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The Potential for Marine Dispersal of *Ammophila Arenaria* (Marram Grass) Rhizome in New Zealand

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ABSTRACT

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Ammophila arenaria (L.) Link was introduced to New Zealand in the 1880s and now dominates most dune systems. The few dune systems of national conservation significance that remain are threatened by ongoing natural dispersal of *A. arenaria*. Temperate dune systems elsewhere, including those of Southeast Australia and North America, are also subject to *A. arenaria* invasion.

Natural dispersal of *A. arenaria* occurs primarily through alongshore marine transportation of rhizome. This process provides a mechanism though which *A. arenaria* can invade remote dune systems. The marine dispersal of *A. arenaria* rhizome is recognised, but remains poorly understood. This study provides the first systematic analysis of *A. arenaria* dispersal in the marine environment. It aims: 1) to determine how long *A. arenaria* rhizome can remain viable in sea water; and 2) to determine how long rhizome remains buoyant in seawater. These two factors, in combination with the speed of surface drift, determine the distance over which *A. arenaria* can disperse.

Laboratory-based experiments establish that rhizome is able to regenerate after 70 days in seawater. Tolerance to seawater immersion is seasonal - rhizome is able to withstand longer immersion during winter months. Rhizome also remained viable for longer in cooler water. Rhizome remained buoyant for up to 161 days, much longer than rhizome retained viability.

A. arenaria is able to invade isolated dune systems through marine dispersal over considerable distances (hundreds of kilometres). These results show that *A. arenaria* could invade all dune systems in New Zealand and highlights the need for ongoing surveillance of isolated dune systems.

ADITIONAL INDEX WORDS: *dunes, conservation, salinity, buoyancy*

INTRODUCTION

Ammophila arenaria (L.) Link (marram grass, European beach grass) is a significant weed of coastal dunes in New Zealand. Deliberately introduced to New Zealand in the late 1800s (ca. 1880), *A. arenaria* has naturalised and spread throughout New Zealand. *A. arenaria* invasion has been identified as the leading threat to the ecology of dune systems in New Zealand (HILTON, 2006). Only a few dune systems in New Zealand now retain a high degree of naturalness (JOHNSON, 1992; PARTRIDGE, 1992; HILTON, 2006). Long distance invasion can occur by marine dispersal. Marine-dispersed *A. arenaria* rhizome poses a significant risk to remote dune systems. The conservation of these dune systems depends, in part, on understanding processes of *A. arenaria* dispersal and invasion. The distance over which rhizome is dispersed depends on interrelated factors of buoyancy, tolerance of salinity and the nature of surface water drift (RIDLEY, 1930; CLARKE and MYERSCOUGH, 1991). Surface water drift is highly variable and depends on the oceanography of the region of dispersal. Buoyancy and tolerance of salinity, however, is more easily quantified, and is the focus of this paper.

The ability of *A. arenaria* to spread through marine dispersal is recognised, but remains poorly understood. The buoyancy of *Ammophila* spp., *A. arenaria* and the closely related *Ammophila breviligulata*, and their tolerance of seawater have previously been investigated. Rhizome was found to sink within five to six days (MAUN, 1983; KENVEL, 2001). It has been established that *A. arenaria* rhizome can withstand between 13 and 71 days immersed in seawater (BAYE, 1990; APTEKAR and REJMANEK; 2000). These studies indicate that the marine dispersal of *A. arenaria* rhizome is limited by buoyancy and that dispersal must take place within five to six days. If the rhizome has not been stranded in a suitable location for growth within this time it will sink, despite retaining viability. Observations of stranded rhizome in southern New Zealand, however, indicates that rhizome is being transported over 100-250 km, more than could be accounted for by surface drift over 5 days. This study aims: 1) to determine how long rhizome of *A. arenaria* can remain viable in sea water; and 2) to determine how long rhizome remains buoyant in seawater. These two factors, in combination with the speed of surface drift, determine the distance over which *A. arenaria* can disperse. Successful invasion of a dune system occurs in specific circumstances related to strand conditions. These processes are the subject of ongoing research by the authors.

METHODS

The buoyancy and salinity tolerance of *A. arenaria* rhizome have been determined experimentally in the present study. *A. arenaria* rhizome was collected from an established foredune population at Allan's Beach, Otago Peninsula, New Zealand (45°52'S Lat, 170°41'E Long), and cut into fragments of approximately 25 cm containing two to three nodes. This length is typical of fragments washed ashore in southern New Zealand. Rhizome was placed in tanks with flow-through sea water at the University of Otago Portobello Marine Laboratory and immersed for between 26 and 40 days, with rhizome being removed and placed in sand in the glasshouse every second day. Five replicates were used for each submergence treatment. Control rhizomes were not immersed in seawater, but immediately planted in beach sand in glasshouse flats. Seawater-treated rhizomes were planted in beach sand after each treatment period. Rhizome was watered with freshwater as needed and allowed to grow for 3 months. Rhizome viability was established if a fragment produced at least one shoot.

Experiments were conducted in December 2004 (summer) and July 2005 (winter) to determine the maximum tolerance of rhizome to seawater and to examine seasonal variation in the tolerance of *A. arenaria* rhizome to seawater immersion. A second longer winter experiment was conducted in July 2006. Rhizome was cut into 10 cm lengths containing one node and immersed for between five and 70 days. Five fragments per treatment were removed every fifth day and planted in sand flats in the glasshouse.

To establish whether seawater temperature affects the viability of rhizome in seawater, rhizome was collected in July 2008 and cut into 10 cm lengths, each containing one node. Rhizome was placed in trays of seawater in growth cabinets at 5, 15 and 25°C. Rhizome was immersed for a maximum duration of 40 days with rhizome being removed every fifth day. Five replicates were used for each treatment period. Seawater was replaced every 10 days.

The buoyancy of *A. arenaria* rhizome was assessed by floating 45 rhizome fragments containing one, two or three nodes. The number of fragments floating was recorded after 12 hrs, every second day for 25 days, and then every seven days until no fragments remained buoyant. Fresh seawater was added every seven days.

RESULTS

A. arenaria rhizome remained viable in seawater for longer during the 2005 winter experiment than the 2004 summer experiment (Table 1). Rhizome extracted from the dune and immersed in seawater during the summer experiment failed to produce any shoots during the treatment period. Rhizome immersed in seawater during the winter experiment retained viability after 40 days in seawater. There was no significant increase or decrease in viability as the duration of immersion was increased; viability per treatment was highly variable. The viability of the summer and winter controls did not differ significantly.

A. arenaria rhizome remained viable for 70 days in seawater, the maximum duration of the experiment conducted in July 2006 (Figure 1). As with the July 2005 experiment viability was variable, with no significant increase or decrease in viability as the duration of immersion increased, although viability appeared to decline after 35 days.

Table 1: Seasonal variation in rhizome viability following seawater immersion.

	Percent of rhizome fragments producing at least one shoot	
Days in seawater	December 2004 (Summer)	July 2005 (Winter)
0 (control)	50	52.63
26	0	8.33
28	0	18.18
30	0	63.64
32	0	0
34	0	25
36	0	16.67
38	0	33.33
40	0	7.69

The relationship between seawater temperature and rhizome viability was examined by immersing a single collection of rhizome in temperature-controlled tanks. Rhizome was able to withstand longer periods of immersion in colder water (Figure 2). Rhizome immersed in 5°C water retained viability after 40 days, while rhizome in 15°C water retained viability for up to 35 days and in 25°C water for up to 20 days. Viability of the 5°C treatment did not decline with increasing immersion duration. Viability of both the 15 and 25°C treatments declined with increasing immersion duration.

Rhizome remained buoyant for up to 172 days in seawater (Figure 3). Buoyancy declined exponentially with time spent in seawater - 50 percent of all fragments had sunk after 11 days in seawater. The presence of at least two nodes appeared to be the most significant factor influencing rhizome buoyancy. With the exception of one fragment all single noded fragments sunk within 14 days. It took more than 60 days for 50 percent of the fragments to sink when single-noded fragments were excluded from the analysis.

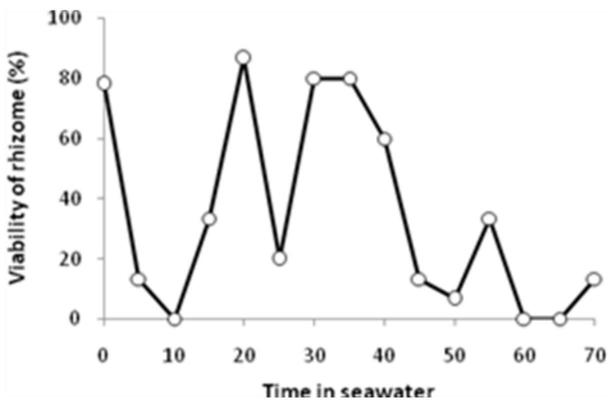

Figure 1. Rhizome viability following seawater immersion.

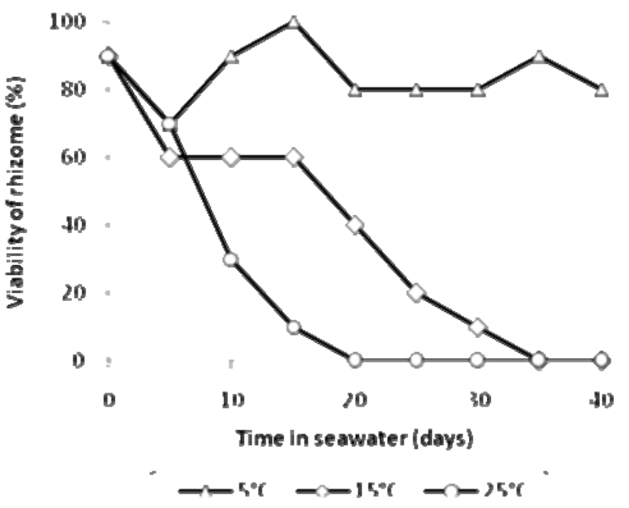

Figure 2. Rhizome viability following seawater immersion at different temperatures.

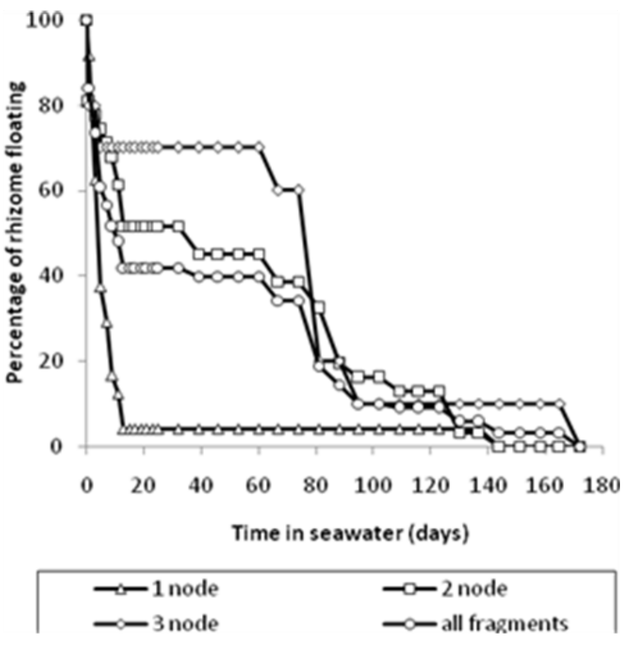

Figure 3. Rhizome buoyancy in seawater.

DISCUSSION

A. arenaria can undergo marine dispersal for much longer periods than previously estimated. The rhizome of *A. arenaria* is able to regenerate after at least 70 days in seawater and can remain buoyant for 161 days. Previous studies indicated that *A. arenaria* rhizome can only undergo marine dispersal over a five day period, and that dispersal is limited by a loss of buoyancy (MAUN, 1983; KNEVEL, 2001), despite retaining viability for 13-70 days in seawater (BAYE, 1990; APTEKAR and REJMANEK; 2000). This study indicates that dispersal is limited by a loss of rhizome viability rather than a loss of buoyancy. The use of only single noded fragments by MAUN (1983) and KNEVEL (2001) may explain the discrepancy between the results presented in the current study and previous buoyancy experiments. The sealed internodes allows rhizome to float for long periods.

Marine dispersal provides a mechanism for *A. arenaria* to enter isolated dune system of high conservation value. Currently less than 50 dune systems remain in a near-natural state in New Zealand, just 5 percent of New Zealand dune systems. For the most part, these systems do not contain *A. arenaria*, or it has only recently established (HILTON, 2006). *A. arenaria* is now widespread throughout New Zealand. Those few dune systems remaining in a near-natural state have mature *A. arenaria* populations nearby. For example, Fiordland National Park in south western New Zealand contains approximately 20 percent of the remaining dune systems of high conservation value. Dune systems to the north and east of Fiordland are largely dominated by *A. arenaria*. *A. arenaria* is also present further south. The Department of Conservation is currently managing several *A. arenaria* infestations within Fiordland National Park, which could only have originated as a result of marine-dispersed rhizome. Rhizome probably originated on the West Coast of the South Island and was carried to Fiordland by the prevailing southerly drift. The *A. arenaria* sites in Fiordland range from approximately 100 to 300 km from the Haast embayment, the nearest substantial *A. arenaria* population on the West Coast. Rhizome may have originated from further afield - assuming transportation in a constant direction at a speed of 0.1- 0.2 m/s, one estimate for rates for wind driven surface drift on the New Zealand shelf (SHARPLES, 1998), rhizome could be transported 604.8 – 1209.6 km over 70 days. This distance is almost the length of New Zealand. All dune systems of high conservation value lie within the reach of marine dispersed rhizome. The probability of successful invasion from any one dispersal event is probably low, however, the supply of rhizome to the marine environment as a result of foredune scarping and river mouth migration is high. A successful stranding of a rhizome fragment is inevitable. Only one fragment is needed to start a new colony, which is then able to generate new rhizome within 12 months.

Seawater temperature appears to exert an important control over rhizome viability in seawater. Treated rhizome retained viability for much longer periods when immersed in seawater during winter months, compared with summer months. The viability of many perennial plants varies seasonally in response to seasonal fluctuations of storage carbohydrates (CHAPIN et al., 1990). However, the samples of rhizome placed directly in the glasshouse, without seawater treatment, showed similar levels of viability. The seasonal variation in rhizome viability is due to the immersion in seawater, and it appears to be linked to seawater temperature. Rhizome retained viability for longer in cooler water. Surface seawater temperatures in New Zealand reach a maximum in late summer and a minimum in late winter (Taylor and Kidson, 1985). Many dune erosion events responsible for depositing rhizome into the marine environment occur during winter storms. Hence, *A. arenaria* has the potential to disperse further in winter when greater quantities of rhizome are likely to enter the sea.

Variations in sea-water temperature may help explain the distribution of *A. arenaria* in New Zealand. Recent observations by the authors indicate that *A. arenaria* is not the dominant or primary foredune species north of 38°S latitude – *Spinifex sericeus* is the dominant foredune species north of this latitude. Furthermore, *A. arenaria* invasion through stranded rhizome is a common occurrence south of this latitude, but stranded rhizome is seldom observed further north. New Zealand covers a wide latitudinal range, from 30°S to 53°S. Surface sea temperatures decline from north to south, ranging from 20.5°C to 13.5°C in late summer and 15.5°C to 10°C in late winter (REID, 1972). The potential for successful dispersal of *A. arenaria* rhizome is much greater in southern New Zealand than northern New Zealand.

CONCLUSION

The potential for marine dispersal of *A. arenaria* is much greater than previously thought. *A. arenaria* rhizome is able to withstand at least 70 days in seawater, hence rhizome has the potential to be transported over long distances. *A. arenaria* has the potential to invade all New Zealand's remaining dune systems of high conservation value. Seawater temperature is an important control on the marine dispersal of rhizome.

LITERATURE CITED

APTEKAR, R. & REJMÀNEK, M., 2000. The effect of sea-water submergence on rhizome bud viability of the introduced *Ammophila arenaria* and the native *Leymus mollis* in California. *Journal of Coastal Conservation*, 6, 107–111.

BAYE, P.R., 1990. Comparative growth responses and population ecology of European and American beachgrass (*Ammophila* spp.) in relation to sand accumulation and salinity. London, Ontario: University of Western Ontario, Ph.D. thesis, 298p.

CHAPIN, F. S.; SCHULZE, E., and MOONEY, H. A., 1990. The Ecology and Economics of Storage in Plants. *Annual Review of Ecology and Systematics*, 21, 423-447.

CLARKE, P.J. and MYERSCOUGH, P.J., 1991. Buoyancy of *Avicennia marina* propagules in south-eastern Australia. *Australian Journal of Botany*, 39, 77–83.

HILTON, M.J., 2006. The loss of New Zealand's active dunes and the spread of marram grass (*Ammophila arenaria*). *New Zealand Geographer*, 62, 105–20.

JOHNSON, P., 1992. *The sand dune and beach vegetation inventory of New Zealand. II. South Island and Stewart Island (Land Resources Scientific Report Number 16)*. Christchurch, New Zealand: Department of Scientific & Industrial Research, 250p.

KNEVEL, I.C., 2001. The life history of selected coastal foredune species of Eastern Cape, South Africa. Grahamstown, South Africa: Rhodes University, Ph.D. thesis, 291p.

MAUN, M.A., 1985. Population biology of *Ammophila breviligulata* and *Calamovilfa longifolia* on Lake Huron sand dunes. I. Habitat, growth form, reproduction, and establishment. *Canadian Journal of Botany*, 63,113-124.

PARTRIDGE, T., 1992. *The sand dune and beach vegetation inventory of New Zealand. I. North Island (Land Resources Scientific Report Number 15)*. Christchurch, New Zealand: Department of Scientific & Industrial Research, 253p.

Reid, S. J. 1972. *Monthly mean sea surface temperatures in the New Zealand region (Technical note number 213)*. Wellington, New Zealand: Meteorological Service, 5p.

RIDLEY, H.N., 1930. *The dispersal of plants throughout the world*. Ashford, England: Reeve. 744p.

SHARPLES, J. 1998. Physical processes on the New Zealand shelf and the rest of the world's islands. *In*: Robinson, A. R. and Brink, K. H. (eds.), *The Sea, the global coastal ocean - regional studies and synthesis (11)*. New York: Wiley & Sons, pp. 965-996.

TAYLOR, B.F., and KIDSON, J.W. 1985. *Sea surface temperatures from satellites (Information publication number 9)*. Wellington, New Zealand: New Zealand Meteorological Service, 6p.