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Processes of *Ammophila arenaria* (Marram Grass) Invasion and Indigenous Species Displacement, Stewart Island, New Zealand

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ABSTRACT

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The present study (1) describes the rates and patterns of *Ammophila arenaria* (marram grass) invasion in a large transgressive dune system (Mason Bay) and on a prograding foredune-ridge barrier (Doughboy Bay), Stewart Island, New Zealand; (2) examines the impact of *Ammophila* on dune morphology and indigenous dune biota; and (3) assesses the significance of geomorphic processes in accounting for the patterns observed. Processes of *Ammophila* invasion are interpreted from evidence of landform development and vegetation change; field observations and survey of dune landforms and dune vegetation; the aerial photographic record and historic accounts of the local botany.

The area dominated by *Ammophila* in the Mason Bay study area has increased from 1.4 ha in 1958, to 17.8 ha in 1978, to 74.9 ha in 1998; a 5,204 percent increase. *Ammophila* invasion of active dune systems in the study areas is clearly associated with dune forming processes—shadow dune development; migration of long-walled parabolic dunes; stoss face blowout development; and barrier progradation. The primary mechanism of native species displacement appears to be burial rather than competition for nutrients. *Ammophila* traps sand and builds dunes at rates that may exceed the threshold of tolerance of local native species. *Desmoschoenus spiralis*, the dominant indigenous foredune species, cannot co-exist with *Ammophila* in the active dune systems investigated.

ADDITIONAL INDEX WORDS: Desmoschoenus spiralis, *foredune complex, parabolic dune migration, Mason Bay, Doughboy Bay, burial, shadow dune.*

INTRODUCTION

Ammophila arenaria (Marram Grass or European Beachgrass) has been introduced to the active dune systems of southeast Australia (HESP and THOM, 1990; CULLEN, 1998); North America (WIEDEMANN and PICKART, 1996); South Africa (HERTLING and LUBKE, 1999a); Chile (HULTEN and FRIES, 1986; CASTRO, 1988) and New Zealand (JOHNSON, 1992; PARTRIDGE, 1992). At most sites it has been planted to construct or re-establish foredunes or stabilise transgressive dune systems.

Ammophila has belatedly been shown to be highly invasive and a threat to the ecology of active dune systems outside its natural range. It may adversely affect indigenous dune flora and the diversity of habitats by stabilizing naturally mobile dunes and accelerating vegetation succession (COOPER, 1958; BUELL, PICKART and STUART, 1995; HERTLING and LUBKE, 1999b). The area of bare sand, species diversity and evenness (uniformity in abundance and cover of species) has been shown to correlate negatively with *Ammophila* along the west coast of the United States (reviewed by PICKART and SAWYER, 1998) and in Tasmania (reviewed by CULLEN, 1998).

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To date, the processes of *Ammophila* invasion and indigenous plant displacement have only been described in general terms. For example, BUELL, PICKART and STUART (1995, p.1591) attribute the rapid and successful spread of *Ammophila* through the dunes of North Spit, Humboldt Bay, California, to "a number of processes and conditions: optimal habitat, multiple introduction, natural and human disturbance, and proximity to the strand where rhizome fragments are washed ashore by storm surf". Increasing our understanding of these processes will assist conservation agencies assess the vulnerability of dune systems to *Ammophila* invasion and increase the effectiveness of *Ammophila* eradication operations.

The impact of *Ammophila* on the native dune flora and fauna of New Zealand has been recognised for some time (*e.g.* JOHNSON, 1992; DEPARTMENT OF CONSERVATION, 1997). New Zealand has three indigenous foredune sandbinders, *Desmoschoenus spiralis* (a sedge), *Austrofestuca littoralis* (a perennial grass) and *Spinifex sericeus* (a perennial grass). *Desmoschoenus* and *Austrofestuca* occur throughout New Zealand while *Spinifex* occurs throughout the North Island and in northern South Island. *Ammophila* has displaced *Desmoschoenus* in many dune systems, but particularly around the south and east coasts of the South Island and the exposed

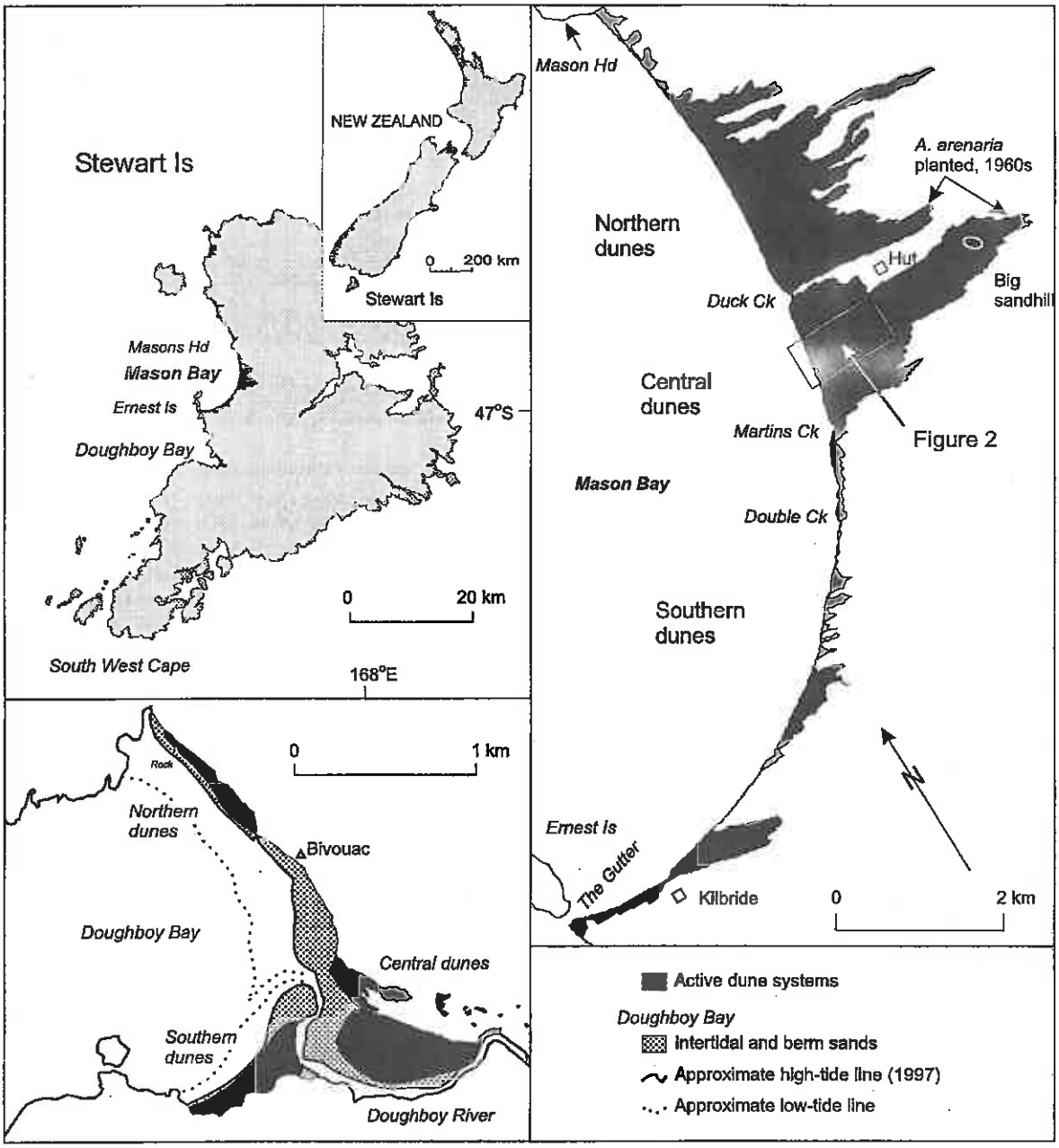

Figure 1. Location of study sites and major Stewart Island active sand dune systems. Wind rose derived from hourly observations, Southeast Cape, Stewart Island (1992–97).

Landform Development and Vegetation Change

Contemporary vegetation cover in the Mason Bay study area was estimated by random sampling (1 m² quadrat) in January 2000. The quadrat data was then stratified into five classes based on geomorphic characteristics: (i) the stoss face of foredune complex (40 sites); (ii) the lee slope of the foredune complex (40); (iii) the deflation zone of the long-walled parabolic dunes (40); (iv) trailing arms (40); and (v) depositional lobe (25). The average ground cover for each stratum was derived by averaging the percent cover of the major species observed in each quadrat. Our interpretation of species diversity at Doughboy Bay is based on data gathered over a three year period (1999–2001) from ten permanent quadrats

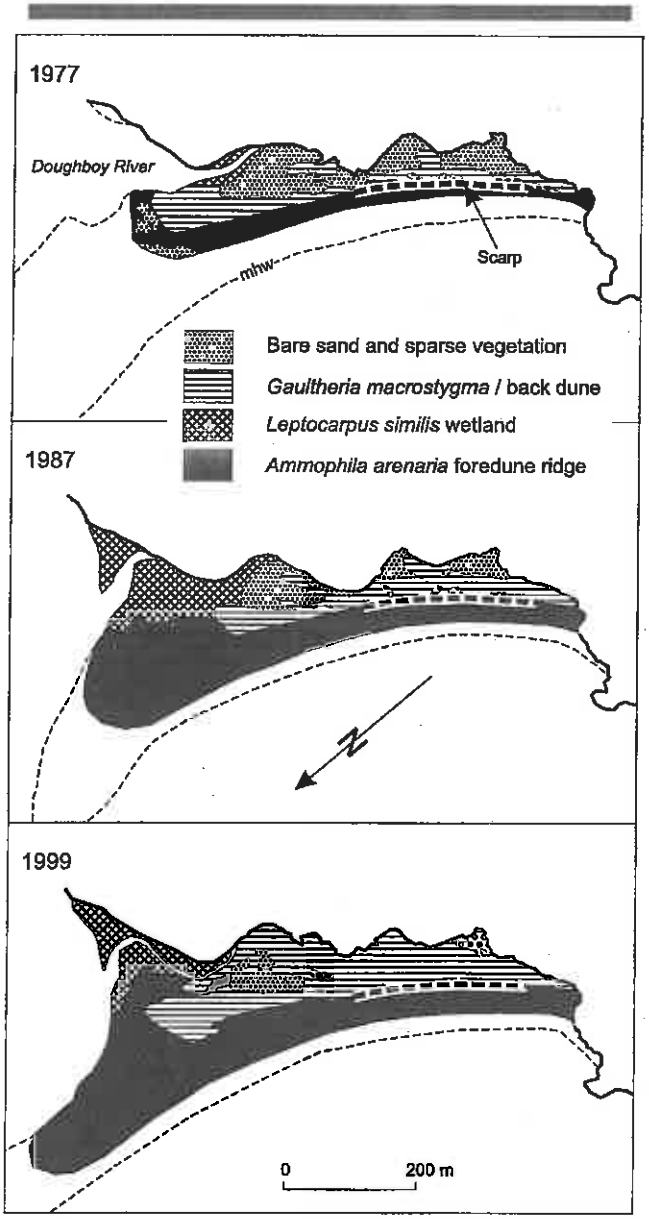

Figure 3. Morphology and plant cover of parabolic dune number six (in 1998). The contemporary dimensions of the foredune complex are compared with Cockayne's (1909) description of the foredune in 1908.

about 1.7 ha in 1977 to about 7.0 ha in 1999, a 412 per cent increase. At the same time the barrier prograded seawards (45–60 m) and towards the north (140 m) (Figure 3). The foredune ridges formed since 1977 have been colonised by *Ammophila* and now *Ammophila* is the only species inhabiting the stoss face of the modern foredune. There is no evidence, exposed rhizome for example, that *Desmoschoenus* has ever formed a significant cover on the foredune ridges, though a handful of isolated plants were observed in 1999.

Landform Development and Vegetation Change

Since the arrival of *Ammophila* the foredune in central Mason Bay study area has undergone considerable change. COCKAYNE (1909) described aspects of the pre-*Ammophila* dune landscape and dune flora of Mason Bay. In 1908 the foredune comprised a line of "low hummocks", 2–3 m high. The probable position and elevation of these dunes relative to the modern foredune complex is shown in Figure 4. COCKAYNE's description of the foredune is consistent with the dune landscape as can be discerned from the 1958 aerial photographs, soon after *Ammophila* established north of Martins Creek. The aerial photographs indicate a hummocky, discontinuous foredune, probably equivalent to the Stage IV foredune of HESP (1988).

The foredune complex developed between 1958 and 1978 as adjacent shadow dunes coalesced and *Ammophila* established a semi-uniform vegetation cover. The foredune is now a relatively massive landform termed a 'foredune complex' (after DOING, 1985). Deposition of sand across the Mason Bay foredune complex has continued as a result of: (1) formation of minor blowouts affecting the stoss face of the foredune; and (2) erosion and transport of sands across the beach during episodes of strong onshore winds. During the latter, sand is transported and deposited across the width of the foredune complex, well inland of the crest. Both processes appear to contribute to the vertical accretion and lateral growth of the foredune complex. Between 1978 and 1998 the morphology of the stoss face of the foredune complex has become more regular as the density of *Ammophila* increased and the extent and frequency of foredune blowouts declined. Narrow blowouts of a few metres wide and 20 m or so deep still occur, but these appear short-lived and are minor compared with the mass of the foredune complex. Periodic scarping during storm conditions limits the growth of *Ammophila* down the lower slopes of the stoss face of the foredune complex; hence, the plan configuration of the seaward edge of the foredune complex has become very regular since the establishment of *Ammophila* (Figure 2).

The long-walled parabolic dunes in the central Mason Bay study area developed before *Ammophila* invasion—they are present in the 1958 aerial photographs and were briefly described by COCKAYNE (1909). They are active transgressive dunes. Their depositional lobes have migrated at average rates of 5.0–7.5 m per year since 1978. The morphology and plant cover of parabolic dune number six is typical of these landforms. Four morphologic components are recognisable: (1) the deflation zone; (2) an area of active erosion incorporating the 'throat'; (3) a depositional lobe comprising a complex of coppice and shadow dunes; and (4) shared trailing arms (Figure 4). These elements of the parabolic dune have been maintained as the throat and depositional lobe advanced inland and the trailing arms lengthened in the period 1978 to 1998.

Live *Desmoschoenus* was observed during 1999 in the deflation zones of most of the parabolic dunes in the study area, (although most was moribund); on the level surfaces of the trailing arms (with *Ammophila* and a range of native dune and opportunistic species); and, occasionally, forming isolated

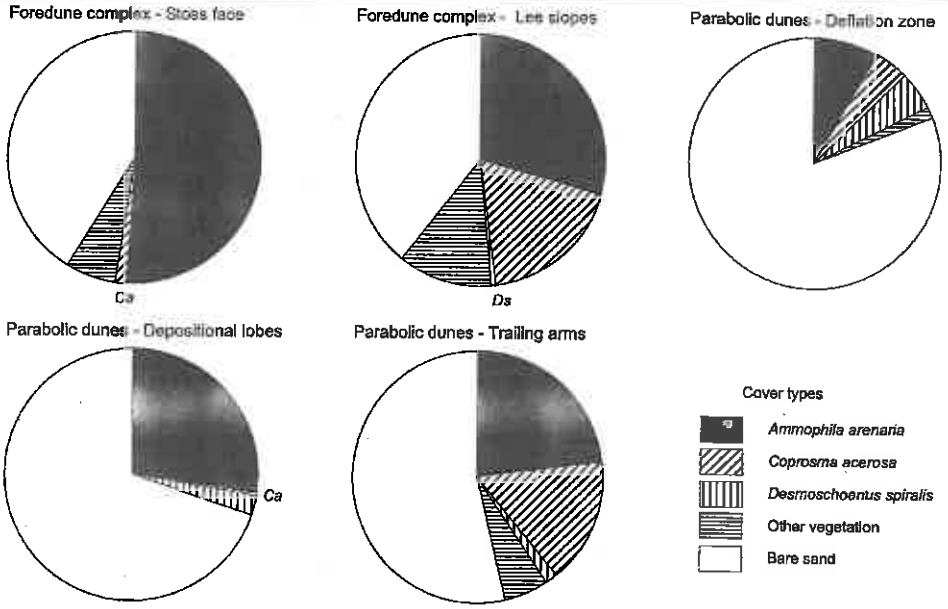

Figure 5. Recent progradational history of the southern dune system, Doughboy Bay, 1977–1999. Progradation has occurred in conjunction with *Ammophila arenaria*. *Desmoschoenus spiralis* is now restricted to the remnant barrier landward of the storm scarp.

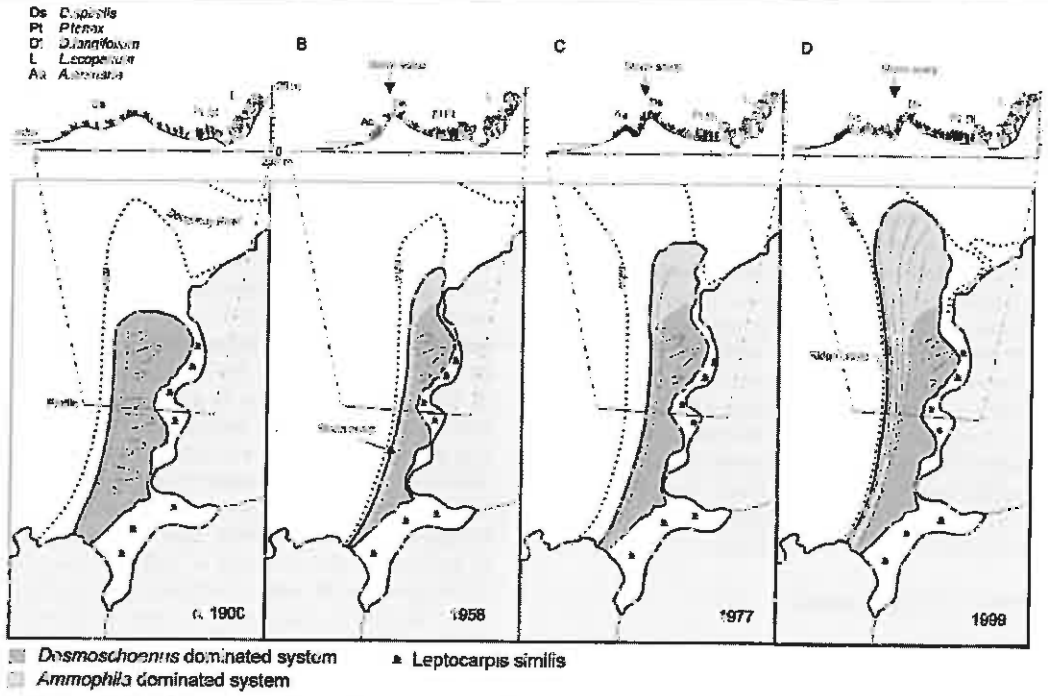

Figure 6. Interpretation of coastal change and *Ammophila* invasion, southern dune system, Doughboy Bay, *ca.* 1900–1999.

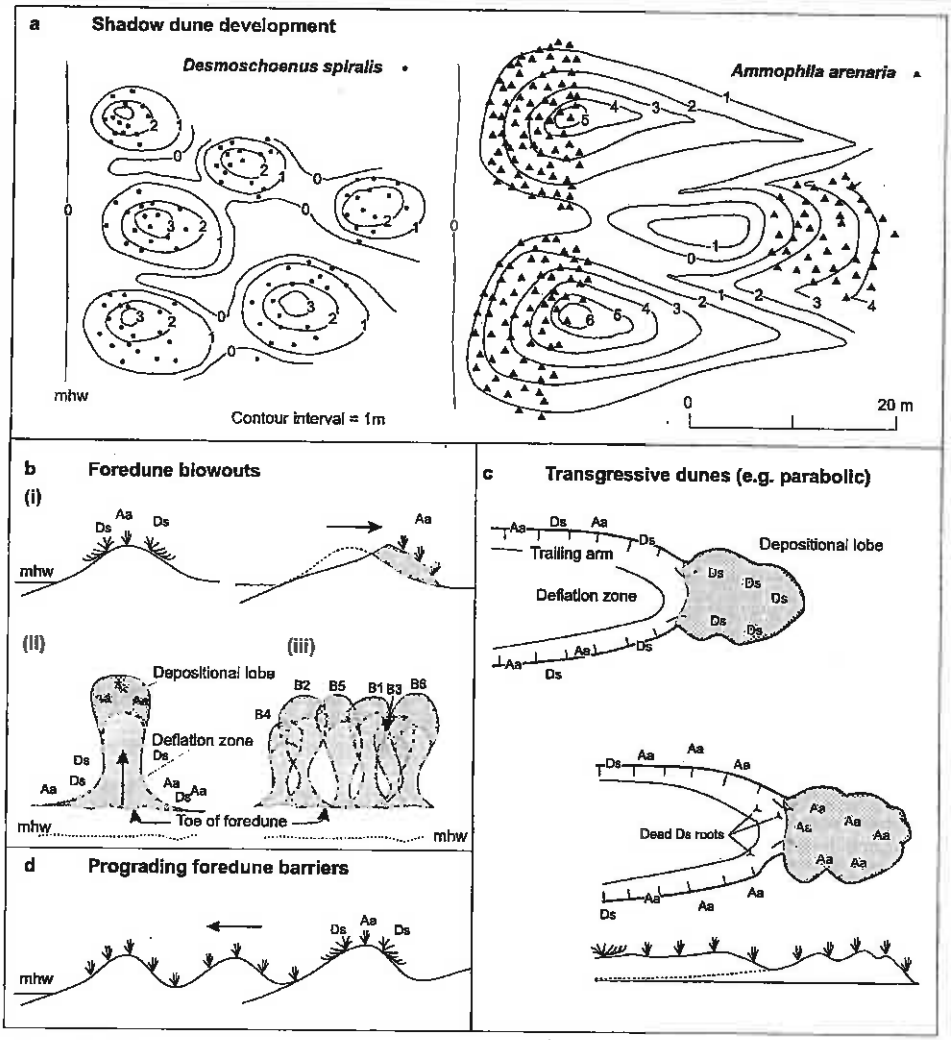

Figure 7. Interpretations of landform development and *Ammophila* invasion in the study areas.

Displacement of *Desmoschoenus* across the long-walled parabolic dunes in Mason Bay has also been rapid since the establishment of *Ammophila*. This process is an inevitable consequence of dune migration. The throat and depositional lobes are eroded as the dunes advance. The eroded sand is transported downwind and landward, usually through a narrow throat, or multiple throats, to contribute to the progressive construction of a new depositional lobe, progressively landward of the former (Figure 7c). In this fashion, the depositional lobes are being continually recycled. The destruction of *Desmoschoenus* is, therefore, a natural process. The failure of *Desmoschoenus* to re-establish in the depositional lobes and trailing arms is a consequence of competition with *Ammophila*. *Ammophila* appears better able and more aggressive at colonising the depositional lobes of these landforms. Once established, *Ammophila* may displace indigenous species by accelerating accretion beyond the survival threshold of these species. At the same time the indigenous species in the depositional lobe and throat zones are destroyed as the dune advances downwind. The trailing arms are relatively stable and hence retain higher indigenous species diversity. Secondly, where *Desmoschoenus* is able to establish in the depositional lobes, it is probably displaced by burial.

Finally, *Ammophila* invasion may be very rapid on coasts experiencing progradation (Figure 7d). Associated loss of native dune species may be equally rapid. *Ammophila* colonized developing foredunes at Doughboy Bay following a significant storm event more rapidly than *Desmoschoenus*. In this case *Ammophila* invasion and *Desmoschoenus* displacement may be very rapid, of the order of years. In such dynamic circumstances inter-specific competition for nutrients is unlikely to be a significant displacement mechanism.

SYKES, M.T. and WILSON, B., 1990a. An experimental investigation into the response of New Zealand sand dune species to different depths of burial by sand. *Acta Botanica Neelandica,* 39, 171–181.

SYKES, M.T. and WILSON, B., 1990b. Dark tolerance in plants of dunes. *Functional Ecology,* 4, 799–805.

WIEDEMANN, A.M. and PICKART, A., 1996. The *Ammophila* problem on the Northwest coast of North America. *Landscape and Urban Planning,* 34, 287–299.

WILLIS, A.J.; FOLKES, B.F.; HOPE-SIMPSON, J.F., and YEMM, E.W., 1959. Braunton Barrows: the dune system and its vegetation. II. *Journal of Ecology,* 47, 249–288.