Nigel Bradly

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The Role Of Iceplant in the North Beach Dune System

INTRODUCTION AND BACKGROUND

The North Beach dunes are part of a continuous dune system which extends 16 kilometres from the Waimakariri river mouth to Southshore (Kirk 1979). The dunes are physically constrained by the close proximity of Marine Parade and by residential development landward of the dunes (Hutton 1992).

The impact of early European settlers with the introduction of fire and grazing has greatly contributed to the loss of the native *Desmoschoenus spiralis* (pingao) cover which once stabilised these dunes (Hutton 1992, Kirk 1979). The main method by which early settlers sought to rectify the problems of dune destabilisation was by planting *Ammophila arenaria* (marram grass). Marram has been planted along the North Beach dunes since the 1870's and has now almost completely replaced pingao. One of the main results of planting marram has been the creation of higher, steeper and more irregular dunes than those usually formed by pingao (Cockayne 1911, Esler 1970). This means that the dunes currently at North Beach present a greater obstacle to the wind and consequently form more blowouts than the original dunes.

Local residents experienced considerable problems as the artificially high dune system, confined to a narrow coastal zone formed a number of blowouts, resulting in large quantities of wind blown sand being carried considerable distances inland, onto roads and into local properties (Hutton 1992).

The Christchurch City Council (C.C.C) in 1989 developed a plan to "maintain and enhance the dunes as a buffer zone for coastal erosion by planting and landscape development" (Hutton 1992, p3). Dunes were reconstructed at five sites in 1990 and 1991 with the twin aims of lowering the dunes and stabilising the sites with vegetation. The dunes opposite Cygnet and Pacific streets were reconstructed in late 1990 with sand being scraped from the road edge and relocated at the front of the dune. In August 1991 the dunes at Effingham street, Pandora street and between Pandora street and Beach road were lowered and reconstructed. At these sites 17 400 cubic metres of sand was removed from the system before regrading and replanting of stabilising vegetation took place (Hutton 1992).

Replanting was carried out with the intention of stabilising the dunes by providing an even, consistent plant cover. There were two main species planted: marram grass and *Carpobrotus edulis* (iceplant). Although marram is widely recognised as one of the worlds most successful dune building plants (Esler 1970), the use of iceplant was largely experimental. Reasons for the widespread introduction of iceplant included the ready availability of large quantities from the Bromley sewage works, a rapid growth growth rate and the mat forming habit of the plant. It was hoped that the mat formed by iceplant would discourage people from walking on the dunes, thereby reducing the problems caused by pedestrian traffic in the dunes (C. Freeman C.C.C pers comm 1992).

The aims of this study are: to determine how the restoration work has affected the various plant communities at North Beach by comparing communities from both modified and unmodified systems and, to assess the role of iceplant in the dune system.

STUDY SITES

Vegetation sampling was undertaken at four sites along North Beach: Pacific street, Effingham street, Cygnet street and alongside the North Beach Surf Club. Pacific street is the Northern-most study site and was regraded in August 1990. The modified portion of Pacific street is 50-60 metres wide and reaches a maximum height of approximately 6.6 metres above mean sea level (Lyttleton datum). Effingham street was the most severely modified site, having had 11 250 cubic metres of sand removed from the system in August and September 1991 (Hutton 1992). It is aproximately 150 metres wide and 4.4 metres above mean sea level. The next site was Cygnet street: this area was regraded at the same time as Pacific street and is of similar dimensions - 50 metres wide and four - five metres above sea level (not yet ascertained). There was also one transect run through the unmodified dunes immediately north of the North Beach Surf Club. With the exception of the North Beach Surf Club site, sampling at each site involved an even mixture of modified and unmodified dunes.

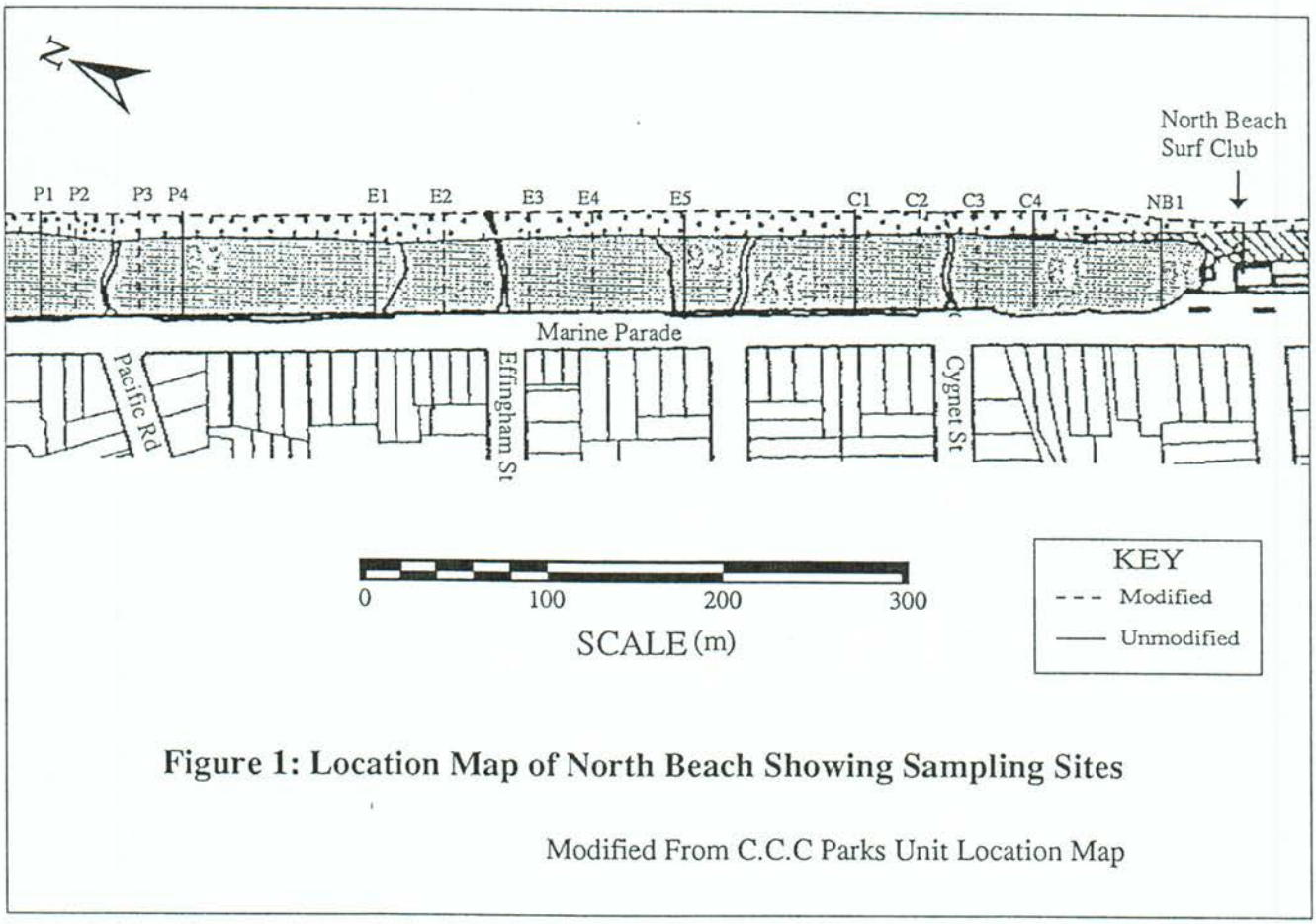

Figure 1: Location Map of North Beach Showing Sampling Sites

Modified From C.C.C Parks Unit Location Map

METHODS

14 transects, ranging in length from 50-70 metres were consructed in the four study sites. The transects began at the strandline, were orientated perpendicular to the shore and continued to the road. At 10 metre intervals along each transect a 2.5 x 2.5 metre quadrat was randomly placed and species rooted frequency was measured in the 25 .5 x .5 metre subquadrats at the site. Species rooted frequency is a measure of the presence or absence of plants in a quadrat, and does not involve any estimate of total numbers or cover of species. The raw data from the 25 subplots at each sampling point was multiplied by 4 to find the abundance of each species at a particular site.

Site and species were classified by cluster analysis. The association measure was Canberra metric and the sorting strategy Flexible with beta set at -.25 to create groups of comparatively even size (Partridge 1992). Plants were grouped into communities based on trends of geographical proximity to other species. Gradients in the data were examined by Detrended Correspondence Analysis (DCA) (Hill and Gauch 1980, Kent and Coker 1992). DCA is a technique is an ordination technique which arranges either sampling sites or species in relation to each in terms of their degree of similarity of species composition or distribution across the quadrats (Kent and Coker 1992). Results are plotted on a scatter diagram with distances between points on a graph being a measure of their degree of similarity or difference. Axes of the graphs produced by DCA are in descending order of importance with the first axis on a graph summarising more information than the second (Kent and Coker 1992). Analyses were performed using the PATN software package (Partridge 1992).

RESULTS

1) Community Descriptions

There were eight communities discriminated by Cluster Analysis. These were formed by the 15 most commonly occurring species, with another 21 species considered too rare to be grouped into communities. Table one summarises frequency of occurence and mean site abundance of each species. Figure two is a map of the communities along the 14 transects, showing which communities occur at each quadrat along a transect.

Community one was found at eight sites and contained scattered iceplant with sometimes dense marram. This community was found throughout the modified dunes at Effingham street and also in the foredune area at one site in the unmodified Cygnet street dunes. *Lupinus arboreus* (Lupin) was the only other species present but was rare.

Table 1. Frequency and Abundance Within the 8 Communities.

Community Number	1	2	3	4	5	6	7	8
Number of Sites	8	5	5	18	4	10	4	16
Carpobrotus edulis	F-7	F-2	F-8	8-6		8-6		4-2
Ammophila arenaria	F-2	6-4		9-6	F-7	7-5	F-9	F-9
Lupinus arboreus	+			6-3	7-2	7-3	7-9	F-5
Hypochoeris radicata				6-1		4-1	7-1	F-4
Lepidium africanum						7-2		5-1
Sonchus oleraceus						8-2	F-1	6-1
Bromus diandrus						7-4	F-6	8-3
Senecio elegans				6-1		5-1		9-2
Leymus sibirica				+		3-3	5-4	3-1
Achillea millefolium						5-1	2-1	
Crepis capillaris						2-+		2-+
Lagurus ovatus						3-+		6-2
Rumex acetosella				+		2-+	2-+	2-1
Agropyron repens						+	F-1	
Bromus willdenowii						+	7-1	

Only the 15 most abundant species are included. For each species the first number is frequency within the community (F=100 %, 9=90-99% etc) and the second is mean site abundance (expressed as frequency in the 25 quadrats). + represents present but rare.

Community two occurred at five sites and contained scattered iceplant with sometimes dense marram. This community was found in the first 40 metres of the modified dunes at all three sites. The unmodified southern transect at Effingham street also contained two quadrats in the foredune area with community two.

Community three, found at five sites was formed by dense, pure iceplant. It occurred predominately in the strandline/foredune area of the modified dunes at Effingham and Cygnet streets but was also found at one site in the unmodified dunes at Cygnet street.

Community four occurred at 18 sites and was dominated by mixed iceplant/marram with some Lupin, *Hypochoeris* and *Senecio*. This community was evenly spread throughout both unmodified and modified systems but tended to be found further landward in modified dunes.

Community five was found at four sites and contained dense marram with scattered lupin. It was the only community in the modified dunes that had no iceplant. It was found mostly in the higher portions of the modified dunes at Pacific street and did not occur in unmodified dunes.

Community six was found in ten sites, six of which were in unmodified dunes. This community was composed of a diverse mixture of species with iceplant the most prevalent and abundant. Other major species found were marram, lupin, *Senecio, Lepidium, Sonchus, Bromus and Achillea*. There were a further 23 species identified, many of which were virtually confined to this community. Community six was found only in the rear of the dunes and included a number of species more often found in non-dune environments such as gardens and pasture, for example *Bromus, Sonchus and Gazania* (Webb, Sykes and Garnock-Jones 1988).

Community seven was found at four sites in the rear of unmodified dunes. It consisted of dense marram with varying densities of *Bromus, Sonchus, Agropyron, Leymus sibirica* (Lyme grass), lupin and *Hypochoeris*. Vegetation at these sites was typically very dense.

Community eight occurred at 16 sites, predominately in unmodified dunes. The dominant species was marram which had 100% frequency and 90% abundance. Overall species composition was similar to community six with a number of non-dune species interacting with typical dune species such as marram, lyme grass, lupin and *Senecio*. This community was widely scattered, ranging from the foredune to the landward margin of the dunes.

2) Summary of Communities

Communities one, two and three formed the typical modified dune vegetation, although each of these communities also occurred in unmodified dunes (Table 2). Communities one-three were almost completely dominated by iceplant which had 100% frequency at all sites. marram was the only other significant species found and varied from no coverage in community three to 100% frequency in comunity one.

Site							
Pacific 1		8	8	8	7		
Pacific 2 (modified)	5	8	5	6	-		
Pacific 3 (modified)	2	4	5	8	6		
Pacific 4	1	4	8	8	6	6	6
Effingham 1	4	8	8	8	6		
Effingham 2 (modified)	5	4	1	1	6		
Effingham 3 (modified)	1	3	3	1	-		
Effingham 4 (modified)	-	1	1	4	6		
Effingham 5	2	4	4	8	7	6	
Cygnet 1	3	1	4	4	6		
Cygnet 2 (modified)	3	4	2	2	4		
Cygnet 3 (modified)	3	4	4	4	4		
Cygnet 4	4	8	8	8	7	7	
Surf Club	4	4	4	8	8		
Strandline							Road

Figure 2. Community Maps of the Four Sample Areas.

The numbers refer to the 8 communities described: dash indicates modified with no vegetation, blank is unmodified with no vegetation.

Communities four and five did not follow the vegetational trends of most other communities: those of modified dunes dominated by iceplant and unmodified dunes dominated by marram. Community four occurred in 18 sites: nine each in modified and unmodified dunes and was comprised of a wide range of species. Community five occurred only in unmodified dunes but contained no iceplant and was instead dominated by marram.

Communities six-eight were marram dominated and generally occurred in unmodified dune systems. These communities had a far wider range of species than communities one-five and tended to occur in the more landward sections of the dunes.

3) Distribution of Communities

A. Modified dunes

In the modified section of Pacific street, only 44% of the quadrats carried vegetation classed as that typical of modified dunes. These dunes were more diverse than other modified sections, especially towards the rear and contained communities six and eight which were usually found in unmodified dunes.

60% of the quadrats at Effingham street were those identified as being typical of modified dunes. Two sites recorded no vegetation with remaining sites consisting of a mixture of species (communities four - six).

Although only 40% of quadrats at Cygnet street carry vegetation considered typical of modified sites, all others carried community four which is spread evenly between both sets of dune systems.

B. Unmodified dunes

The unmodified dunes at Pacific street were dominated by communities six-eight which are marram dominated with a diverse mixture of other species. Only two quadrats (both on the strandline) contained anything other than typical unmodified dune communities.

The remaining three unmodified sites were similar in composition to Pacific street. 80% of sampled sites contained communities four, six, seven or eight and were marram dominated. No communities classified as typically 'modified' were found landward of the foredune at these sites.

4) Distribution of Iceplant

Figure three depicts the percentage abundance of iceplant at each site. iceplant was found in 84% of quadrats in the modified systems, generally at abundances of 50% or greater. The most notable exceptions to this dominance occurred in the middle quadrats at both Pacific and Cygnet streets. These sites were dominated by marram communities which appeared to have outcompeted iceplant.

Table 2. Number of Modified and Unmodified Sites Within Each Community

Community	Modified	Unmodified
1	6	2
2	3	2
3	4	1
4	9	9
5	4	-
6	4	6
7	-	4
8	2	14

The only two sites at which iceplant appeared relatively abundant in the unmodified dunes were at north Cygnet street and the North Beach Surf Club where it occurred in all quadrats. It occurred mostly in communities four and eight which contain a wide variety of species but are generally dominated by marram.

Table three shows the frequency with which iceplant occurred in all sites. Although the frequency in unmodified dunes was generally between 20 and 30% it apears that iceplant was largely replaced by marram beyond the strandline. In the modified dunes, iceplant frequency was consistently high, with the possible exception of the middle quadrats which also contained some marram dominated communities.

5) Ordination

DCA site ordination is presented in figure four using seperate diagrams for unmodified and modified sites to avoid clutter. There is a clear distinction between unmodified and modified dunes with modified sites being densely grouped to the right of axis one while unmodified

Site							
Pacific 1		-	-	-	-		
Pacific 2 (modified)	-	6	-	8			
Pacific 3 (modified)	2	8	-	6	9		
Pacific 4	5	-	-	-	9	9	8
Effingham 1	-	2	-	-	-		
Effingham 2 (modified)	-	7	5	9	4		
Effingham 3 (modified)	9	9	9	9			
Effingham 4 (modified)		8	9	9	6		
Effingham 5	4	3	7	4	-	-	
Cygnet 1	9	3	7	9	9		
Cygnet 2 (modified)	7	3	2	2	8		
Cygnet 3 (modified)	7	7	-	9	8		
Cygnet 4	-	-	-	-	-	-	
Surf Club	9	8	1	6	3		
Strandline							Road

Figure 3. Distribution of Iceplant in the Four Sample Areas

The numbers refer to the 8 communities described: - indicates vegetation recorded but no Carpobrotus, a space means no vegetation.

sites are evenly spread across the lower half of the ordination diagram. This indicates that

Table 3. Amount of Iceplant in Each Quadrat

Quadrat	Mod	Unmodified
a	4	4.5
b	7	2
c	4	2
d	7	2
e	7	3
f		3
g		8

Expressed as percentage occurrence along each transect

any point in the lower left of the diagram represents a community that occurs in unmodified dunes only. Any point in the lower right of the diagram represents a community that could be found in either dune system.

Figure five shows that the points found on the lower right of the diagram represent the species that form communities one - five, while those on the left are the species that form communities six - eight. Species with the lower values on axis one tend to be plants that are not normally associated with dunes, such as *Achillea*, *Ulex* and *Crepis* while plants that prefer the dune environment such as marram, lupin and iceplant occur on the right of the

axis (Webb, Sykes and Garnock-Jones 1988).

Figure six seperates the sites by distance inland from the strandline, each diagram representing a 10 metre step. Diagram A is clumped towards the right of axis one, indicating that these sites were dominated by communities one - five regardless of whether they occur in unmodified or modified sections. The difference in species composition between modified and unmodified dunes becomes more obvious in diagram B which is more evenly spread across the lower half of the diagram. Sites C, D and E have clearly distinguishable differences between modified and unmodified sites, with communities six - eight, which tend to be found toward the rear of unmodified dunes occurring in the left of the ordination diagrams.

Axis one on these ordination diagrams represents the difference between modified and unmodified dunes while axis two exhibits a weaker trend of plants typically found within the dunes occurring at lower levels than non-dune species.

Discussion

The restoration work carried out by the CCC in 1990-91 has had a major effect on the physical and biotic components of the North Beach dunes. The restoration involved either the removal or relocation of thousands of cubic metres of sand and reduced the dunes to only a few metres above sea level. The vegetational character of the dunes has also changed significantly. The large scale changes in dune morphology caused the removal of the plant communities that were occupying the dunes and lead to the replanting with new species, such as iceplant.This has resulted in the establishment of several new plant communities dominated by iceplant in the modified sections of the dunes. These communities are very different in species composition from those found in unmodified dunes, where marram is the dominant species

The results clearly show that iceplant dominates marram in the modified dunes. One of the major reasons for the dominance of iceplant is thought to be its greater tolerance of salt. Huiskes (1979, p367) stated that "in the early stages of a growing dune, especially in foredunes, marram is often present only in small numbers and the vegetation is dominated by more salt tolerant species." Even though marram is regarded as a dune builder it is relatively intolerant to salt spray and tends to be outcompeted in areas such as the windward side of the foredune and crest which receive the greatest amounts of salt (Oostings and Billings 1942). marram seedlings tend to be more affected by salt spray than larger plants (Sykes and Wilson 1988). This is reflected by the inability of marram to grow freely down the front face of the foredune and by the low rate of survival of seedlings that have been planted on the front face of the dunes at North Beach (Esler 1970, Sykes and Wilson 1988).

In comparison, iceplant spreads rapidly downslope and appears far more salt tolerant than marram. The succulence of iceplant leaves is an adaption to allow it to tolerate high levels of salt spray (**CHECK**). Succulence of plants growing in saline environments has been attributed to the absorption of salt by the roots and their subsequent concentration in the mesophyll tissue, resulting in salt induced hypertrophy (swelling) (Boyce 1951).

The results shown in figure two indicate that iceplant is better at spreading into the more seaward areas than marram which doesn't begin to dominate until the middle of the dunes. The changing dominance in more landward sections of the dunes is related to two factors: increasing distance from salt spray and changing dune height. As dune height increases, salt is unable to reach the higher portions of the dunes. Another factor relating to increasing dune height is the formation of lee slopes which provide further protection from wind borne salt spray (Huiskes 1979, Oostings and Billings 1942, Sykes and Wilson 1988).

The effect of decreasing salt concentrations with increasing height can be seen in figure two where community five occurs in the central section of the Pacific street dunes. The Pacific street dunes are higher than the Effingham and Cygnet street dunes and community five may represent a community of the future for the modified dunes: salt levels decrease as dune heights increase, and marram gradually outcompetes iceplant. The effect of height is further shown in the unmodified dunes where iceplant only dominates in the areas that receive the most salt such as thestrandline and lower foredune.

Huiskes (1979, p367) notes that "in subsequent stages of dune formation marram often becomes the dominant species in an association called the *Ammophiletum arenaria.*" This association is often divided into pure (or nearly pure) marram in more heavily accreting parts (eg community five at Pacific street) and mixed marram in less mobile areas, especially lee slopes (eg communities four, six, seven and eight which are widespread in stable areas of the dunes). Huiskes (p369) listed a number of species often found occurring in the mixed *Ammophiletum* association in Britain, several of which were found at North Beach: *Holcus lanatus, Crepis capillaris, Plantago lanceolata, Ranunculus repens, Rumex acetosella and Trifolium repens*. The presence of community four in both modified and unmodified dunes indicates that this may be a transitional community between those dominated by iceplant and the mixed *Ammophiletum* described by Huiskes.

Another important role of iceplant has been to partially fill the niche previously occupied by lupin. lupin has traditionally been a species that dominates toward the rear of the dunes where levels of salt spray and moving sand are lower (Cockayne 1911). In recent years, lupin stands have been severely affected by the fungus *Colletotrichum gloeosporioides* which kills virtually all plants in the area (Molloy, Partridge and Thomas 1991). Repeated fungal attacks on a regular, yearly basis haved turned lupin into what is virtually an annual plant: seedlings germinate and grow for almost a year and are then killed off by the fungal attack. It appears that the *Colletotrichum* fungus has reduced the role of lupin in the dunes, allowing iceplant to expand its role from the front of the dunes to the rear to act as a sand holder and to initiate soil development (Cockayne 1911, Molloy, Partridge and Thomas 1991).

The success of iceplant in the modified dunes has important implications for future dune reconstruction work. It is tolerant of salt spray and outcompetes marram in the foredune environment. Once dune height increases above the upper limits of salt spray marram becomes more dominant and replaces iceplant as the dominant species. marram forms

diverse communities in both unmodified and modified dune systems and appears to be the more successful of the two species in the longer term. Iceplant however provides an even plant cover, is extremely fast growing and seems to be an ideal species for the strandline/ foredune environment in newly forming dune systems.

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