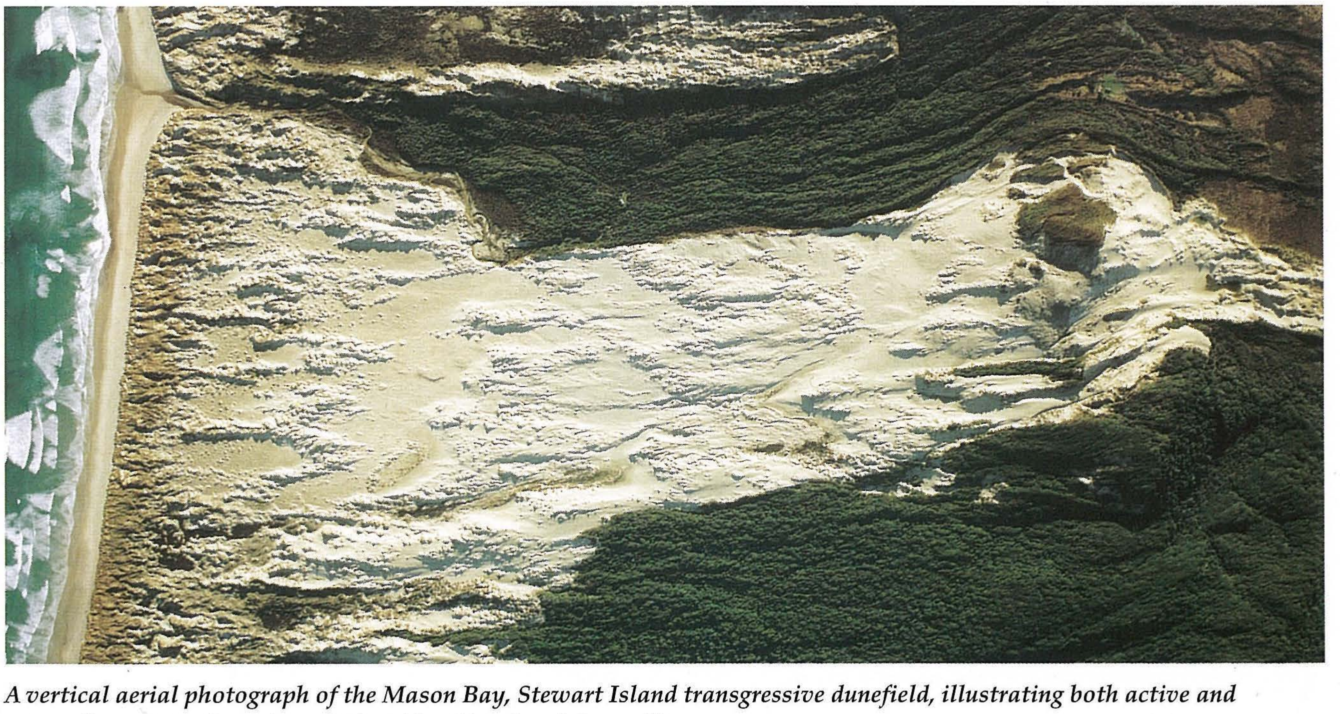
Transgressive dunefields (and parabolic dunefields) have commonly formed in phases, or episodically (Hesp and Thom, 1990; Muckersie and Shepherd, 1995). It is common to find an active dunefield fronting one or more stabilised, fully vegetated, older dunefields. The groups of dunes or individual transgressive phases may be separated by deflation basins and plains, or a series of lagoons and wetlands. Separate dune phases may also overlie each other to various degrees (e.g. 90 Mile Beach, Northland). As yet, our understanding of the mechanisms or factors responsible for the initiation of dunefield phases, or pulses of dune development is exceedingly limited.

Natural stabilisation of dunefields

Transgressive dunefields (and parabolic dunes) may become vegetated or stabilised over time. Plants may initially establish a hold in small areas within a dunefield which are either protected to some degree from the wind, or are wetter and more stable areas. Pioneer plants such as spinifex may preferentially grow on the landward precipitation ridges (and slip faces) where sand deposition is high.

From these small areas an entire dunefield may eventually become fully stabilised. For example, large hummocks or low mounds may form in vegetated areas within interdune depressions (i.e. between dunes). These "**bush pockets**" slowly expand, reducing sand movement and eventually colonise slipfaces and dune crests. Deflation plains and basins are quite rapidly colonised by vegetation once most aeolian erosion has ceased and the water table is close to, or at, the surface. Again plants spread out from these centres and colonise the adjoining dunefield. Periods when the climate is milder (e.g. less wind, higher rainfall) for a time may aid this natural plant stabilisation process.

It is common to find fully, or partially vegetated transgressive dunefields, and in some cases, the whole dunefield including the precipitation ridge may become vegetated with little change of form.



A vertical aerial photograph of the Mason Bay, Stewart Island transgressive dunefield, illustrating both active and naturally vegetated portions (© Southland Regional Council).

THE IMPORTANCE OF COASTAL DUNES

Sand dunes are a natural feature of our environment from which we all derive benefits. Their value has often been ignored or taken for granted, and there is no doubt that human activity over the last 800 years has had a negative influence on their unique character. The natural forces that govern their formation and evolution must be properly understood and taken into account if we wish to halt this degradation. Failure to make use of our collective knowledge can only result in further destruction of a valuable resource.

Some of the key reasons why we need to protect and restore coastal dune systems are outlined below.

Natural character of coasts

What is natural character? Preservation of the natural character of the coast is described as a "Matter of National Importance" in New Zealand's 1991 Resource Management Act. A major objective in coastal management seeks to maintain healthy coastal ecosystems and this objective can be most obviously met by preserving natural character.

"Natural character" refers to qualities that derive from natural, as opposed to human influences on the coastal system. In New Zealand law, landforms, vegetation and other natural patterns and processes are all recognised as elements of the natural character of the coast. Human-built structures are not regarded as contributions to the natural character because development usually degrades natural features.

What does it mean for NZ dune systems? Sand dunes, their formation and natural vegetation, are an essential part of the natural character of sandy beaches. Dunes and their vegetation also help to preserve the natural character of the coastal environment by screening adjacent human coastal development from sight. It is therefore important to safeguard their natural height and shape, and the processes of dune building, erosion and repair. The re-establishment of any degraded vegetation cover with appropriate native vegetation communities is a valuable opportunity for enhancement of the natural character of coastal dune sites. Many New Zealand dune areas have been denuded of vegetation as a consequence of historical land clearance. The destruction of naturally regenerating trees and shrubs in order to gain a views of the sea continues to this day.

The existence of coastal dunes provides us with examples of dynamic natural processes and helps us to understand the evolution of landforms and the nature of the ecosystems that they support. All landforms and their ecosystems have intrinsic value. Their unique, changing form and the specialised plants, animals and other organisms which inhabit them increase our understanding of the diversity that exists in our environment. Such knowledge can be put to good use in other contexts. For example, coastal dunes provide excellent opportunities for carefully-managed education and eco-tourism.

Beach and dune environments are particularly attractive for residential and recreational development. Subdivision of coastal property often occurs in close proximity to the sea and usually results in the modification of vegetation and landforms. Native herbs, shrubs, trees and coastal forest are becoming increasingly rare. This loss of natural character is compounded by inappropriate introduction (planned and accidental) of exotic species.

Traditional solutions to erosion along our foredunes has often involved armouring beaches with rock and concrete walls. These approaches not only destroy the natural character of sand dunes including associated native flora and fauna, they also seriously impact on amenity use and aesthetics of beaches and interrupt the natural processes of dune erosion and repair.

Water quality

Coastal dunes act as a natural filter which enhances ground water quality. Sewage disposal, drainage of coastal wetlands and wetland pollution have all contributed to the deterioration of coastal ground water quality. Such deterioration can be arrested by protection of natural dune landscapes (including seasonal and permanent dune wetlands and lakes) and restoration of vegetation cover.

Coastal protection

Coastal dunes play a vital role in protecting land and property from hazards such as shoreline erosion and flooding. They provide a natural and flexible buffer against erosion, and a reservoir of sand against long term erosion and sea level rise. If they are artificially lowered, or if erosion is allowed to progress to the point where sand mobility itself becomes a threat, this protection will be lost. It is vitally important that the consequences of dune modification or disturbance of the vegetation cover should be thoroughly understood. In this way their natural character and usefulness can be maintained with minimum intervention. Inappropriate actions or use can result in serious management problems for which simple and cheap solutions are rarely available.

Cultural and archaeological values

Coastal dunes are culturally important where they are associated with past or present Maori settlements. A number of archaeologically important sand dune sites have been recognised, and these are a tangible reminder of our history. Ancient middens are frequently visible. Less obvious, but of great significance, are the urupa or burial grounds. Many sites are waahi tapu, areas considered by Maori to be sacrosanct. Sand dunes thus contain much important information on Maori settlement, evidence of the availability of marine resources and the effects of human activity during the last 800 years. New Zealand has no contemporary written records of the pre-European era, and it is important that these aspects of our heritage should be preserved. Coastal archaeological sites are vulnerable to damage if the stability of dunes is threatened. An understanding of sand dune processes is essential if culturally important sites are to be treated with sensitivity.

Amenity value

Dunes and dune vegetation provide a natural and appealing backdrop to sandy beaches, contributing significantly to our enjoyment of coastal recreation. They offer a degree of privacy, shade from the sun, some shelter from the wind, a sense of open freedom and naturalness, and an elevated view of the beach and surf. Well-planned subdivision and development of coastal property can enhance the amenity value of beaches and dunes by maximising the available sand dune area. Wise management will ensure that the vegetation cover is maintained and protected.

Conclusion

New Zealand's coastal sand dunes are a critically important ecosystem. They result from a unique set of dynamic processes involving wave and wind forces, sand transport, erosion, and deposition, vegetation growth and sand trapping.

Dunes have become a habitat for many specialised plants, animals, birds and other organisms. This habitat and many other attributes associated with protection, amenity and cultural heritage have been seriously degraded. Understanding the processes governing sand erosion, accretion and stabilisation, and the formation of coastal dune landforms can lead to wiser management of our sandy coasts and ultimately to their conservation as a national asset.

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GLOSSARY

Accretion. Deposition of sand leading to vertical or horizontal extension of a beach, dune or dunefield.

Aeolian. From the Greek Aeolus, God of the Wind. Refers to processes or landforms formed by the action of the wind (hence: aeolian processes; aeolian dunes).

Annual plant. A plant that completes its life cycle in one year.

Back Dunes. A colloquial expression which may be used to generally refer to dunes that occur landwards of the foredune. Sometimes used interchangeably with rear dunes. Terms such as 'back dunes' or 'rear dunes' are sometimes wrongly used to describe parts of a foredune such as the crest or lee slope of a foredune. This is incorrect. Rather than use the term rear- or backdune it is preferable to describe the type or types of landward dunes (e.g. are they relict foredunes, blowouts, parabolic dunes, transgressive dunefields, or combinations of these?).

Backshore. The zone of beach lying between the berm or high tide line and the dune toe (see Figure 3).

Bar. A convex sand mound in the surf zone.

Barchan. A discrete, free moving dune which has a crescentic (or three-quarter moon) shape with wings or horns which extend downwind. A slipface is formed between the horns.

Beach. Typically the zone extending from the mean low water mark to the dune (or cliff) toe (see Figure 3).

Beach face. The sloping section of the beach below (seawards of) the berm crest. May also be termed foreshore.

Berm. An asymmentric, wave built terrace comprising a seaward swash slope, a crest, and a low, often flat, sometimes concave, beach top slope. Some beaches have berms, some do not (see Figure 3). Sometimes incorrectly used to describe an incipient foredune.

Beach ridge. Beach ridges are wave deposited ridges. They are typically continuous alongshore, symmetric or asymmetric, triangular to convex ridges, formed of sand, gravel or shell sediments (or combinations of these).

Beach ridge plain. A plain comprising a series (two or more) of beach ridges. Generally formed due to beach progradation, but may also be due to tectonic uplift.

Blowout. Blowouts are erosional dune landforms. They are either saucer-, cup-, bowl- or trough-shaped depressions or hollows formed by wind erosion of a pre-existing sandy substrate or dune (see Figure 7).

Breakpoint. The point in the surfzone where waves first break.

Breaker zone. The zone of breaking waves in the surfzone. Illustrated in Figure 3.

Bush pocket. Literally a discrete area of bush or vegetation within an active, largely unvegetated dunefield.

Coppice dune. An isolated dune, often semi-circular and conical in shape, formed by sand deposition within an isolated plant or group of plants.

Creep. A term used to describe the rolling or shuffling motion that occurs when sand grains are transported by the wind along the ground.

Deflation basin. A wind eroded depression formed by aeolian erosion of sand. May also be a slack in some circumstances.

Dissipative beach. A beach on which wave energy is dissipated by repeated wave breaking in an extensive surf zone. Typically a wide, flat beach. Illustrated in Figure 4c.

Erosion. The process of sand removal by winds or waves is known as erosion.

Established Foredune. Established foredunes are older, more permanent foredunes. They develop from incipient foredunes and are distinguished by the growth of intermediate, often woody plant species, and commonly by their greater complexity of form, height and width.

Foredune. Foredunes are shore-parallel, convex, symmetric to asymmetric dune ridges formed on the backshore by wind blown (aeolian) sand deposition within vegetation. There are two types of foredunes, incipient (newly forming) and established foredunes (see Figures 5 and 6).

Foredune plain. A coastal plain comprising two or more foredunes.

Holocene. A geological epoch which extends from 10000 years before present to the present day.

Incipient Foredune. A new foredune formed by aeolian sand deposition within pioneer plants commonly on the back of the beach above the spring high tide line.

Intermediate beach. A beach which displays a combination of reflection and dissipation of wave energy. Bars range from slightly sinuous to transverse, and rips are usually present.

Microtidal. Refers to the tidal range of a beach and in this case means that the beach has a tidal range of 0.1 to 2 metres. On mesotidal beaches the tidal range extends from 2 - 4 metres, and 4+ metres on macrotidal beaches.

Morphology. Literally "form". Refers to the form or shape of a landform or object.

Nearshore zone. The nearshore zone extends from the point where waves first interact with, or "feel" the sea bottom to the point where waves first break (Figure 3).

Offshore zone. The zone seawards of the low tide mark.

Overwash . Overwash occurs where storm waves (or perhaps very high tides) wash over a beach or barrier into a lagoon or onto a landward area not usually reached by waves.

Parabolic dune. Parabolic dunes are U-shaped or V-shaped dunes which roughly describe a parabola (upside down U) in outline. They are characterised by trailing ridges which terminate downwind in a parabolic-shaped depositional lobe. They may be active or relict (i.e. fully vegetated) (see Figure 8).

Perennial plant. A plant with a life span of greater than two years.

Pleistocene. A geological epoch extending from 10,000 years before present to approximately 1.8 million years ago.

Glossary (*cont.*)

Precipitation Ridge. A long-walled and often sinuous slipface formed on the landward side of a transgressive dunefield. Precipitation ridges are typically steep slipfaces, lying at the angle of repose of sand (around 32 to 34 degrees) and above, and form as sand is transported off the dunefields into surrounding vegetation.

Progradation. Building out of the coast in a seaward direction.

Rear Dunes. A colloquial expression which is sometimes used to generally refer to dunes that occur landwards of the foredune. Sometimes used interchangeably with back dunes. The term 'rear dune' is sometimes incorrectly used to describe parts of a foredune such as the crest or lee slope of a foredune.

Reflective beach. A beach on which wave energy is principally reflected back to sea. Typically a steep, narrow beach with a narrow surf zone (Figure 4a).

Remnant Knob. A dune remnant formed by erosion of an original sand dune.

Rhizome; Rhizomatous. Underground stem. The stem of a plant which grows below the ground and from which roots and leaves grow.

Saltation. A term used to describe the bounding motion of sand grains transported by the wind.

Sea level regression. Sea level fall. Usually occurs during a glacial period, but may also occur as a result of tectonic movement (e.g. uplift).

Sea level transgression. Sea level rise. Usually occurs following melting of the ice sheets during a Post-glacial period, but may also occur as a result of tectonic movements (down warping or faulting).

Shadow dune. A pyramidal shaped dune formed in the lee (or 'shadow') of an isolated plant or discrete group of plants.

Slack. A wind eroded hollow or depression, or topographically low area where water is permanently or seasonally ponded.

Slipface. Steep lee or downwind dune slope where sand grains fall and assume their natural angle of rest. The lee slope may be referred to as a slipface if it is lying at, or above the angle of repose (around 32 degrees for dry medium size sand). "Slipface" because the sand slips or slumps down slope.

Stolon. Stem above ground. A stem that is horizontal or arched running above the ground, rooting and capable of growing a new plant from the rooted points. Hence stoloniferous. Colloquially termed "runners".

Stoss face. The seaward face or slope of a dune. Opposite of lee face - the landward slope of a dune.

Surf zone. The zone of wave breaking (see Figure 3). The surf zone extends from the landward edge of the nearshore zone to the intertidal area or swash zone. The surf zone may contain bars, troughs and rip channels.

Swales. Swales are lee dune depressions that are generally created by seaward growth (or accretion) of a foredune. They develop as low to limited sand deposition zones and become deeper as seaward foredunes become higher.

Swash. A broken wave which washes up the beach face.

Swash limit. The landward point or limit to which swash reaches on the upper beach. May also sometimes be referred to as the wrack or drift line because this is where drift material such as logs, vegetative matter and rubbish are commonly deposited by waves.

Swash zone. The intertidal zone in which fully broken waves occur. Usually extends from the inner surfzone up the beach face. Illustrated in Figures 3 and 4.

Transgressive dunefield. Transgressive dunefields are relatively large scale aeolian sand deposits formed by the downwind and / or alongshore movement (or transgression) of sand over vegetated to semi-vegetated terrain.

Transverse dunes. Asymmetric, triangular, free moving dunes formed at right angles to the wind.

Wrack line. A line of debris, wood, flotsam etc. deposited by waves at the upper limit of the swash zone (also termed **drift line**).

THE COASTAL DUNE VEGETATION NETWORK

The Coastal Dune Vegetation Network (CDVN) was formed in 1997. It provides linkages between researchers, local and central government agencies, tertiary education institutes, private companies, consultants and community groups having a mutual concern for the rehabilitation of degraded sand dunes, particularly using revegetation techniques which incorporate indigenous coastal species.

The aims of the CDVN are:

- to provide direct funding support for dune research projects;
- to provide leverage to attract government funding and optimise returns to the CDVN;
- to respond to coastal resource managers and user-sourced research priorities through a process of mutual prioritisation in consultation with collaborators;
- to provide high quality, timely, research-based information and management outcomes to CDVN membership through field trips, meetings, newsletters and other appropriate means.

For more information, contact the CDVN Secretary, ***Forest Research,*** Private Bag 3020, Rotorua.
Phone (07) 343 5899; Fax (07) 343 5332.

CDVN TECHNICAL BULLETIN SERIES

Pingao on Coastal Dunes: Guidelines for Seed Collection, Propagation and Establishment by D. O. Bergin and J. W. Herbert, 1998. CDVN Technical Bulletin 1.

Spinifex on Coastal Sand Dunes: Guidelines for Seed Collection, Propagation and Establishment by David Bergin, 1999. CDVN Technical Bulletin 2.

Sand Tussock on Coastal Sand Dunes: Guidelines for Seed Collection, Propagation and Establishment by David Bergin, 2000. CDVN Technical Bulletin 3.

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