Use of *Ammophila arenaria* for Dune Stabilization in South Africa and Its Current Distribution—Perceptions and Problems

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ABSTRACT / This paper examines the use of the European dune pioneer plant *Ammophila arenaria* (marram or European beach grass) for dune stabilization in South Africa in the past and present, its present distribution in South Africa, and the perceptions of coastal management agencies and the public about its further use. The planting of *A. arenaria* became the most important means of dune stabilization, by human intervention, along the South African Cape coast in this century. Its modern distribution from the semiarid west coast to the subtropical shores of the Eastern Cape extends through various climatic zones. Although historical data are missing for some areas, there is no indication of its unaided spread. *A. arenaria* occurs at most sites because of its prior planting. The South African climate appears to affect its vigor. However, concern about the use of the alien grass has been raised since it has proved to be a highly invasive species in other parts of the world, particularly along the North American west coast and in Tasmania. While the CSIR (Council of Scientific and Industrial Research) promotes its use, CNC (Cape Nature Conservation) follows a policy that restricts the use of any alien plant, including *A. arenaria,* and requests further research on its invasive properties. Although a questionnaire survey shows that stabilization sites featuring large areas of *A. arenaria* are accepted by the South African public, current coastal management practices need to be analyzed critically. A thorough investigation of the potential invasiveness of *A. arenaria* on South African coastal dunes will be essential and shed new light on the American *A. arenaria* problem.

Ammophila arenaria as Primary Agent for Dune Stabilization in South Africa

More than 80% of the South African coastline consists of sandy beaches backed by dunes (Tinley 1985), which are largely unvegetated and mobile. Coastal driftsands usually originate in dune fields where the equilibrium between open sand, the natural dune vegetation, and the forces of nature have been disturbed (Stehle 1987). Such disturbance can be caused by natural agents such as sea currents, storms, and changes in climatic patterns, or through human activities such as the removal of vegetation for firewood or thatching, inconsiderate development, and trampling of vegetation by stock animals, humans, or off-road vehicles. The sandy Cape Flats to the east of Cape Town, for example, used to be vegetated and comparatively stable. However, following the first European settlement in Cape Town in the 17th century, the natural vegetation of the Cape Flats was rapidly destroyed by wagons, trampling, and overgrazing, and they turned into an inhospitable area of shifting sands difficult to cross and even more difficult to develop.

European settlement in South Africa led to both the further spread of driftsands as well as the need for their stabilization. The history of stabilization practices in South Africa has been dealt with by several authors (Braine 1903, Keet 1936, King 1939, Walsh 1969, Shaughnessy 1980, Stehle 1982, Avis 1989). The use of European marram or beach grass [*Ammophila arenaria* (L.) Link] for dune stabilization was initiated in the 1870s in the vicinity of Cape Town. After many trials with the grass, which had by then proved to be a capable sand binder in Europe and other parts of the world, it was finally agreed that the planting of *A. arenaria* was the best method for temporary dune stabilization in South Africa (Heywood 1894, Hutchins 1901, Lubke and Hertling 1995). Since 1896, *A. arenaria* has been planted on a large scale in the Cape province of South Africa (Stehle 1982). Artificial dune stabilization with *A. arenaria* is still a common practice along the entire Cape coast, mainly to prevent sand encroachment of existing development, but also to make new development such as hotels and holiday resorts feasible (McGwynne and others 1993, Hertling 1997).

KEY WORDS: *Ammophila arenaria;* Marram; European beach grass; Dune stabilization; South Africa; Coastal management

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Adverse Impacts of *Ammophila arenaria* in Other Parts of the World

A. arenaria has proved to be a highly invasive species along the west coast of North America, where it was introduced in the mid-19th century. It appears to induce changes in dune topography (Barbour and Johnson 1977, Wiedemann 1984); it causes the decline or even elimination of indigenous dune plants and their communities (Barbour and others 1976, Wiedemann 1984, 1993, Boyd 1992, Pickart and others 1990, Wiedemann and Pickart 1996); it spreads rapidly even on stable inland dunes (van Hook 1983, Buell and others 1995) by means of sexual as well as vegetative reproduction (Baye 1990, Bencie 1990); and it bears many physiological advantages that ensure its competitive superiority over indigenous dune plant species (Pavlik 1983a,b). In spite of this, *A. arenaria* continues to be used along the coast of California and Oregon, both by public agencies and private individuals and organisations (Wiedemann 1987, Wiedemann and Pickart 1996).

Cullen (1999) describes a severe case of biological invasion by *A. arenaria* in Tasmania, where the grass was also introduced in the mid-19th century. As in California and Oregon, it transforms the topography of Tasmanian dunes, grows well even on stable dunes further inland, and was observed to spread alongshore by vegetative reproduction: Cullen (in preparation) found that on the west coast of Tasmania spread of *A. arenaria* has resulted from the development of steep transgressing foredunes more prone to wave attack, the consequential release of tillers into the sea, and the tillers being washed ashore further along the coast where they would form vigorous new colonies. For economic and environmental reasons, *A. arenaria* has not been planted in Tasmania since 1997 (M. Pemberton personal communication 1998). Adverse impacts of *A. arenaria* on dune biota and dune geomorphology have also been reported in mainland Australia (Mitchell 1974, Heyligers 1985, Sacheti and Scott 1986), where the grass is still planted in smaller amounts (Druett 1991, G. Druett personal communication 1997), and in New Zealand (Esler 1970, Johnson 1982, 1993, Smith and others 1985), where the National Parks Board has ruled out the use of *A. arenaria* in its reserves (Johnson 1982), but where it may still be used in other areas.

Objectives of the Present Study

Concern regarding the further use of the grass for dune stabilization in South Africa was raised in 1994, and research about its potential invasiveness in South African coastal dune systems was initiated (Lubke and Hertling 1995, Hertling 1997). In this paper, we examine the use of *A. arenaria* in South Africa in the past and present and compare sites of its use with those of its current distribution in order to establish the possible spread of the alien grass. Perceptions of South African people about stabilization sites involving *A. arenaria* are recorded through a questionnaire at a large stabilization site at Tableview, north of Cape Town.

Methods

Information about the use of *A. arenaria* in South Africa in past and present was obtained from past issues of the Agricultural Journal of the Cape Colony and other literature, archive material of CNC (Cape Nature Conservation), and through personal communications with municipalities, farmers, landowners as well as government and semigovernment organizations such as the Department of Water and Forestry, CNC, and CSIR (Council of Scientific and Industrial Research), which are or have been actively involved in the planting of *A. arenaria*. The current distribution of *A. arenaria* along the Cape coast was recorded for location and size of *A. arenaria*-covered area during 1995 and 1996 between St. Lambert's Bay on the west coast to the Kei River mouth in the Eastern Cape. Further north or east *A. arenaria* has never been planted—with the exception of one unsuccessful trial at Walvis Bay in Namibia (see below)—and is unlikely to occur due to the adverse dry and hot climate. Preliminary survey results were published by Lubke and Hertling (1995), but the present results yield more detailed information. The occurrence of *A. arenaria* along the Cape coast was put in relation with mean annual rainfall and temperatures of the relevant areas, using climate data from Heydorn and Tinley (1980).

To gain information on people's perception of stabilization sites, and of *A. arenaria* as the predominant plant in these, we conducted a survey at the large stabilization site of Tableview north of Cape Town (Figures 1 and 2). Between 1991 and 1994, some 4 km of the Tableview coastline were stabilized with *A. arenaria* at a width of 50 m, resulting in about 20 ha of stabilized dunes (Figure 2). The area is fenced off, but wooden footpaths give access to the beach. In April 1997, one hundred people were interviewed at Tableview on their views about *A. arenaria* and the surrounding stabilization site. The questionnaire (Appendix 1) was undertaken as a random sampling, although we ensured that people of different social and racial backgrounds were interviewed.

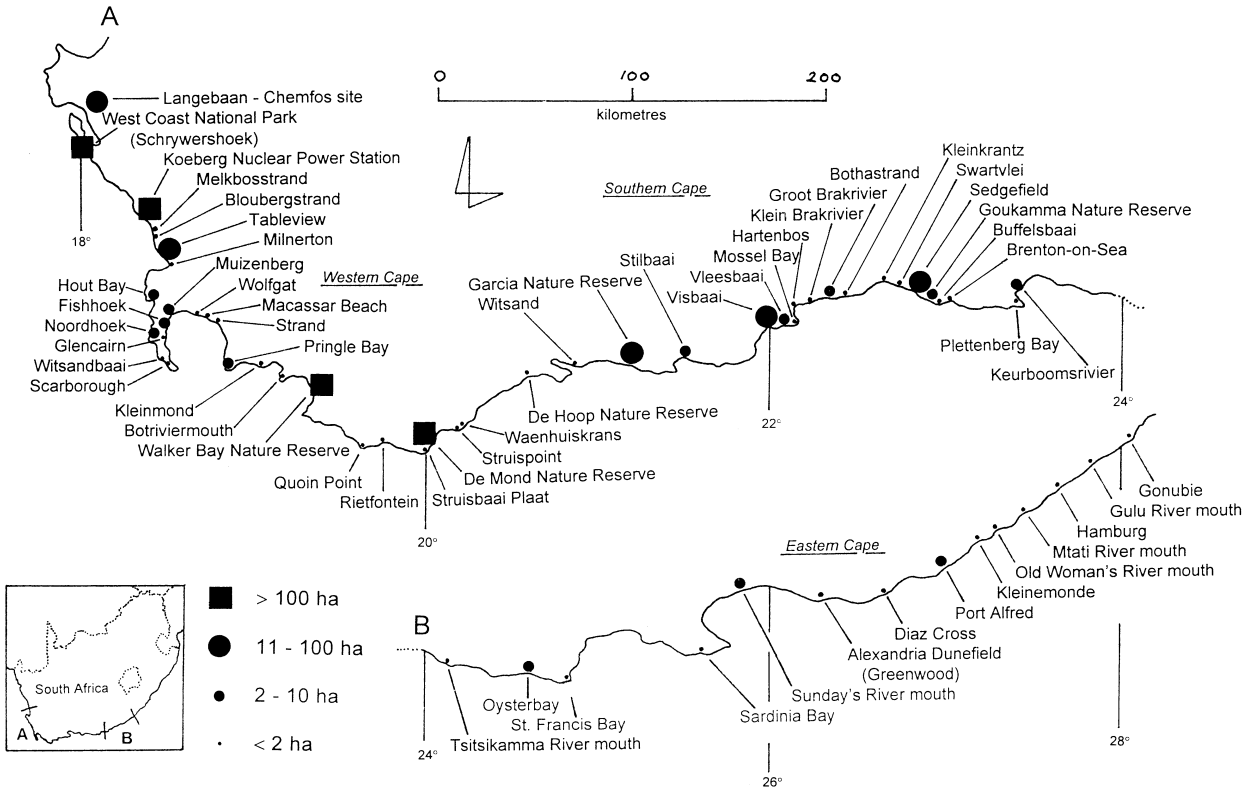

Figure 1. Present distribution of *A. arenaria* along the South African coastline. Every known site of occurrence of *A. arenaria* is shown and its approximate cover with the grass illustrated (in hectares).

Results

Use of *Ammophila arenaria* for Dune Stabilization in South Africa in the Past and Present

The use of *A. arenaria* for dune stabilization spread rapidly from the Cape Flats area near Cape Town with the primary sites of Bellville and Eersterivier along the coast, both to the north and east. From 1900, dune stabilization was carried out on such a large scale that by 1909 an area of 3130 ha, and by 1934 an area of 66,886 ha had been stabilized in the Cape Colony (Stehle 1981, Avis 1989). The northernmost area in South Africa where *A. arenaria* was ever used is Elandsbaai on the west coast. The easternmost known stabilization site involving *A. arenaria* is at Gonubie near East London. *A. arenaria* was also tried unsuccessfully at Walvis Bay, then South West Africa, in the early 1970s (Le Roux 1974).

All known stabilization areas in South Africa are listed in Table 1, although much data on the use of *A. arenaria* were lost. It is not known, for example, whether *A. arenaria* was repeatedly introduced to South Africa from European or even Australian or American sources, or whether the material used for the stabilization was always derived from existing local populations. Today there is no new *A. arenaria* stock being introduced to South Africa. The country contains large enough *A. arenaria* populations to supply its own need for stabilization projects. For many of the recent projects, the grass was obtained, for example, from the extensive Koeberg stabilization site on the west coast (see Table 1).

Present Distribution of *Ammophila arenaria* in South Africa

A. arenaria occurs today along some 1300 km of the South African Cape coast from the semiarid Langebaan area on the west coast to subtropical Gonubie near East London (Figure 1). It is widespread in the winter rainfall area of the Western Cape, but grows well enough in the drier and warmer climates of the bimodal rainfall area of the Southern Cape. The Eastern Cape is also characterized by bimodal rainfalls, but the overall climate becomes increasingly subtropical, and *A. arenaria* occurs in much smaller numbers here. Most of the Eastern Cape sites marked in Figure 1 consist of merely a few degenerating clumps of *A. arenaria.* In contrast, some sites in the the Southern and Western Cape are covered with up to 500 ha (De Mond Nature Reserve) of *A. arenaria.*

Figure 2. Tableview stabilization site near Cape Town in January 1996 (view to southwest towards Table Mountain). Between 1991 and 1994 about 4 km of this coastline were stabilized with *A. arenaria*.

Although planted in the Eastern Cape as well as in the Western and Southern Cape, *A. arenaria* does not last as long in this area. The sites at the mouths of the Old Woman's River and Mtati River in the Eastern Cape were stabilized in the early 1980s and today carry only a few degenerating clumps of *A. arenaria* (Figure 3A). In contrast, the sites of Visbaai, Vleesbaai, and Garcia Nature Reserve in the Southern Cape were stabilized in the 1960s and early 1970s and are still covered with vigorous *A. arenaria* (Figure 3B). The subtropical Eastern Cape to the east of Port Elizabeth appears to be too warm for *A. arenaria,* with mean annual temperatures at East London and Great Fish Point of 18.7°C and 18.0°C respectively (Table 2). Equally unfavorable conditions prevail along the dry west coast, with a mean annual precipitation of 229 mm at Cape Columbine (Table 2). This area is characterized by a dry period from at least November to April. Consequently, at the stabilization sites of Elandsbaai and Ysterfontein, both created in the late 1970s (Table 1), no *A. arenaria* was observed in 1995. However, even the more favorable climatic regions of the southwestern Cape (weather stations of Cape Town and Cape Agulhas in Table 2) do not receive sufficient, continuous rainfall, and artificial watering remains a prerequisite for the successful long-term stabilization of South African dunes with *A. arenaria.*

People's Perceptions on the Use of *Ammophila arenaria*

The subjects were first shown three postcards with scenic views of Table Mountain from the Tableview/Bloubergstrand coastline, featuring different plant species in the foreground (Figure 6). When asked which of these postcards would be their preferred choice to send to friends overseas as a ''typical South African scenery,'' 32% voted for postcard A, which featured the *A. arenaria* stabilization as a foreground to Table Mountain. However, even more people (46%) voted for the equally unnatural garden community of postcard B, complete with bitter aloe (*Aloe ferox*), which does not grow naturally on southwest coast dunes. Only 22% preferred postcard C with a naturally occurring beach daisy (*Didelta carnosa*) hummock in the foreground. While postcards A and B were chosen mostly because of their photographic quality and layout (41% and 24%, respectively), people voted for postcard C almost certainly because of the plants in the foreground (82%). The indigenous *Didelta carnosa* was acknowledged by these people as the only ''real'' west coast plant.

The stabilizing grass of postcard A and the surround-

Table 1. Stabilization of South African coastal driftsands with *A. arenaria* (from west to east)[a]

Site	Total area planted with *A. arenaria* (ha)	Time of plantings	Source of *A. arenaria*	Plantings carried out by
Elandsbaai	—	1975–1980	—	Forestry
Saldanha—Danger Bay	*0.4*	*1920s–1930s*	—	*private*
Langebaan—Chemfos site	—	1996	Koeberg	Top Turf
West Coast Nt. Park—Schrywershoek	—	—	—	—
Ysterfontein	—	1975–1980	—	Forestry
Koeberg Nuclear Power Station	400	1980–1982	—	Eskom
Melkbosstrand	—	1991	Koeberg	"Water's Edge" Dev., CSIR
Bloubergstrand	*19*	*until 1918*		*Cape Forestry*
Big Bay	0.76	1995–1996	Koeberg	Regional Services
Tableview	20	1991–1994	Koeberg	Milnerton Municipality, CSIR
Milnerton—Zonnekus	—	—	—	"Woodbridge Island" Dev.
Bellville (then Durbanroad)	*sowing exp. (failure)*	*1876*	*seed from England*	*Cape Forestry (J. Storr Lister)*
Bellville	*planting*	*1904–1937*	—	*Cape Forestry*
Robben Island	*36*	*1907–1908*	—	*Colonial Secretary*
Cape Peninsula in general	—	*1907–1917*	—	*Cape Forestry*
Hout Bay	—	1990	Koeberg	Forestry, CSIR
Kommetjie	—	1951		Forestry
Witsandbaai	10	1996 (and earlier)	Koeberg	CNC
Glencairn	—	ca. 1988	Fishhoek	CSIR
Fishhoek	1.5	1980s, 1994–1995	Fishoek, Tableview	Local Authorities, CSIR
Muizenberg	—	*1897*	*nurseries*	*Cape Forestry*
Muizenberg, Seekoevlei	—	*from 1936*	—	*Forestry*
Muizenberg	—	1991–1992	Koeberg	Cape City Council, CSIR
Strandfontein, Swartklip	—	*1897*	*nurseries*	*Cape Forestry*
Strandfontein	*95*	*until 1918*		*Cape Forestry*
Macassar Beach	—	1994–1995	Koeberg	Weskaap SDR
Eersterivier	*sowing exp. (±success)*	*1892*	*seed from France*	*Cape Forestry (A.W. Heywood)*
Eersterivier	*planting: 193*	*until 1918*	*nurseries*	*Cape Forestry*
Strand	ca. 0.5	1994–1995	Koeberg	Strand Municipality
Pringle Bay	ca. 8	1970s, 1991	West Coast	Overberg District Council, CSIR
Blesberg	—	late 1970s	—	Forestry
Middelvlei (Botriviermouth)	*137*	*until 1917*		*Cape Forestry*
Walker Bay State Forest	*ca. 5*	*1912–1920*	*own nurseries (2.5 ha)*	*Cape Forestry*
Walker Bay State Forest	ca. 750	1920–1968	own material	CNC
Pearly Beach	—	1960s	—	Forestry
Uilenkraal	—	since 1950	—	Forestry
Quoin Point, Buffeljags	—	*1930s–1950s*	—	*Forestry*
Rietfontein	—	*1930s*	—	*Forestry*
Brandfontein	*40*	*1930s*	—	*Forestry*
Cape Agulhas	*61*	*1901–1906*	—	*Public Services Dept.*
Cape Agulhas—Papenkuilsfontein	—	*1930s*	—	*Forestry*
De Mond	ca. 900	1931–1996	—	Forestry
Waenhuiskrans—Struispoint	ca. 200	1960s	—	Forestry
Waenhuiskrans—village	—	—	De Mond	Forestry
Ryspunt, Skipskop	—	1930s–1960s	—	Forestry
De Hoop	—	*from 1934*	—	*Forestry*
De Hoop	2	1994	De Mond	CNC
Witsand (S. Cape)	5	1984–1987	De Mond	Heidelberg C.P., Forestry
Garcia State Forest	—	1970–1975	—	Forestry
Kleinjongensfontein	—	1980–1985	—	Forestry
Stilbaai	*4*	*1901–1909*	—	*Cape Forestry*
Stilbaai	*ca. 450*	*1932–1951*	—	*Forestry*
Stilbaai—Lappiesbaai	ca. 3	1994	Goukamma Nat. Reserve	Local Council, CSIR, Hydromulch
Visbaai	—	1960s	—	private?

Table 1. (Continued)

Site	Total area planted with *A. arenaria* (ha)	Time of plantings	Source of *A. arenaria*	Plantings carried out by
Vleesbaai	—	1960s	—	private?
Mosselbaai—Voorbaai	—	1990	Koeberg	CSIR
Hartenbos	*49*	*1904–1907*	—	*Railway Dept.*
Hartenbos	—	1968	—	private
Klein Brakrivier	—	1966	—	Divisional Council
Groot Brakrivier	—	—	—	—
Hersham	ca. 1	—	De Mond?	Searles Holdings
Bothastrand	—	—	—	—
Kleinkrantz	—	early 1980s	—	—
Swartvlei	—	—	—	—
Sedgefield	ca. 6	1992–1993	Goukamma Nat. Reserve	Private Dev., CSIR
Goukamma Nature Reserve	—	1920s–1970s	—	—
Plettenberg Bay—Keurboomsrivier	—	—	—	—
Tsitsikamma River mouth	*ca. 1*	*1930s*	—	*Forestry*
Oysterbay/St. Francis Bay	*358*	*1917–1924*	—	*Forestry*
Oysterbay/St. Francis Bay	—	since 1964	—	—
Sardinia Bay	—	—	—	—
Port Elizabeth	—	*1890s–1990*	*Western Cape*	*Harbour Board, Divisional Council, Forestry*
Port Elizabeth—Cape Recife	—	1976–1977	own material	Port Elizabeth Municipality
Sunday's River mouth	4	1960s–1977	—	—
Alexandria Dunefield—several areas	ca. 500	1981–1991	—	Forestry
Diaz Cross	—	—	—	—
Port Alfred	*sowing exp. (success?)*	*1883*	—	*Port Alfred Harbour Authorities*
Port Alfred	—	—	—	—
Kleinemonde	—	—	—	—
Fish River mouth—Fish Point	0.8	1973	—	—
Old Woman's River mouth	—	1980	—	Forestry
Mtati River mouth	—	1978–1982	—	Forestry
Hamburg	—	—	—	—
Gulu River mouth	—	1978–1982	—	Forestry
East London—Gonubie	—	1990s	Alexandria, De Hoop	Gonubie Municipality

[a]Data in italics are from before 1950s. All data obtained through questionnaires sent to municipalities, CNC (Cape Nature Conservation), CSIR (Council of Scientific and Industrial Research) and to the Department of Forestry, as well as from Keet (1936), King (1939), Walsh (1968), Stehle (1980, 1981), McLachlan and others (1982), Lubke (1985b), Reyneke (1985), Avis (1989, 1992), van Zyl (1989), Burns and Barwell (1989), and P.G. Reyneke (personal communication, September 1997). No data available (—).

ings was identified positively by 15% of all subjects as ''marram.'' However, only 6% of all people thought that it was probably not South African, but introduced from Europe. Most people (72%) did not recognize it from any other site in South Africa. Although in the majority, it is noteworthy that only 65% of subjects thought that *A. arenaria* was actually planted at Tableview, while not less than 35% were convinced of its occurring naturally there. Table 3 displays results of the questionnaire related to the aesthetic impact of *A. arenaria* in South Africa: People who accept *A. arenaria* as an attractive plant tend to believe that it occurs naturally at Tableview, while people that think of it as unattractive are more aware of the fact that it is artificially planted. The latter are also more aware of the problems of invasiveness that some exotic plants have created in South Africa. Furthermore, they do not use the Tableview beachfront as regularly as the people who find *A. arenaria* attractive, which can imply that they are not used to its looks to the same degree. Lastly, they tend to prefer natural beaches to built-up beaches.

Although only 58% of the interviewed people were able to name an exotic plant species in South Africa, 64% were aware of or had heard of the problem of invasiveness of exotic plants in this country. *A. arenaria* was never mentioned as an exotic plant, although two subjects, both longtime Tableview residents, were con-

Figure 3. **A:** Remnants of *A. arenaria* at the Old Woman's River mouth near Port Alfred, Eastern Cape (February 1996). **B:** Vigorous *A. arenaria* at Visbaai near Mossel Bay, Southern Cape (August 1995).

cerned about the grass and commented on its growth as ''it doesn't seem to give room for other plants'' and ''marram is going to be as bad as Port Jackson and will spoil our beautiful coastline.'' The latter resident was disapproving of the stabilization as being undertaken merely to give people a better view and was particularly upset about the replacement of the previously varied west coast dune plant community, composed of colorful

Table 2. Mean annual temperature and rainfall data from weather stations along the South African Cape coast (data from Heydorn and Tinley 1980), and from European places in the vicinity where *A. arenaria* occurs naturally (data from Kendrew 1930; Geurts 1982; Harding 1998)

Weather station	Mean annual temperature (°C)	Mean annual precipitation (mm)
South Africa		
Cape Columbine (Langebaan)[a]	15.1	229
Cape Town (Tableview)	17.3	627
Cape Agulhas (De Mond)	16.8	445
Cape St. Blaize (Visbaai)	17.9	417
Cape St. Francis (Oysterbay)	17.0	666
Port Elizabeth (Sunday's River Mouth)	17.3	576
Great Fish Point (Port Alfred)	18.0	559
East London (Gonubie)	18.7	808
Europe		
Bergen	7.1	2057
Hamburg	8.3	699
Vlissingen	9.9	739
London	9.9	622
Bordeaux	12.4	779
Lisbon	15.4	754
Nice	15.1	862
Genoa	15.6	1321

[a]Largest *A. arenaria* population in vicinity (see Figure 1) is given in parentheses.

plants like the hottentot fig (*Carpobrotus edulis*) and the beach daisy (*Didelta carnosa*).

Discussion

Use of *Ammophila arenaria* for Dune Stabilization in South Africa in Past and Present

Ammophila arenaria *as "noninvasive" alien.* *A. arenaria* is the main dune stabilizing agent in South Africa. It is the general belief among South Africans involved with dune stabilization that South African *A. arenaria* is a weak seeder and therefore poses an insignificant threat as an invasive species (P. Raal personal communication 1994). In fact, *A. arenaria* is believed to be the best stabilizer at present in South Africa. CSIR, a semi-government organization which is actively involved in many recent stabilization projects (see Table 1), compared aerodynamic characteristics and associated sand trapping effectiveness of *A. arenaria* with those of the indigenous dune plants sea wheat (*Thinopyrum distichum*) and pipe grass (*Ehrharta villosa*) and found those of *A. arenaria* to be far superior (P. Raal personal communication 1994). Furthermore, *Thinopyrum distichum is not robust enough for the task of dune stabilization, suffering in summer even more from heat stress than A. arenaria, whereas Ehrharta villosa grows too sparsely and cannot withstand as much wind as A. arenaria (M. Burns personal communication 1995).*

Table 3. Selected results of a questionnaire at the Tableview stabilisation site (see text)

	Of 63% who find *A. arenaria* attractive	Of 37% who do not find *A. arenaria* attractive or find it unattractive
Believe *A. arenaria* to occur naturally at Tableview	42.9%	32.4%
Are aware of problem of invasiveness of exotic plants in South Africa	65.1%	72.9%
Use Tableview beach promenade regularly	73.0%	70.3%
Use Tableview beach promenade daily	42.9%	35.1%
Prefer natural beaches to built up beaches	55.6%	62.2%
Prefer built up beaches or like both types	44.4%	37.8%

The use of *A. arenaria* is further justified by CSIR through the observation that it declines in vigor with increasing sand stability and gets replaced by indigenous plants within some 10 years, therefore acting as a nurse plant to indigenous species (P. Raal personal communication 1994). The same view is shared by the Department of Forestry, whose policy involves the sowing of indigenous plants among new *A. arenaria* plantings to ensure the quick replacement of *A. arenaria* (P. G. Reyneke personal communication 1997). Similarly, in Australian dune stabilization projects, *A. arenaria* is nowadays used only in connection with indigenous dune plants and is then observed to be replaced fairly well (Druett 1991, G. Druett personal communication 1997).

The controversy

Even though *A. arenaria* proves to have many positive characters, its use has been criticized by various individuals from about the late 1980s, mainly on the grounds of its foreign origin. During the 1980s South Africa experienced a green movement, which highlighted more than ever the negative impacts that alien species can have on South African ecosystems. When CNC, a government organization, took over many dune areas from the Department of Forestry in 1987, no more plantings of

A. arenaria were carried out. CNC adopted as a policy the removal of all alien species from proclaimed nature reserves, and it was emphasized that *A. arenaria* is included (G. Hellström personal communication 1994).

The controversy over the use of *A. arenaria* for dune stabilization in South Africa was enforced during the international DUNES 94 conference held in South Africa in January 1994. Concern about the use of *A. arenaria* has since then not only been based on the mere ''alienness'' of the grass in South Africa, but also on proven facts about its invasiveness in other areas of the world (see above). In the wake of the conference, CNC therefore called for further research to better understand the invasive properties of marram as a matter of urgency (G. Hellström personal communication 1994). While CNC promotes a policy that restricts the use of all alien plant species in South Africa, including *A. arenaria,* the CSIR will continue using *A. arenaria* unless research shows that it has adverse effects on South African coastal ecosystems.

Dune stabilization under critical review. Due to the unusual vigor and spread of Australian acacias such as rooikrans (*Acacia cyclops*), Port Jackson wattle (*A. saligna*), and long-leaved wattle (*A. longifolia*), which had been raised since the 1930s, the South African Forestry Department changed its policy in 1974 to the effect that ''the use of alien plants should be phased out and only indigenous species and the noninvasive marram grass be used'' (Avis 1989). In consequence, the noninvasive *A. arenaria* gained importance for dune stabilization. Since 1980 the stabilization of dunes itself has been questioned as extremely artificial human interference into natural coastal dynamics, to the extent that it was only to be carried out when farmland or settlements were immediately threatened by sand encroachment. Driftsands were now looked upon as natural areas of great ecological and recreational value and to be preserved as such, rather than stabilized (Avis 1989, Council for the Environment 1991), particularly since it was found that their stabilization can lead to severe beach erosion as the sand supply for adjacent beaches is cut off (Lubke 1985a), which is confirmed by observations in Tasmania (M. Pemberton personal communication 1998).

An argument for the reduction of dune stabilization was also the financial aspect. Stabilization costs in the Alexandria dunefield near Port Elizabeth were estimated at R 1800/ha for the period 1981–1982; thus the stabilization of the entire dunefield would have added up to ca. R 32 million (McLachlan and others 1982). Only small-scale stabilization efforts have been undertaken in this area since the 1960s, and most of the dunefield is now a nature reserve, managed by CNC. Although stabilization efforts have obviously been reduced radically since the first half of this century, it is clear from Table 1 that there is still a fair amount of it undertaken today, usually involving *A. arenaria.*

Despite the efforts to control dune stabilization practices in South Africa, stabilization projects are frequently undertaken not only to prevent sand encroachment on existing development, but also in order to permit new development. Development of hotels and holiday resorts close to the tideline has often led to the stabilization not only of dunes but of backbeach areas as well, causing frequent erosion of the stabilization site (Figure 4). A recent survey of 26 South African dunefields (McGwynne and others 1993) shows that in 18 of these (69%) stabilization efforts were in progress, mostly with the intention of combatting natural destabilization or accommodating development. Only in one case was stabilization undertaken in reaction to immediate sand encroachment problems. However, the development of even the smallest holiday chalet should take into account the natural sediment movements in the area in order to avoid sand encroachment problems a few years later (Figure 5).

Present Distribution of *Ammophila arenaria* in South Africa

It appears as though *A. arenaria* occurs at all sites because of prior planting in the area. Clear historical data are missing in some cases: besides the fairly well-recorded stabilization efforts of government and semigovernment organizations such as the Forestry Department or the CSIR (Council of Scientific and Industrial Research), *A. arenaria* has also been planted by farmers and other private landowners. Records of this use are nonexistent or unobtainable, and information gained from local residents is sparse. However, historical and geographical research so far does not indicate that unaided spread of *A. arenaria* into any of the areas shown in Figure 1 has occurred, as is so obviously the case along the west coast of North America (Buell and others 1995). It can be concluded with acceptable certainty that all sites shown in Figure 1 are or were stabilization sites, which is confirmed by their close correlation with the stabilization sites listed in Table 1.

European temperature and rainfall data from both northern and southern European stations (Table 2) reflect an overall colder and more humid climate in *A. arenaria*'s home territories. It appears as though South African areas of appropriate temperature regimes are too dry, while those of appropriate rainfall regimes are too warm. In addition to unfavorable temperature and precipitation regimes, South African

Figure 4. Eroded stabilization sites too close to the high water mark at Sedgefield near George, Southern Cape (September 1995).

shores are subjected to higher radiation and stronger winds than the European ones and, furthermore, lack regular frost periods, which have been found to enhance germination (Huiskes 1979, van der Putten and van Gulik 1987, van der Putten 1990).

People's Perceptions on the Use of *Ammophila arenaria*

Concern about the grass or about invasiveness in general was unusual. A connection between *A. arenaria* as an exotic species and the detrimental effects that certain other exotic plant species have shown in South Africa is not necessarily drawn. This unsuspicious viewpoint is reflected in an investigation on perceptions of professional ecologists compared to business leaders about priorities of environmental issues in South Africa (Preston and others 1989): 55% of the professional ecologists perceive the problem of invasion of South African ecosystems by exotic plant and animal species as ''critical,'' ''very serious,'' or ''serious,'' compared to only 13% of the business leaders. A severe lack of information on ecological issues such as invasion becomes apparent among nonprofessionals. Environmental awareness in South Africa is closely connected to the level of education. However, some issues—like that of biological invasion—appear to be hardly known at all outside a small circle of professional ecologists.

Conclusions

Since its introduction in the second half of the 19th century, *A. arenaria* has become one of the most important plant species for the artificial stabilization of driftsands in South Africa. It was and is planted in South Africa to such an extent that it presently occurs from the semiarid west coast to the lush, subtropical shores of the eastern region of the Eastern Cape. However, an analysis of the use of *A. arenaria* in the present and past in relation to its modern distribution does not indicate any tendency of *A. arenaria* to spread unaided into areas in which it is not needed as a stabilizer. A reason can be found in the South African climate. Although *A. arenaria* has so far been looked upon as extremely tolerant towards a variety of different climatic conditions, the South African climate is possibly one important factor preventing the aggressively vigorous growth of the grass in South Africa that can be observed so clearly along the temperate shores of north California, Oregon, and Tasmania, which have cool maritime climates.

Although the current practice of stabilizing driftsands with *A. arenaria* appears to be widely accepted by South Africans, it is advisable to exercise more caution regarding the use of *A. arenaria* in South Africa. The grass is presently the primary and in most cases the only plant in South African stabilization projects. Consider-

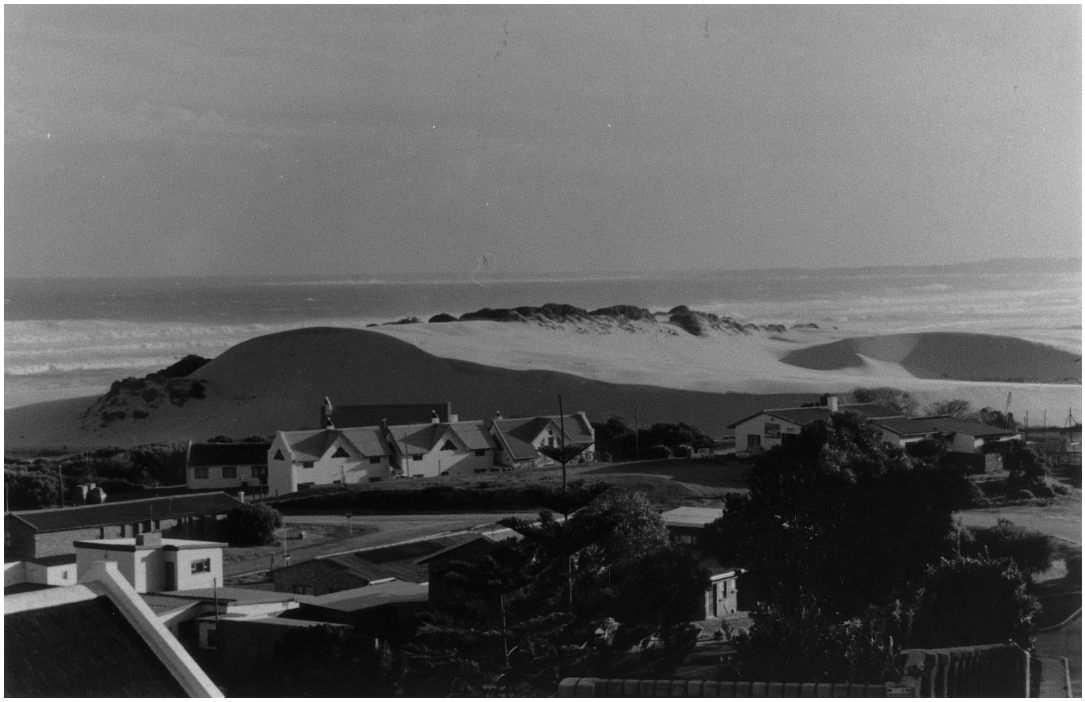

Figure 5. Driftsands threatening an inappropriate resort development at Oysterbay near Cape St. Francis, Eastern Cape (July 1995).

ing that 69% of South African dunefields examined by McGwynne and others (1993) were affected by development of houses, roads, car parks, camping facilities, sewage pipelines and other human-induced structures, it becomes obvious that South African dunefields are severely threatened by human expansion. In the long run, the stabilization of many dunes will be unavoidable. Therefore, a critical analysis of present stabilization methods and their improvement should be tackled sooner rather than later.

Despite the amount of information on the adverse impacts of *A. arenaria* along the North American west coast, a controversy about the further planting of *A. arenaria* between different environmental management agents similar to the controversy in South Africa has not taken place in California and Oregon. *A. arenaria* continues to be used, if on a smaller scale, and it is likely to continue to spread since eradication efforts are extremely time- and labour/cost-intensive and possibly restricted to nature reserves (van Hook 1983, Wiedemann 1987, Wiedemann and Pickart 1996, Pickart and Sawyer 1999). Although a lot of research has been done to find reasons for *A. arenaria*'s invasiveness in California and Oregon, many questions remain open. Research topics such as the reproductive behavior of *A. arenaria,* its genetics, and interactions with soil pathogens will be addressed in the South African study, as will aspects of the community and population biology of the grass (Hertling 1997). The establishment of a potential for invasion of *A. arenaria* on South African Cape coastal dune systems will not only evaluate current coastal management practices in South Africa but also further our knowledge about the biology of this worldwide-used European dune pioneer species and on its possible invader qualities. It will therefore shed new light on the American *A. arenaria* problem.

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Appendix 1. Questionnaire used in the survey at the Tableview stabilisation site, based on postcards A–C (Fig. 6)

Questionnaire—beach promenade Tableview (Cape Town), April 1997

1a. Which of these three postcards do you think is most typical of S. Africa?, which one would you send to friends overseas to show them S. Africa?
A B C
1b. Why?
A: because of layout/composition and photographic quality of postcard
B: because of plants in foreground of postcard
C: both A and B
D: other reason:
1c. Can you name any of the plants on the postcards?
Y N
yes:
1d. Do you think any of the plants on the postcards have been planted or are they natural here?
A: planted: B: natural:
2a. Do you think this grass (pointing at marram around) has been planted or is it natural here?
A: planted B: natural
2b. If A: do you know why it has been planted?
A: beauty B: stabilization of beach
C: other reason: D: don't know
2c. Have you seen this grass anywhere else along the South African coast?
Y N
2d. Do you like the look of this grass?
Y N can't say
2e. Do you know where it comes from?
Y N
2f. Have you ever read any of these signs which explain about the stabilisation?
Y N
3a. Can you name an exotic plant species in S. Africa?
3b. Are you aware of the problem of invasiveness of exotic plants in S. Africa?
Y N
4a. Do you live in South Africa?
Y N
no, in:
4b. If yes, are you from
A: the coast B: inland
4c. If inland: do you go to the coast regularly?
Y N
how often:
4d. Do you prefer natural beaches or built up beaches like this?
A: natural beaches B: built up beaches
C: depends on purpose of visit
4e. Do you use the Milnerton/Tableview beach promenade regularly?
Y N
how often:

Figure 6. Three postcards on sale in Cape Town souvenir shops, showing the view from the Tableview-Bloubergstrand coastline north of Cape Town across Table Bay with *A. arenaria* (A), various indigenous species in a garden (B), and the indigenous *Didelta carnosa* (C) in the foreground.

Figure 6 (continued).

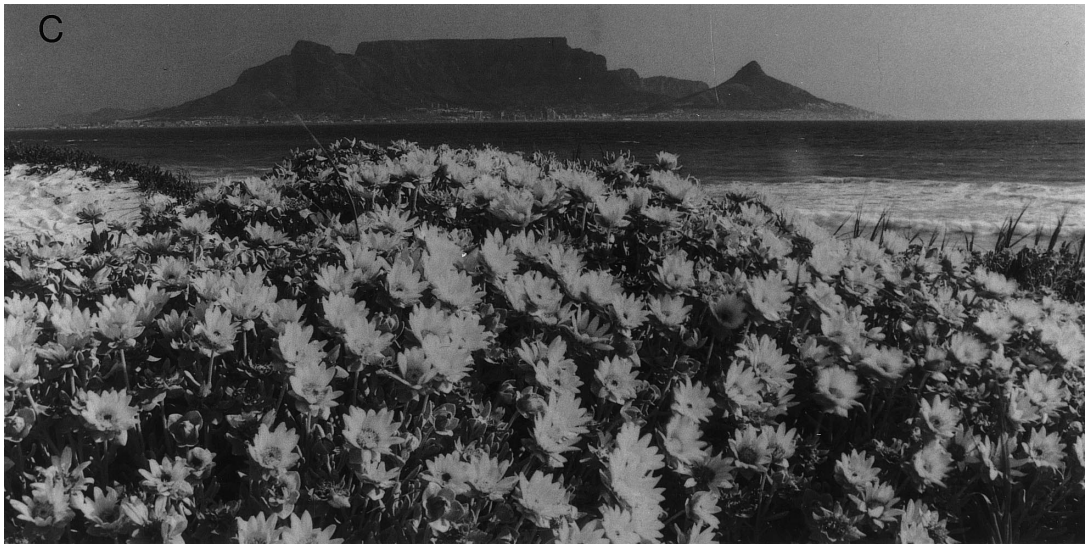

Figure 6 (continued).