CHARACTERISTICS AND DYNAMICS OF THE SAND DUNE VEGETATION AT NORTH BAY, TASMANIA

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(with four tables, five text-figures and nine plates)

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The vegetation of the coastal sand dunes at North Bay on the Forestier Peninsula was surveyed in 80 quadrats along seven transects. A total of six plant communities was identified; four from the back dunes and two from the fore dunes. The back dunes were dominated by *Banksia marginata* Cav. and the fore dunes by *Spinifex sericeus* R.Br.and *Acacia sophorae* (Labill.) R.Br. Size class analysis of age classes of the back dune vegetation indicated an eventual senescence of the dominant *B. marginata* and a replacement by closed canopy trees from wet eucalypt forest, such as *Notelaea ligustrina* Vent. Two communities were found to be of high conservation significance: a *S. sericeus* grassland from the fore dune and a closed-forest community from the back dunes. Both communities are in a relatively undisturbed state, although the *S. sericeus* grassland has been invaded by exotic herbs. For these significant communities to remain intact, weeds and human activity must be controlled on the fore dunes and fire excluded from the back dunes.

Key Words: ***Banksia*, sand dune vegetation, conservation, management, succession, Tasmania.**

INTRODUCTION

The coastal sand dune vegetation of Tasmania has close affinities with the coastal sand dune vegetation of the humid temperate parts of southeastern Australia (Kirkpatrick 1993, Clarke 1994). This vegetation has been relatively well-described, both for the State as a whole (Harris 1991, Kirkpatrick 1993, Kirkpatrick & Harris 1995, 1999), and for particular areas (Bowden & Kirkpatrick 1974, Chladil & Kirkpatrick 1989, Harris & Kirkpatrick 1996). However, the two detailed studies of succession in Tasmanian coastal sand dune vegetation (Bowden & Kirkpatrick 1974, Chladil & Kirkpatrick 1989) relate to dune systems that have been subject to a high degree of disturbance from either clearance and stock grazing, or the invasion of marram grass (*Ammophila arenaria* (L.) Link).

North Bay (42°52'S 147°56'E), located on the northern end of the Forestier Peninsula, southeast Tasmania, has one of the few coastal sand dune systems in eastern Tasmania that has not been strongly disturbed by people and has not been invaded by marram grass. Blowouts have been substantial between the 1940s and the present (pls 1, 2), possibly caused by rising sea levels (Komar *et al.* 1991, Healy 1996, Nicholls & Leatherman 1996). The patterns of fires on aerial photographs indicate that two lagoons, Swan Lagoon and Top Lagoon, and their outlet to the sea, have provided a barrier to the movement of fire from adjacent dry eucalypt forest into the dune system (fig. 1, pl. 1). Only two parts of the coastal dune system have been burned since 1946, one between 1966 and 1975, probably in 1967, and one between 1975 and 1986, possibly in 1983. The 1946 photograph clearly shows the effects of fire on a more substantial part of the dune (pl. 1). This may have occurred in the fire year of 1939. Within the area that was not burnt in these fires, there is evidence of an older fire which burned all but a small part of the dune system on which trees of species with aerial parts that are normally killed by fire are substantial enough in size to suggest a century without its incidence. This fire possibly occurred in the fire year of 1898. These four distinct fire ages (putatively 1898, 1939, 1967, 1983) provided us with an opportunity to infer the nature and dynamics of long-term succession in eastern Tasmanian back dune systems. We also describe the zonation patterns on the relatively undisturbed fore dunes and discuss the conservation management needs of the system.

METHODS

A total of 80 5 x 5 m quadrats were surveyed along seven transects, located orthogonally to the line of the dunes (fig. 1). Quadrats were located contiguously in each transect. All species of vascular plant within each quadrat were recorded, using the following cover scale: 1 = < 1%, 2 = 1–5%,

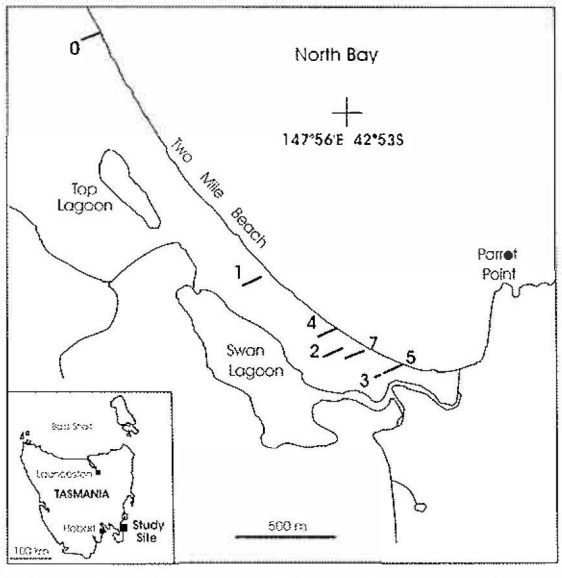

FIG. 1 — Location of North Bay showing the position of the seven transects along the dune system. Transect 6 is the fore dune portion of transect 0.

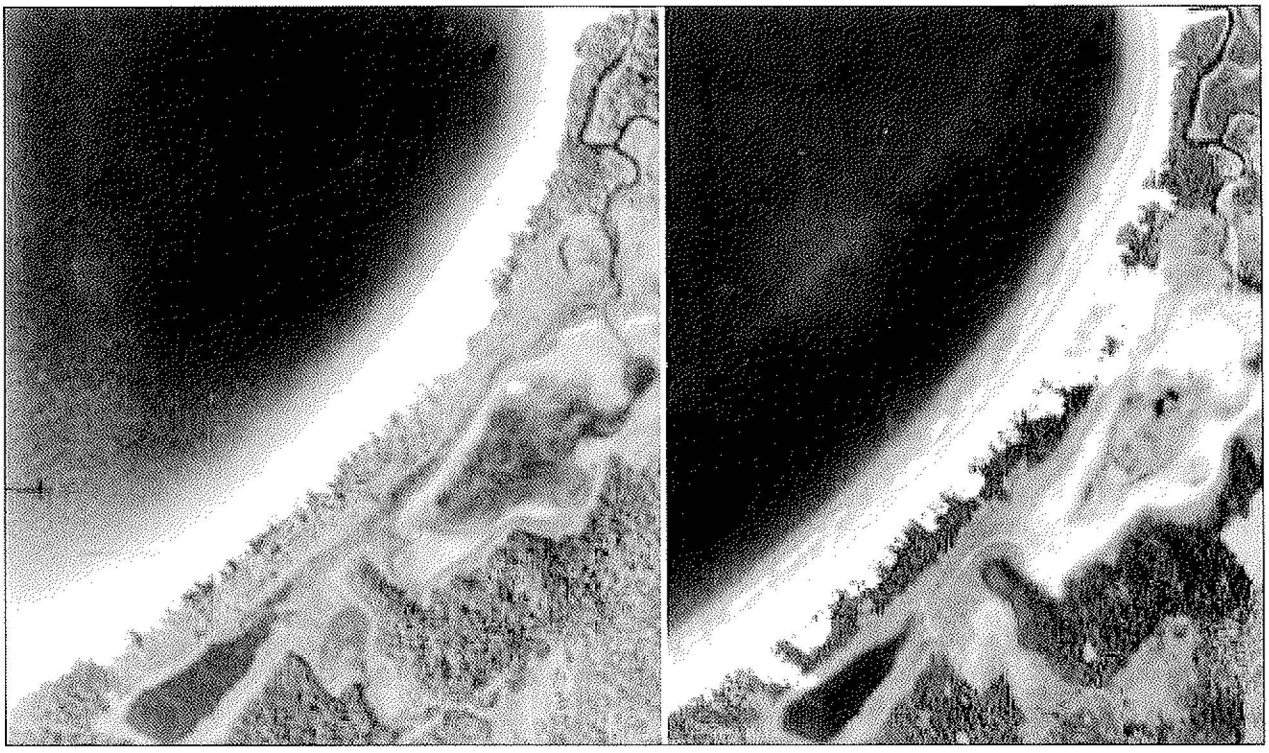

PLATE 1

The dune system in 1946 (left) and 2000 (right). The eastern end of the beach is at the top of the photographs. Note the unburned section between the beach and the dune outlet in 1946, and the transgression of sand between the two dates.

PLATE 2

The major blowout on North Bay Beach. Note Leptospermum lanigerum *in foreground.*

PLATE 3

Spinifex sericeus *grassland on the beach berm.* Cakile *spp. occur to the seaward of* S. sericeus. *Note the receding foredune.*

PLATE 4

Spinifex hirsutus *grassland with* Acacia sophorae *heath on the seaward slope of the fore dune at the eastern end of the beach. The live eucalypts in the background are not on the sand dune system.*

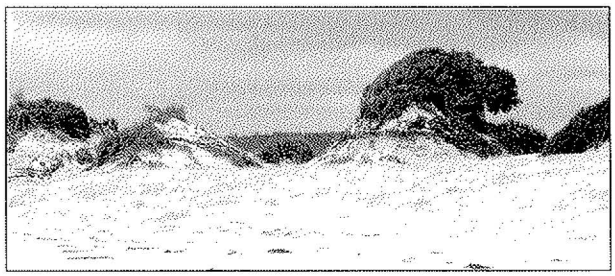

PLATE 5

Exposed Banksia marginata *roots provide evidence of retreat of the line of the foredune. Note the fossil soil horizon exposed by the retreat.* Spinifex sericeus *grassland in the foreground.*

3 = 5–25%, 4 = 25–50%, 5 = 50–75%, 6 = 75–100%. A species was considered to be present if any of its aerial organs were found overhanging the quadrat. Species nomenclature follows Buchanan (1999).

Within each quadrat the location and circumference at breast height (1.3 m) of each stem of all trees were recorded and the basal area calculated. Where a tree had more than one stem, the area of each stem at breast height was calculated. These figures were added to give the basal area for the individual. The height and number of branch whorls of all seedlings of *Banksia marginata* Cav. were also noted. The slope of the quadrat was measured using a clinometer and the soil noted as grey or yellow sand.

The quadrats were ordinated, using the default options for global non-metric multidimensional scaling in DECODA (Minchin 1994). The cover codes were used as input. The scores for dimensions 1 to 4 were used as the input to a classification of quadrats which used Ward's agglomerative method with Euclidean distance in Minitab 13 for Windows. One-way ANOVA was used to test for significant differentiation between ages of back dune forest in the ordination scores and species richness.

RESULTS AND DISCUSSION

Beach Berm and Fore Dune Vegetation

Two of the six communities selected from the dendrogram were located on the seaward side of the fore dunes. These were 4 and 6 (tables 1, 2). Community 4 was a *Spinifex sericeus* R.Br. – (*Austrofestuca littoralis* (Labill.) E. Alexeev) tussock grassland (pl. 3), in which *S. sericeus* was the dominant species, constituting 13.93% of the plant cover and occurring in all the quadrats (tables 1, 2). Other common taxa in the community were *Cakile* spp., with a cover of 1.1% occurring in 30% of surveyed quadrats, *Correa alba* Andrews (0.5% cover in 20% of the quadrats), *Pteridium esculentum* (Forst. f.) Cockayne and *Isolepis nodosa* (Rottb.) R.Br. (both with 0.2% cover and in 20% of the quadrats).

Acacia sophorae (Labill.) R.Br. shrubland occurred where the seaward slope of the foredune was stable (pl. 4). *A. sophorae* was present in all quadrats in group 6 and constituted more than half the plant cover (tables 1, 2). *S. sericeus* and *Carpobrotus rossii* (Haw.) Schwantes were the next most frequent species occurring in 40% of the quadrats, with 13.1% and 0.4% cover respectively (tables 1, 2). A herb that is absent from secure reserves in Tasmania, *Calystegia soldanella* (L.) R.Br., also occurs in the community.

While typical sequences of species on the seaward side of the dunes are shown in figures 2 and 3, it must be noted that the prevailing condition of the dunes was retreat (pls 1, 2), with root systems of *B. marginata* being exposed in many places (pl. 5). The exposure of a palaeosol has given the opportunity for soil-stored seed of a heath plant, *Aotus ericoides* (Vent.) G.Don, to germinate and establish (pl. 6). This species was not observed on any part of the back dune, and may indicate more frequent fire than at present in the eighteenth or nineteenth centuries, as it is usually a component of heath or heathy understories to eucalypt woodland/forest.

The presence of the original native sand-binders (e.g., *S. sericeus* and *A. littoralis*), and the relatively low abundance of introduced species, is a distinct feature of the fore dune vegetation at North Bay. Many Tasmanian beaches, especially those of the north and east coasts, have been invaded by the exotic species *A. arenaria* and *Euphorbia paralias* L., which have displaced many of the native sand-binding species (Kirkpatrick & Harris 1999). The fore dune vegetation at North Bay has high conservation significance, as it is one of the last beaches on the Tasmanian east coast where the native sand-binders still retain dominance. However, individuals of *E. paralias* have been uprooted by the owners of most of the dunes, and were observed and removed in the course of our data collection.

Succession on the Back Dunes

Four age classes were evident in the back dune vegetation at North Bay. The 1983 age class (0, table 3) still had charcoal on dead large individuals of *B. marginata*, and had numerous *B. marginata* seedlings and shrubs, with whorl counts that varied from 1 to 42 (fig. 4).

The quadrats in this age class all belonged to community one (table 4). *P. esculentum* is the species with the most cover in this community. The relatively open conditions favoured a high species richness, consisting mostly of herbs and grasses (tables 1, 2, 3).

The vegetation of the area of the back dunes that was probably burned in both 1939 and 1967 (1, table 3) was a tangled *B. marginata* closed-scrub interspersed with small patches of *P. esculentum* fernland. The quadrats fell in communities 2, 3 and 5 (table 4), indicating that variation in the vegetation of the back dunes as a whole was not responding only to time since fire. *Leucopogon lanceolatus, Leptospermum scoparium* and *L. lanigerum* were relatively abundant as small trees at this site (table 3). There was a very small basal area of dead stems compared with the older sites, and quadrat species richness was the lowest of all four age classes (table 3). The numerous individuals of *B. marginata* generally have relatively small basal areas (fig. 5), and there are no seedlings.

The quadrats in the area probably last burned in 1939 (age class 2, table 3) supported a *B. marginata* open forest with a scattered layer of small trees of *Monotoca glauca* (Labill.) Druce, in turn overlaying a dense bracken understorey. There was a large proportion of dead stems of *B. marginata*, and a small area near the wetland where *Acacia melanoxylon* R.Br. occurred. The quadrats mostly fell into group 3, but there were some in groups 1 and 2 (table 4). There is a wide range of basal area classes of *B. marginata* in the stand, but few fall in the smaller classes (fig. 5), and there are no seedlings.

A late stage in succession in the back dune vegetation is evident in the area possibly last burned in the fire year of 1898 (age class 3, table 3), where many *B. marginata* individuals are dead or dying (pl. 7). The mean basal area of dead stems of *B. marginata* is approximately two-thirds of the mean basal area of live stems (table 3). Large and healthy individuals of *Notelaea ligustrina* Vent., *Pittosporum bicolor* Hook., *Olearia argophylla* (Labill.) Benth. and *Coprosma quadrifida* (Labill.) Robinson (table 3) appear to be in the process of forming a closed-canopy forest (pl. 7). However, no seedlings of any tree species were found in the quadrats. Dense and tall bracken occurs everywhere except directly under the densest parts of the tree canopies (pl. 8). This dense cover may inhibit tree establishment. There is some evidence that the above species have established adjacent

TABLE 1
Mean percentage cover of species by communities defined by floristic composition

	Community					
Species	1	2	3	4	5	6
Atriplex cinerea	–	–	–	0.05	–	–
Austrofestuca littoralis	–	–	–	0.1	–	–
Cakile spp.*	–	–	–	1.1	–	–
Calystegia soldanella	–	–	–	0.05	–	–
*Euphorbia paralias**	–	–	–	0.05	–	–
Spinifex sericeus	–	0.2	–	13.925	–	13.1
Correa alba	–	0.2	–	0.5	–	–
Rhagodia candolleana	5	–	–	0.05	–	–
Acacia sophorae	–	1.267	–	–	–	56.1
Carpobrotus rossii	–	0.333	–	–	–	0.4
Isolepis spp.	–	0.2	0.071	0.2	–	–
Pelargonium australe	–	0.067	0.071	0.15	–	–
Actites megalocarpa	–	0.2	0.071	0.15	0.063	0.2
Pteridium esculentum	38.727	17.2	9.357	0.2	29.656	0.2
Leucopogon parviflorus	1.909	5.167	1.357	0.05	–	–
Austrodanthonia setacea	4.909	–	0.071	–	–	0.2
Acacia melanoxylon	–	2.5	–	–	–	–
Carex appressa	–	0.067	–	–	–	–
Deyeuxia spp.	–	0.067	–	–	–	–
Dichelachne crinita	–	0.133	–	–	–	–
Olearia phlogopappa	–	0.2	–	–	–	–
Picris spp.*	–	0.067	–	–	–	–
*Acetosella vulgaris**	0.273	0.067	–	–	–	–
Leptinella reptans	0.091	0.067	–	–	–	–
Senecio minimus	0.727	0.133	–	–	–	–
Wahlenbergia spp.	1.909	0.067	–	–	–	–
*Leontodon taraxacoides**	–	0.067	0.071	–	–	–
Lobelia alata	–	0.133	0.143	–	–	–
Solanum laciniatum	–	0.067	0.214	–	–	–
Dianella tasmanica	0.636	0.067	–	–	0.063	–
Leptospermum scoparium	–	1.4	0.357	–	0.125	–
Senecio spp.	–	0.133	0.357	–	0.375	–
Agrostis billardierei	0.182	0.4	0.714	–	0.25	–
Banksia marginata	10.5	13.567	51.893	–	12.938	–
Dichondra repens	1.091	0.2	0.357	–	0.063	–
Lomandra longifolia	8	0.067	0.429	–	4.344	–
Olearia lirata	10.318	0.133	5.571	–	2.469	–
Oxalis perennans	2.182	0.067	0.143	–	0.063	–
Coprosma quadrifida	–	–	–	–	11.406	–
Goodenia lanata	–	–	–	–	0.063	–
Laginifera stipitata	–	–	–	–	0.063	–
Notelaea ligustrina	–	–	–	–	15.938	–
Olearia argophylla	–	–	–	–	7.188	–
Pittosporum bicolor	–	–	–	–	16.75	–
Selliera radicans	–	–	–	–	0.063	–
Acacia verticillata	1.636	–	–	–	0.188	–
Hydrocotyle hirta	–	–	0.357	–	0.688	–
Leucopogon lanceolatus	–	–	7.143	–	1.125	–
Monotoca glauca	–	–	10.857	–	2.125	–
Polystichum proliferum	–	–	0.357	–	4.594	–
Viola hederacea	–	–	0.071	–	0.125	–
Ehrharta stipoides	0.818	–	0.071	–	0.063	–
Acaena novae–zelandiae	0.091	–	–	–	–	–
Aira sp.*	3.455	–	–	–	–	–
Astroloma humifusum	0.818	–	–	–	–	–

* exotic taxon.

TABLE 2
Percentage frequency of species by communities defined by floristic composition

	Community					
Species	1	2	3	4	5	6
Atriplex cinerea	–	–	–	5	–	–
Austrofestuca littoralis	–	–	–	10	–	–
Cakile spp.*	–	–	–	30	–	–
Calystegia soldanella	–	–	–	5	–	–
*Euphorbia paralias**	–	–	–	5	–	–
Spinifex sericeus	–	6.67	–	100	–	40
Correa alba	–	6.67	–	20	–	–
Rhagodia candolleana	63.64	–	–	5	–	–
Acacia sophorae	–	20	–	–	–	100
Carpobrotus rossii	–	20	–	–	–	40
Isolepis spp.	–	20	7.14	20	–	–
Pelargonium australe	–	6.67	7.14	15	–	–
Actites megalocarpa	–	6.67	7.14	15	6.25	20
Pteridium esculentum	100	100	42.86	20	100	20
Leucopogon parviflorus	45.45	60	21.43	5	–	–
Austrodanthonia setacea	72.73	–	7.14	–	–	20
Acacia melanoxylon	–	6.67	–	–	–	–
Carex appressa	–	6.67	–	–	–	–
Deyeuxia spp.	–	6.67	–	–	–	–
Dichelachne crinita	–	13.33	–	–	–	–
Olearia phlogopappa	–	6.67	–	–	–	–
Picris spp.*	–	6.67	–	–	–	–
*Acetosella vulgaris**	9.09	6.67	–	–	–	–
Leptinella reptans	9.09	6.67	–	–	–	–
Senecio minimus	36.36	13.33	–	–	–	–
Wahlenbergia spp.	45.45	6.67	–	–	–	–
*Leontodon taraxacoides**	–	6.67	7.14	–	–	–
Lobelia alata	–	13.33	14.29	–	–	–
Solanum laciniatum	–	6.67	7.14	–	–	–
Dianella tasmanica	27.27	6.67	–	–	6.25	–
Leptospermum scoparium	–	20	21.43	–	12.5	–
Senecio spp.	–	13.33	21.43	–	37.5	–
Agrostis billardierei	18.18	13.33	28.57	–	25	–
Banksia marginata	100	86.67	100	–	93.75	–
Dichondra repens	72.73	20	21.43	–	6.25	–
Lomandra longifolia	90.91	6.67	28.57	–	56.25	–
Olearia lirata	63.64	13.33	21.43	–	18.75	–
Oxalis perennans	54.55	6.67	14.29	–	6.25	–
Coprosma quadrifida	–	–	–	–	75	–
Goodenia lanata	–	–	–	–	6.25	–
Laginifera stipitata	–	–	–	–	6.25	–
Notelaea ligustrina	–	–	–	–	37.5	–
Olearia argophylla	–	–	–	–	18.75	–
Pittosporum bicolor	–	–	–	–	37.5	–
Selliera radicans	–	–	–	–	6.25	–
Acacia verticillata	18.18	–	–	–	6.25	–
Hydrocotyle hirta	–	–	35.71	–	56.25	–
Leucopogon lanceolatus	–	–	14.29	–	12.5	–
Monotoca glauca	–	–	50	–	25	–
Polystichum proliferum	–	–	21.43	–	31.25	–
Viola hederacea	–	–	7.14	–	12.5	–
Ehrharta stipoides	45.45	–	7.14	–	6.25	–
Acaena novae–zelandiae	9.09	–	–	–	–	–
Aira sp.*	72.73	–	–	–	–	–
Astroloma humifusum	45.45	–	–	–	–	–

* Exotic taxon.

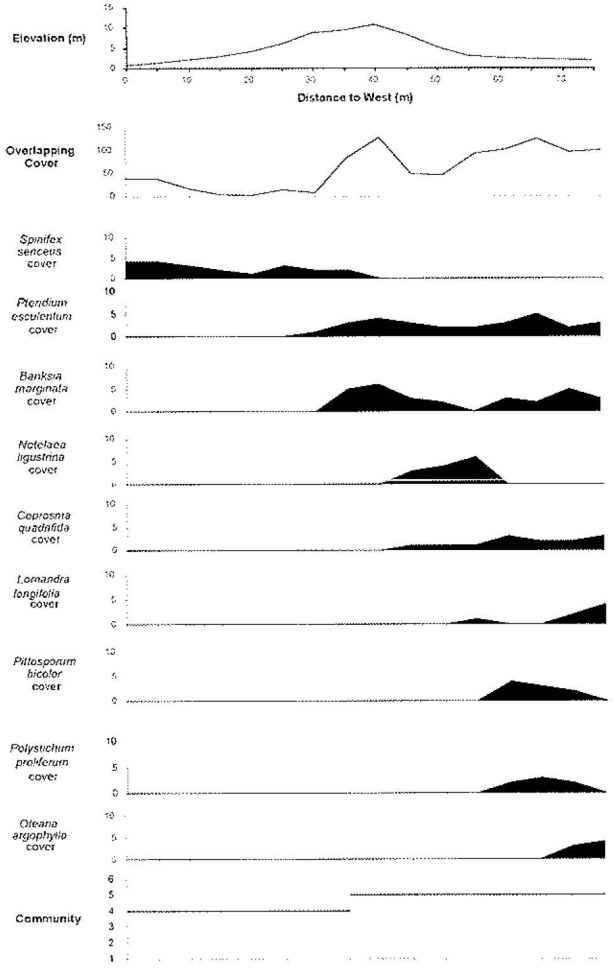

FIG. 2 — Topography, overlapping cover and species cover code value for plant species at transects 3 and 5.

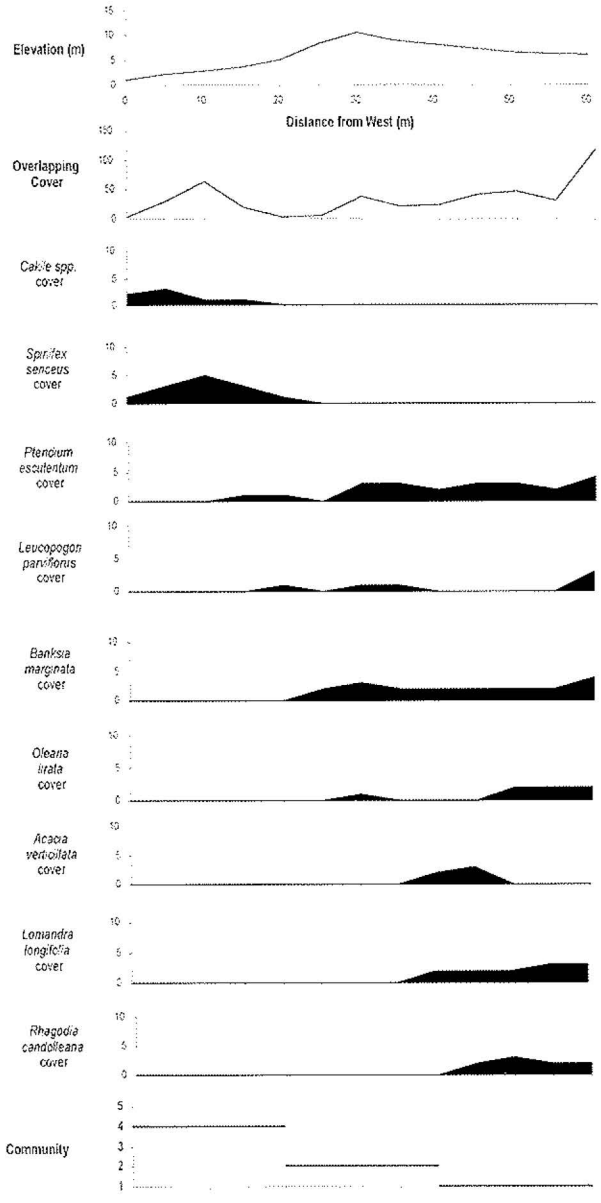

FIG. 3 — Topography, overlapping cover and species cover code value for plant species at transect 6.

to the trunks of individuals of *B. marginata* (pl. 8). This may relate to a high likelihood of bird-dispersed species being found under perching trees, or to the relative lack of shoot competition where the *B. marginata* roots inhibit bracken growth.

Between the *B. marginata* scrub and forest and the wetland herbfields to the rear, there is a zone of low closed forest dominated by *A. melanoxylon* and a zone of closed scrub dominated by *Leptospermum lanigerum* (Aiton) Smith. The large blowout dune shown in plate 2 has partly buried both these zones and large areas of *B. marginata* forest. Only *L. lanigerum* has been able to survive this burial, protruding anomalously from the top of the tallest dune in the system (pl. 2).

At the eastern end of the back dunes there are several large dead eucalypts (pl. 9). The canopies of these eucalypts are visible in the 1946 photograph. As the area has not been burned since 1946, we assume that the eucalypts died of old age.

CONSERVATION AND MANAGEMENT

The *S. sericeus* grassland has the higher conservation significance of the two communities on the fore dunes at North Bay. Despite being well-reserved in Tasmania (Kirkpatrick & Harris 1995), it does not occupy a large area, due to its displacement by exotic species such as *A. arenaria* and *E. paralias* and destruction by off-road vehicles. The unreserved herb *C. soldanella* also occurs in the fore dune vegetation. The *S. sericeus* grassland at North Bay is of high conservation significance not only in terms of the vegetation it contains, but also for the local beach-nesting birds such as the Hooded Plover (*Thinornis rubricollis* Mathews, 1912). The Hooded Plover uses the open vegetation above the high tide mark for nesting sites. On beaches where introduced species, especially *A. arenaria*, have established, the vegetation is transformed from an open grassland to a closed, much more dense one

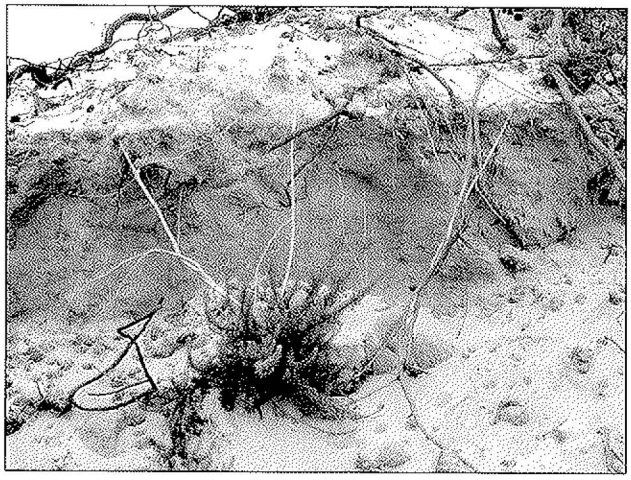

PLATE 6
Aotus ericoides, *still attached to the exposed fossil soil horizon within the truncated fore dune.*

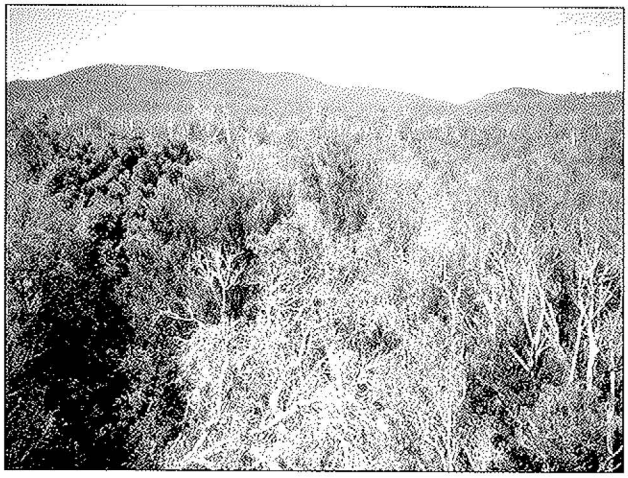

PLATE 7
Closed canopy trees, including Notelaea ligustrina *and* Pittosporum bicolor *among senescing* Banksia marginata.

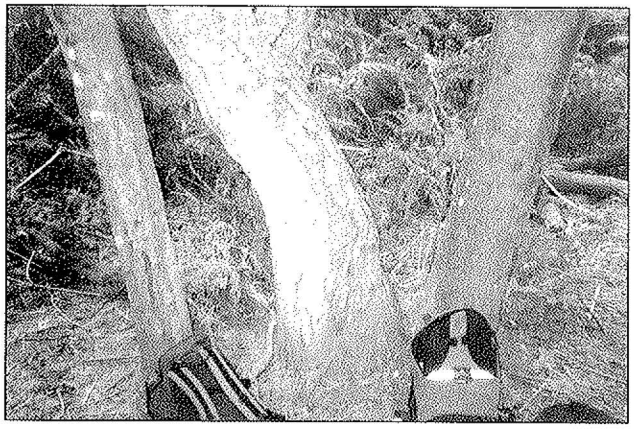

PLATE 8
Two Pittosporum bicolor *trunks on either side of a dead* Banksia marginata.

PLATE 9
Dead eucalypt at the eastern end of the back dune system.

where the Hooded Plover, and other beach-nesting birds, are prevented from establishing their nests. These birds prefer the open vegetation where they nest among natural debris and, occasionally, in *C. rossii*. Thus it is imperative that the integrity of the fore dune vegetation be maintained, through the prevention of weed establishment and the continued exclusion of off-road vehicles. Both *A. arenaria* and *E. paralias* are spread by ocean currents and collectively are the most serious threats to coastal biodiversity in Tasmania. Landowners and users of the beach at North Bay need to be vigilant to prevent the establishment of these exotic species. Monitoring of the fore dune vegetation must be constant in order to recognise the arrival of exotic species and remove them before they can become established.

The vegetation of the long-unburned part of the back dune system is not replicated in eastern Tasmania, although a form of peat-forming rainforest is known from long-unburned coastal dunes in southwest Tasmania (Jarman *et al.* 1991). Thus, although we have some indication in the vegetation (pls 6, 9) that the dune system may have been burned more frequently in the past, continued exclusion of fire seems the best management option to maintain overall diversity in Tasmania's coastal vegetation, while obviously potentially leading to the local depletion of some disturbance-requiring coastal species.

The area of closed-forest, behind the dunes at North Bay and the *B. marginata* sand dune scrub/forest community, are important features of the back dune vegetation. *B. marginata* sand dune scrub is poorly-reserved in Tasmania (Kirkpatrick & Harris 1995), while closed forests dominated by *N. ligustrina* occupy only a small area of Tasmania, but are widely distributed, usually confined to deep, south-facing rocky gullies in the driest parts of the State, where there is topographic protection from the northwest; the direction followed by most fire fronts in Tasmania.

While the exclusion of fire is the major management requirement for the back dune vegetation, there is also a possibility of invasion of the dunes from a population of Montpellier Broom (*Genista monspessulana* (L.) L.Johnson) currently established behind Lagoon Bay, about 1 km from the eastern end of North Bay. Eradication of this stand would remove this possibility.

A major cause of loss of the back dune vegetation has been burial by sand blown from the beach in a large number of blowouts. It may be worth attempting to stabilise the blowouts at the eastern end of the beach, where the closed forest is currently being overwhelmed, although general stabilisation is probably both inappropriate and futile. Given the low degree of anthropogenic disturbance of the dune system, the blowouts seem most likely to be attributable to

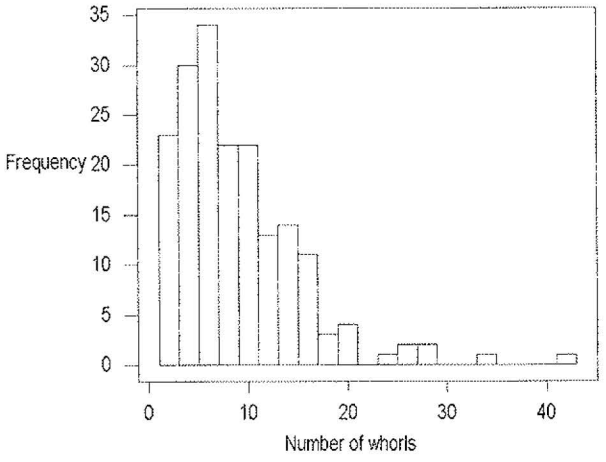

FIG. 4 — Number of whorls counted on seedlings at site 0.

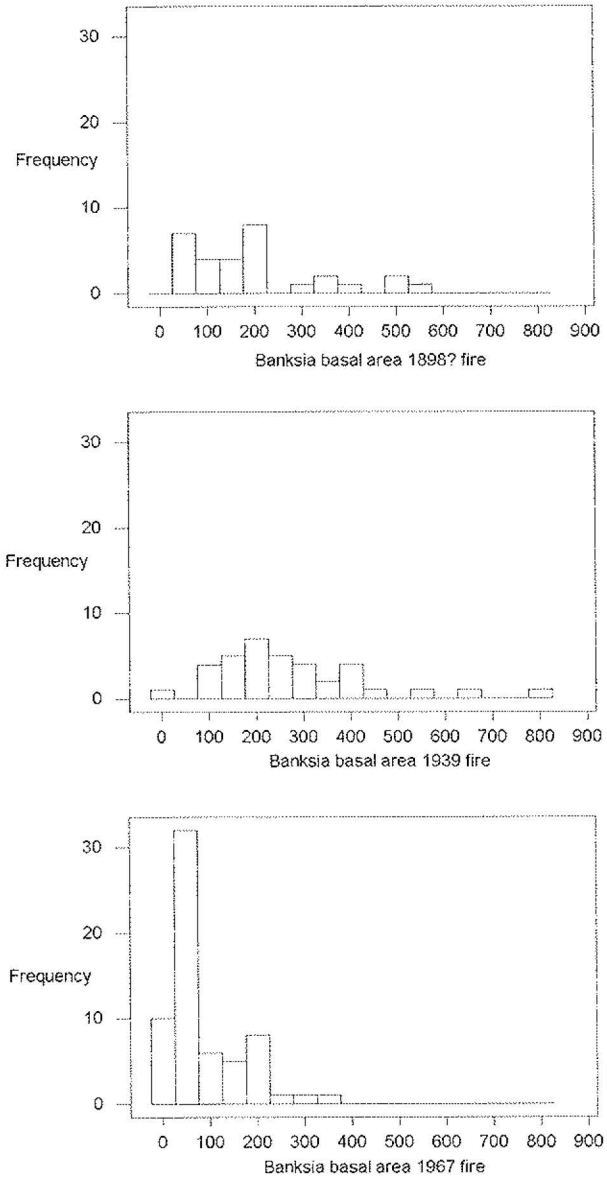

FIG. 5 — Size class distributions of banksias at varying ages since last fire. Figures are cm²/25 m².

TABLE 3
Means for basal area variables, ordination scores, and species richness for the four age classes of back dune vegetation.

	Age Class*			
	0	1	2	3
	n = 10	n = 10	n = 10	n = 15
Live basal area (cm²/25 m²)				
Acacia melanoxylon	0	0	80	0
Banksia marginata	0	528	1138	386
Cassinia aculeata	0	17	0	0
Coprosma quadrifida	0	0	0	34
Leptospermum lanigerum	0	6	0	0
Leptospermum scoparium	0	51	0	0
Leucopogon lanceolatus	0	57	7	0
Monotoca glauca	0	10	21	15
Notelaea ligustrina	0	0	0	60
Olearia argophylla	0	0	0	48
Olearia lirata	0	0	0	1
Pittosporum bicolor	0	0	0	108
Total basal area	0	669	1246	652
Dead basal area (cm²/25 m²)				
Acacia melanoxylon	0	0	19	0
Banksia marginata	579	1	432	243
Cassinia aculeata	0	4	0	0
Olearia argophylla	0	0	0	33
Leucopogon lanceolatus	0	32	0	0
Monotoca glauca	0	0	0	7
Total basal area	579	37	455	283
Floristics and richness				
Ordination score axis 1	0.84	0.74	0.84	0.61 NS
Ordination score axis 2	0.11	-0.18	-0.43	0.30 ***
Ordination score axis 3	-0.14	0.16	-0.21	0.34 ***
Ordination score axis 4	-0.41	0.43	0.16	-0.14 ***
Species richness	10.9	5.7	8.5	6.4 **

* 0 = youngest, 3 = oldest.
NS = $P > 0.05$, ** = $P < 0.01$, *** = $P < 0.001$

the recent accelerated rise in sea level (Cazenave *et al.* 2003), a phenomenon not controllable by local action.

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