# Flora of the Stockton and Port Hunter sandy foreshores with comments on fifteen notable introduced species.

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***Abstract:*** Between 1993 and 2005 I investigated the introduced plant species on the Newcastle foreshores at Stockton and Macquaries Pier (lat 32º 56' S, long 151º 47' E). At North Stockton in a rehabilitated area, cleared of **Chrysanthemoides monilifera* subsp. *rotundata,* and planted with **Ammophila arenaria* interspersed with native shrubs, mainly *Acacia longifolia* subsp. *sophorae* and *Leptospermum laevigatum*, is a rich flora of introduced species of which **Panicum racemosum* and **Cyperus conglomeratus* have gradually become dominant in the groundcover. Notwithstanding continuing maintenance, **Chrysanthemoides monilifera* subsp. *rotundata* has re-established among the native shrubs, and together with *Acacia longifolia* subsp. *sophorae,* is important in sand stabilisation along the seaward edge of the dune terrace.

The foredune of Little Park Beach, just inside the Northern Breakwater, is dominated by *Spinifex sericeus* and backed by *Acacia longifolia* subsp. *sophorae*-**Chrysanthemoides monilifera* subsp. *rotundata* shrubbery. In places the shrubbery has given way to introduced species such as **Oenothera drummondii*, **Tetragonia decumbens* and especially **Heterotheca grandiflora*.

At Macquaries Pier **Chrysanthemoides monilifera* subsp. *rotundata* forms an almost continuous fringe between the rocks that protect the pier against heavy southerlies. However, its presence on adjacent Nobbys Beach is localised and the general aspect of this beach is no different from any other along the coast as it is dominated by *Spinifex sericeus*.

Many foreign plant species occur around the sandy foreshores at Port Hunter. Since the first coal exports in the 1850s the Newcastle wharves and ballast-ground at Stockton became points of entry for foreign species, either directly, or via stopovers at other Australian ports. Some of these, **Panicum racemosum*, **Tetragonia decumbens*, **Ursinia speciosa, *Hebenstretia dentata* and until recently, **Heterotheca grandiflora,* remained restricted to the Newcastle region, while others, e.g. **Chrysanthemum monilifera* subsp. *rotundata*, **Hydrocotyle bonariensis*, **Gladiolus gueinzii* and **Oenothera drummondii*, spread further afield, but only colonised their preferred coastal habitat. Many more species spread far and wide, their port of introduction no longer recognisable. Other species were introduced as garden plants, escaped and became naturalised. However, for most foreign, generally widespread, species their mode of entry can no longer be determined. 99 species were recorded in the six areas regularly visited, about 25% native to Australia, and 75% about evenly divided between species from Africa, Asia and Europe. More detailed information on 15 of the more notable introduced species is provided in an appendix.

On the dune terrace vegetation of North Stockton, only about 20% of the 50 species are native to Australia, the only one of any prominence being *Acacia longifolia* subsp. *sophorae*. Nevertheless, on first impression this 'multinational' assemblage looks quite normal, and when one compares the ecological functioning of the 1930s vegetation with that of the present vegetation, it appears that, due to presence of more graminoids, and the fact that **Panicum racemosum* produces a denser sward than *Spinifex sericeus*, the present vegetation is more effective in sand-catching and dune stabilisation than the vegetation in the 1930s would have been. However in view of the increasing influence of climate change, e.g. a rise in sea level and more extreme weather events, there is no indication that the present terrace, notwithstanding the increased density of the rhizomatous species and a sprawling shrubby vegetation along the crest, will endure such attacks any better than in the 1990s.

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## Introduction

During a reconnaissance of the New South Wales North Coast in 1993 for introduced plant species, the foreshores around Port Hunter provided some unexpected discoveries which triggered follow-up visits to see what else was present. From the first overseas coal exports in the 1850s, Port Hunter (lat 32º 56' S; long 151º 47' E) has been an increasingly busy harbour (Jeans 1972) and over this long period many foreign species could have 'jumped ship.' However, a cursory investigation of the inner harbour foreshores only revealed widespread, usually ruderal exotic species and, hence, my interest remained focused on the seashore on both sides of the harbour entrance (Fig. 1).

## Methods

My observations, made between 1993 and 2005, have been limited to walking over the sites and taking notes about occurrence, condition and location of the species seen. Erosion and ongoing foreshore rehabilitation at several sites made it impracticable to establish permanent plots but, given the limited size of the sites, orientation presented no difficulties. I made collections of 47 species for confirmation of identifications or to document their presence. The specimens were lodged in the Australian National Herbarium (CANB) with a duplicate in the National Herbarium of New South Wales (NSW) if there was sufficient material. Introduced species have been preceded with an asterisk throughout the text.

For nomenclature the Flora of New South Wales (Harden 1990–1993, 2002) was used except for two species new for the State. Walsh and Entwisle (1994) was followed for Victoria and Marchant *et al*. (1987) for Western Australia. The specific epithet of **Tetragonia nigrescens* has been changed to *decumbens* (Heyligers 1999b); the taxonomy of *Senecio pinnatifolius* follows Thompson (2005), that of *Ursinia speciosa* Thompson (2007). For some species of special interest, collections in the Australian National Herbarium (CANB), the National Herbarium of New South Wales (NSW) and the Queensland Herbarium (BRI) were inspected. Information on species distribution was obtained from the Flora of New South Wales and checked against the Germplasm Resources Information Network database (http://www.ars-grin.gov/cgi-bin/npgs/html/taxgenform.pl).

### *Study sites*

#### *The foreshore of North Stockton*

This area, north of the seawall built to protect the township of Stockton, can be split into four sections, namely the zone seaward of the Corroba Park sports fields, the area between Eames Avenue and the beach, the regularly mown area ('the lawn') along Barrie Crescent and the adjoining dune terrace, separated from the lawn by a shade cloth windbreak fence (Figs. 2 and 3). The Eames Avenue and Barrie Crescent foreshores were overrun by **Chrysanthemoides monilifera* subsp. *rotundata* and have been subject to restoration, while at Corroba Park only a narrow zone along the playing fields has received similar treatment.

#### *The beaches around Port Hunter*

Little Park Beach is the southernmost beach of the Stockton foreshore and lies inside the Port between the Northern Breakwater and Pirate Point. It comprises a low, narrow foredune backed by a wider, gently sloping area leading to the Pitt Street Reserve, which is a mainly grassed public park (Fig. 4). Macquaries Pier was constructed between 1818 and 1846 to connect the mainland with Nobbys Island at the mouth of the Hunter River. In the 1870s the pier was reinforced and breakwaters were built to improve access to the Port (Jeans 1972; information on monument at the pier entrance; Fig. 5). The pier obstructed offshore sediment flow which led to the formation of Nobbys Beach. Inside the port, at the base of the pier, lies Horseshoe Beach. This low dune terrace abuts a public reserve and is subject to restoration work.

#### *The local climate*

The study area is part of the humid subtropical coast of eastern Australia (de Castro Lopo 1979). The annual rainfall at the meteorological station on Nobbys Head is about 1135 mm. The wetter season, with monthly rainfall averages around 119 mm, starts in March and lasts till June, while from August till November the average rainfall is about 74 mm per month. However, monthly figures vary over a large range; the highest recorded maxima, more than 540 mm, have been in the months of February, March, April and August, while monthly minima may be less than 5 mm at any time of the year (Bureau of Meteorology website).

Average monthly maximum and minimum temperatures range from about 25ºC and 19ºC during summer to about 17ºC and 9ºC in winter. The regional wind regime is predominantly onshore, generally light to moderate during summer, but moderate to strong during other seasons, especially in the afternoon when seabreezes come in and displace lighter winds from other directions. Regional tides are semi-diurnal and have an amplitude of about 1.5 m with a daily inequality of about 0.5 m between High Waters (Bureau of Meteorology website and Australian National Tide Tables).

## Results

#### *The local flora*

The total number of species recorded, including some only found outside the study sites, was just over one hundred, but this is not a complete inventory as some inconspicuous species not in flower will have gone unrecorded. However, I am confident that I have not missed any of the dominant components of the vegetation. Table 1 provides an overview of the species found on the six areas under observation and their distribution. When I analysed the data I was surprised to discover how 'unaustralian' the vegetation on the study sites really is (Table 2a). Only one-quarter of the 99 species listed in the table are indigenous to Australia. 16 of these are limited to coastal habitats including the 10 species used in restoration planting. Some of the latter, e.g. *Acacia longifolia* subsp. *sophorae*, *Leptospermum laevigatum* and possibly *Lomandra longifolia* now spread naturally on the rehabilitated sites. Australian (but non-local) species used in the plantings are *Acacia saligna* from Western Australia and *Casuarina equisetifolia*, the characteristic species of tropical beaches but occurring naturally only as far south as Laurieton on the NSW North Coast (Wilson & Johnson 1990).

A geographical analysis of the 78 introduced species shows that species from Africa, America and Europe (including North Africa and south-western Asia), are represented in about equal proportions, while only ten species have a wider distribution (Table 2b). 18 out of 23 of the African species came from southern Africa, 14 of the 20 American species were from South America, while of the 22 'European' species only four are restricted to Europe. The other 18 are also found in countries bordering the Mediterranean Sea, while many distributions extend into south-western Asia as well, a reflection of the long habitation and commodities interchange in this region.

Many of the foreign species arrived in Australia unnoticed, in ballast or with agricultural imports (Table 3). However, there are also a fair number of ornamental species which escaped from cultivation or persisted after having been discarded as garden waste. Examples of escapees are **Lobularia maritima* and **Gazania rigens*, of discarded plants **Lampranthus multiradiatus* and **Yucca aloifolia*. About one-third of the foreign species are restricted to coastal habitats, but only **Ammophila arenaria* and possibly **Panicum racemosum* were used in the initial stages of dune restoration. The other foreign species are generally widespread occurring along roadsides, on wasteland and in other disturbed environments.

### *The North Stockton Foreshore*

*The initial regeneration period of the early 1990s*

In the late 1980s the **Chrysanthemoides monilifera* subsp. *rotundata* scrub on the Eames Avenue foreshore was bulldozed into trenches and covered (Conway pers. comm. 1994). Rehabilitation was begun by planting **Ammophila arenaria* on a regular grid and followed up by adding *Acacia longifolia* subsp. *sophorae*, *Leptospermum laevigatum* and *Banksia integrifolia* (Fig. 2b). However, a large seed source of **Chrysanthemoides monilifera* remained on the dunes along the sports field and further to the north. Over time, despite removal efforts, **Chrysanthemoides monilifera* re-established and now, together with *Acacia longifolia* subsp. *sophorae*, forms an integral part in the low shrubbery fringing the immediate shoreline.

During inspections in August 1993 and March 1994, I found a large number of introduced species among the **Ammophila arenaria*, the more common ones being **Oenothera drummondii*, **Hebenstretia dentata*, **Ambrosia artemisiifolia*, **Arctotheca calendula*, **Gazania rigens*, **Lobularia maritima*, **Medicago truncatula*, **Hydrocotyle bonariensis*, **Galenia pubescens* and **Tetragonia decumbens* (Table 1). In addition to *Spinifex sericeus* on the seaward slope, *Senecio pinnatifolius* var. *pinnatifolius* and *Carpobrotus glaucescens* were the only notable native species. *Spinifex*

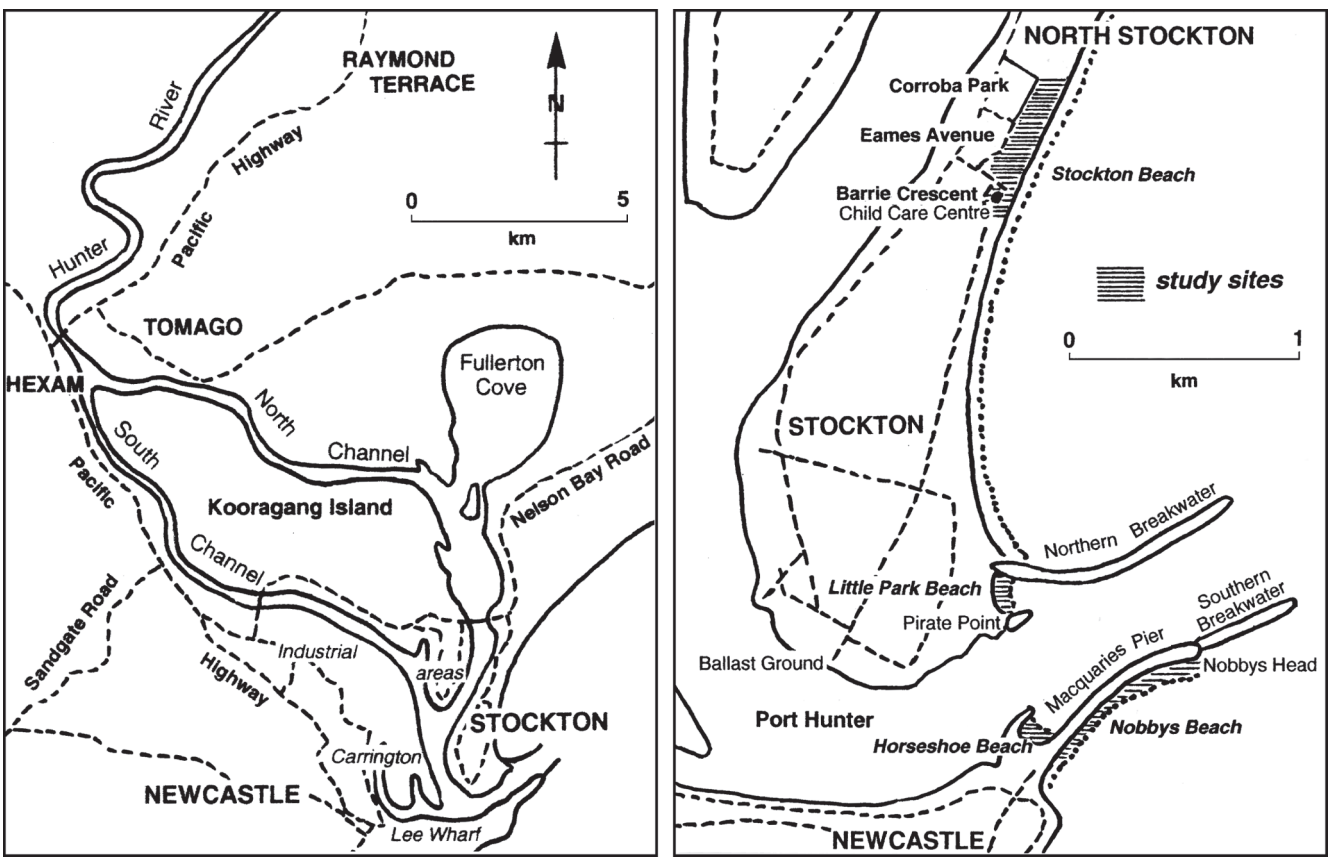


**Fig. 1.** Location maps of the Port Hunter and Stockton areas.

*sericeus* also grew down onto the upper beach off Corroba Park, together with a similar grass **Panicum racemosum*, indigenous to the coastal dunes of eastern South America (Heyligers & Lazarides 1997), of which I had seen a patch on the terrace (Fig. 2a).

*Developments between 1995 and 2005*

During the following years the aspect of the area changed almost beyond recognition. In 1995 two storms in quick succession washed out a 10 m wide slice of the dune terrace, removing the foredune in the seaward zone of **Ammophila arenaria* plantings and a section from the flatter area. Early in 1997 another storm eroded the terrace even further (pers. comm. of a local citizen). Subsequently, the situation more or less stabilised with a scree slope building up against the cliff and limited foredune building on the rim of the cliff, the sand being caught in the low sprawling *Acacia longifolia* subsp. *sophorae* and **Chrysanthemoides monilifera* subsp. *rotundata* shrubs.

At the Eames Avenue section **Panicum racemosum* has become the dominant groundcover, completely eliminating **Ammophila arenaria* which, subject to drought stress and the lack of wind-blown sand, never grew well on the terrace (Fig. 2c and d). **Panicum racemosum* vigorously bounced back after a fire destroyed much of the **Chrysanthemoides monilifera* shrubbery about five years ago. In the early 1990s there was a small area near the road where **Cyperus congestus* was common and over the ensuing years, thanks to its vigorous rhizome growth, it spread as strongly through the roadside section as **Panicum racemosum* had done elsewhere. **Gladiolus gueinzii* is fairly common, but unless seen flowering in spring, it goes unnoticed as its foliage blends in with **Panicum racemosum*. Other species that

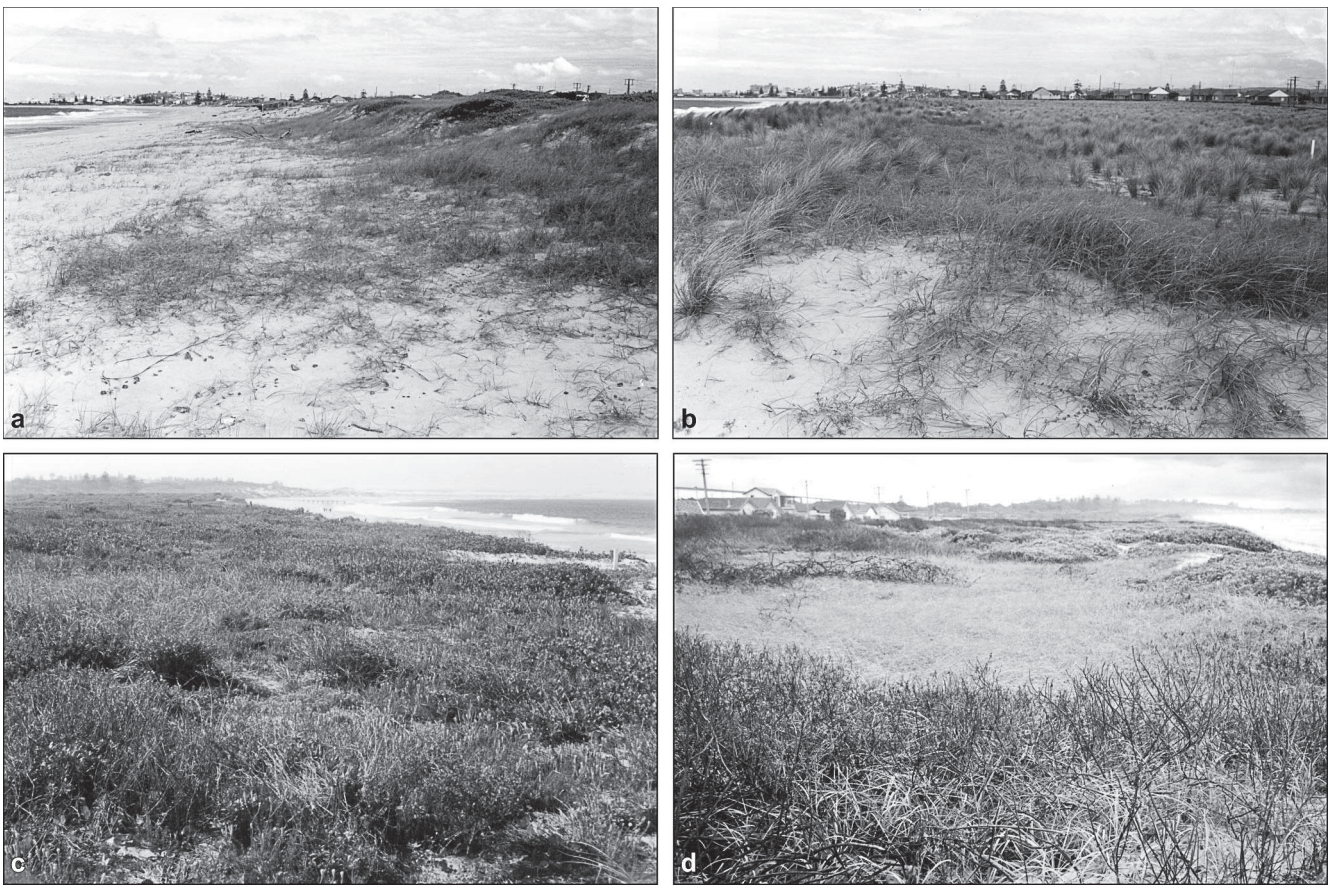


**Fig. 2.** The Eames Avenue and Corroba Park areas; **a)** the upper beach and scree slope seaward of Corroba Park in March 1994 with **Panicum racemosum* and **Hydrocotyle bonariensis*, both introductions from the Atlantic coast of South America, and occasional *Spinifex sericeus* with **Chrysanthemoides monilifera* subsp. *rotundata* on the terrace; **b)** on the same day a view over the dune terrace of Eames Avenue from the north-eastern corner with **Panicum racemosum* on the low ridge in the foreground and planted **Ammophila arenaria* elsewhere (photos P. J. Fullagar). These pictures were taken before the severe storms of 1995 washed away a wide section of the foreshore; c. and d. are northerly views over the seaward area of the Eames Avenue terrace; **c)** taken in August 1997, shows the heterogeneous vegetation with abundant **Hebenstretia dentata*, much of it dead, and patches of **Chrysanthemoides monilifera* subsp. *rotundata* and **Panicum racemosum*; **d)** taken in April 2003, shows the dominance of **Panicum racemosum*, with **Chrysanthemoides monilifera* subsp. *rotundata* still alive and well on the cliff edge accumulations, but scorched by fire and dead in the foreground as are the shrubs of *Acacia longifolia* subsp. *sophorae* and *Leptospermum laevigatum* which were planted further away from the shore.

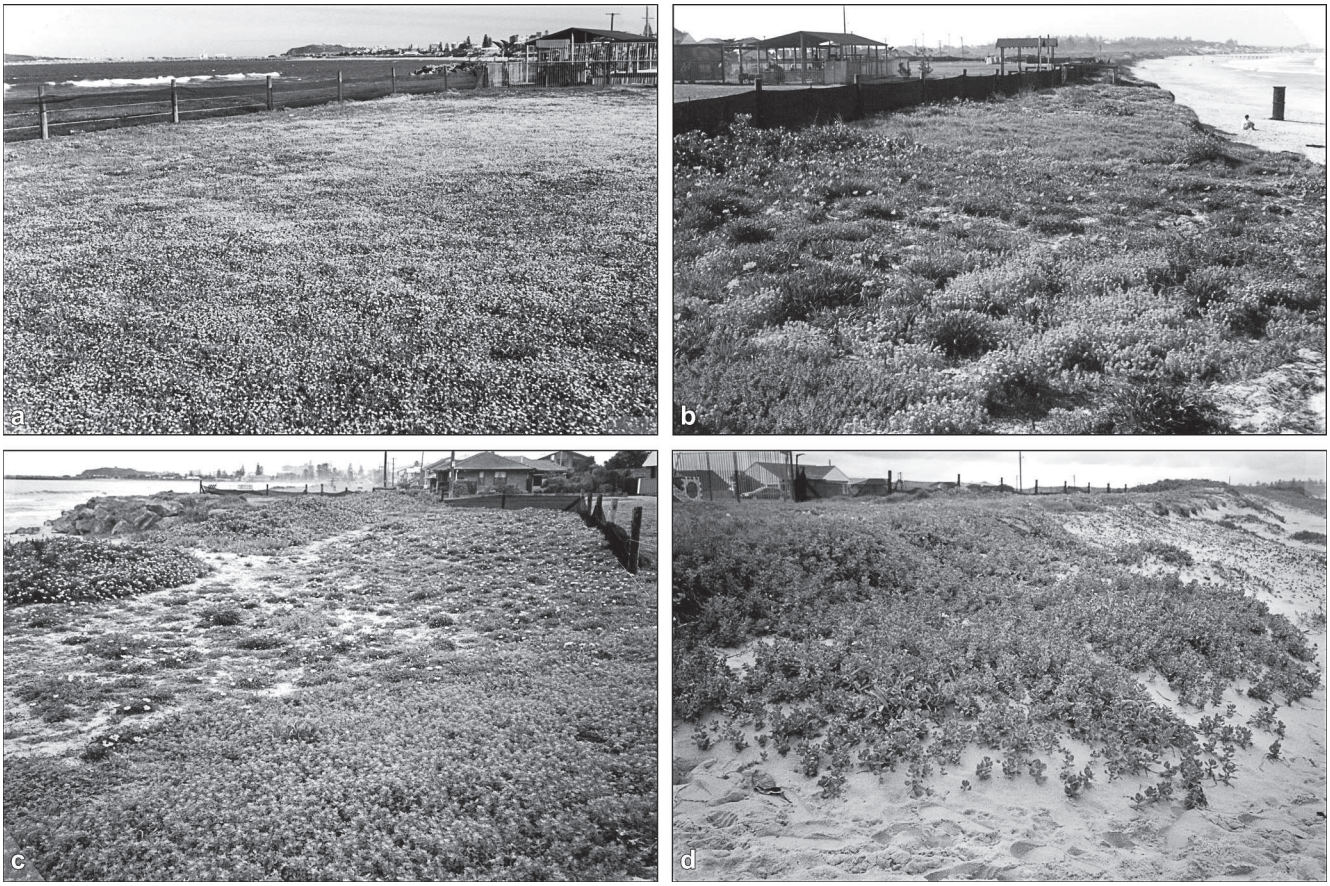


**Fig. 3.** The Barrie Crescent area; **a)** the 'lawn' around the Child Care Centre in August 1999, when it was overwhelmingly dominated by **Cotula turbinata*; b) a northerly view over the terrace in August 1997, before the windbreak was moved to the school ground fence after much of the terrace had been washed out. In the foreground **Lobularia maritima*, **Gazania rigens* and **Chrysanthemoides monilifera* subsp. *rotundata*, further away a patch dominated by *Cynodon dactylon*; c) a southerly view over the same area in April 2003, with **Galenia pubescens* in the foreground, **Chrysanthemoides monilifera* subsp. *rotundata* along the seaward edge and **Gazania rigens* elsewhere; **d)** the scree slope in April 2003 with, in the foreground, a large patch of **Tetragonia decumbens* with some **Cakile maritima* and much **Hydrocotyle bonariensis* in the middle ground.


**Fig. 4.** Little Park Beach; **a)** the beach and terrace shrubbery seen from near the Northern Breakwater in May 1999. *Acacia longifolia* subsp. *sophorae* and **Chrysanthemoides monilifera* subsp. *rotundata* dominate along the seaward edge, while planted *Leptospermum laevigatum* and *Melaleuca armillaris*, together with a few *Casuarina equisetifolia*, form the edge along the Pitt Street Reserve. In the foreground at the right the lawn of the Reserve, at the left a disturbed area with *Spinifex sericeus* and **Heterotheca grandiflora*. At the left in the distance, beyond the base of Pirate Point, Fort Scratchley across the harbour entrance; **b)** **Heterotheca grandiflora* in an open patch along one of the beach access paths with, on the other side, *Acacia longifolia* subsp. *sophorae* and, to the right, **Chrysanthemoides monilifera* subsp. *rotundata*.

| Fam. | Species | Status | Source | Eames Avenue | terrace Barrie Cr. | lawn Barrie Cr. | Corroba Park | Little Park | Macquaries Pier | Nobbys Beach | Distribution in NSW | Native distribution of foreign species |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Faba | *Acacia longifolia* var. *sophorae* | n, r | | 4 | | | | 4 | 2 | | coastal | |
| Myrt | *Leptospermum laevigatum* | n, r | | 3 | | | | 3 | 2 | | S from Nambucca Heads | |
| Prot | *Banksia integrifolia* | n, r | | 2 | | | | 3 | 2 | | coastal, widespread | |
| Casu | *Casuarina equisetifolia* | i, r | | 2 | | | | 2 | | | coastal, N from Laurieton | |
| Prot | *Banksia serrata* | n, r | | 2 | | | | | | | coastal, widespread | |
| Loma | *Lomandra longifolia* | n, r | | 2 | | | 2 | | 3 | | widespread | |
| Poac | *Ammophila arenaria* | i, r | | 1 | 1 | | | | | | coastal S from Newcastle | Europe, Mediterranean |
| Lami | *Westringia fruticosa* | n, r | | | | | 2 | | | | coastal, also cult. | |
| Aizo | *Carpobrotus edulis* | i, r | h | 1 | | | 2 | | 3 | | CC, SC | S Africa |
| Myrt | *Melaleuca armillaris* | n, r | | | | | | 2 | | | coastal, heath inland | |
| Ruta | *Correa alba* var. *alba* | n, r | | | | | | | 2 | | coastal, S from Pt Stephens | |
| Faba | *Acacia saligna* | i, r | | | | | | | 2 | | mainly coastal | Western Aust. |
| Faba | *Medicago truncatula** | i | w | 4 | 4 | 4 | 4 | | 2 | 1 | widespread | Mediterranean, SW Asia |
| Poac | *Cynodon dactylon* | n? | b? | 4 | 3 | 4 | 3 | | 3 | | widespread, pasture, lawn | cosmopolitan |
| Poac | *Panicum racemosum** | i, r? | b | 4 | 3 | 1 | 2 | | | | (Geelong) | S America |
| Aste | *Cotula turbinata** | i | b | 2 | 1 | 4 | 1 | | | | (sandy lawns, swWA) | S Africa |
| Faba | *Medicago polymorpha** | i | w | 4 | 4 | 4 | | | | | widespread | Eur., Mediterr., SW Asia |
| Aste | *Gazania rigens* | i | h | 3 | 4 | 4 | | | 1 | | coastal, Sydney-Gosford | S Africa |
| Bras | *Lobularia maritima* | i | h | 2 | 4 | 1 | | | | | coastal, garden escape | Mediterranean |
| Aste | *Chrysanthemoides monilifera* subsp. *rotundata* | i | b | 4 | 3 | | 4 | 2 | 3 | 2 | coastal | S Africa |
| Onag | *Oenothera drummondii** | i | b | 4 | 4 | | | 3 | 2 | 3 | coastal N from Sydney | N America |
| Apia | *Hydrocotyle bonariensis* | i | b | 4 | 4 | | | 3 | 3 | 3 | coastal | S America |
| Cype | *Cyperus congestus** | i | w | 4 | 2 | | | | | | sporadic CC NT NWS | S Africa |
| Sela | *Hebenstretia dentata** | i | h | 4 | | | 4 | 3 | 3 | | cult., Newcastle-Nelson Bay | S Africa |
| Aizo | *Galenia pubescens** | i | b | 3 | 4 | 2 | 2 | 2 | 2 | | not common, mine sites | S Africa |
| Aste | *Senecio pinnatifolius* var. *pinnatifolius** | n | | 3 | 3 | 2 | 2 | 2 | 2 | | widespread | |
| Aste | *Ambrosia artemisiifolia* | i | w | 2 | 3 | 2 | | 3 | 1 | | wasteland N from Sydney | N America |
| Asph | *Trachyandra divaricata* | i | b | 3 | 3 | 1 | | 1 | | | coast Pt Steph-Wollongong | S Africa |
| Aizo | *Tetragonia decumbens** | i | b | 3 | 3 | | 2 | 3 | 3 | 2 | NC, CC | S Africa |
| Irid | *Gladiolus gueinzii* | i | b | 3 | 2 | | | | | 2 | coast Macleay R-Currarong | S Africa |
| Aizo | *Carpobrotus glaucescens* | n | | 2 | 2 | | 2 | | | 2 | coastal | |
| Bras | *Cakile maritima* | i | b | 2 | 2 | | 2 | 2 | 2 | 2 | coastal S of Woy Woy | Eur., Mediterr., SW Asia |
| Onag | *Oenothera mollissima** | i | w | 1 | 2 | | | 3 | 2 | | N from Sydney, NWS, NWP | S America |
| Oxal | *Oxalis pes-caprae** | i | h | 2 | 2 | | 2 | | | | widespread | S Africa |
| Oxal | *Oxalis debilis* var. *corymbosa** | i | w | 2 | 2 | | | | | | coastal | S America |
| Aste | *Ursinia speciosa** | i | h | 1 | 1 | | | | | | coastal at Stockton | S Africa |
| Aste | *Arctotheca calendula* | i | b | 1 | 1 | 4 | | 1 | 2 | | widespread | S Africa |
| Alli | *Nothoscordum borbonicum** | i | h | 2 | 1 | 1 | | | | | widespread | S America |
| Comm | *Commelina benghalensis** | i | h | 2 | 1 | 1 | | | 1 | | NC N from Comboyne | Africa, Asia |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Poac | *Stenotaphrum secundatum* | i | h | 2 | 3 | 1 | | | | | coastal, lawns | Amer, Africa |
| Poac | *Spinifex sericeus** | n | | 3 | 3 | | 3 | 4 | 2 | 4 | coastal | |
| Poac | *Zoysia micrantha* | n | | 2 | 2 | | | | 1 | | coastal | |
| Poac | *Panicum maximum* var. *maximum** | i | p | 1 | 1 | | | 3 | | | pasture, roadsides | Africa |
| Zygo | *Tribulus terrestris* | i | w | 1 | | 2 | | | | | widespread | Europe, Africa, Asia |
| Poac | *Bromus diandrus** | i | b | 1 | | 1 | | 2 | | | widespread | Eur., Mediterr. SW Asia |
| Bras | *Brassica tournefortii* | i | w | 1 | | | 2 | 2 | 2 | | widespread | Mediterranean, SW Asia |
| Faba | *Trifolium repens* | i | p | 1 | | | | 1 | 1 | | widespread | Europe, Mediterr., Asia |
| Faba | *Kennedia rubicunda* | n | | 1 | | | | | | | coastal | |
| Good | *Scaevola calendulacea* | n | | 1 | | | | | | | coastal | |
| Aste | *Senecio madagascariensis** | i | w | 1 | | | | | | | mainly coastal | S Africa |
| Aste | *Hypochaeris glabra* | i | w | 1 | | | | | | | widespread | Europe, Mediterranean |
| Myop | *Myoporum parvifolium** | i | h | 1 | | | | | | | cult., inland species | |
| Plan | *Plantago lanceolata* | i | w | 1 | | | | | | | widespread | Europe, Asia |
| Verb | *Lantana camara* | i | h | 1 | | | | | | | coastal | S America |
| Aspa | *Protasparagus aethiopicus* | i | h | 1 | | | | | | | coastal N from Sussex Inlet | S Africa |
| Agav | *Yucca aloifolia* | i | h | 1 | | | | | | | cult., near Forster | N America |
| Amar | *Gomphrena celesioides** | i | w | 1 | | | | | | | widespread | S America |
| Conv | *Ipomoea cairica* | i | h | 1 | | | | | | | coastal, NWS, NFWP | pantropic |
| Bras | *Brassica rapa subsp. sylvestris** | i | h,w | 1 | | | | | | | widespread | Europe |
| Aizo | *Lampranthus multiradiatus* | i | h | 1 | | | | | | | CC, cult., occ. naturalised | S Africa |
| Bora | *Heliotropium amplexicaule** | i | h | | 2 | 3 | 2 | | | | widespread | S America |
| Malv | *Malva parviflora** | i | w | | 1 | | | 2 | | | widespread | Mediterranean, SW Asia |
| Poac | *Bromus catharticus** | i | p | | 1 | | | 2 | | | widespread | S America |
| Aste | *Heterotheca grandiflora** | i | b | | 1 | | | 3 | 2 | | localised on wasteland | N America |
| Aste | *Conyza parva** | i | w | | 1 | | | 2 | 1 | | sandy soils N from Tathra | S America |
| Sola | *Solanum tuberosum** | i | h | | 1 | | | | | | cultivated | S America |
| Conv | *Dichondra repens* | n | | | 2 | | | | | | widespread | |
| Aste | *Arctotis venusta** | i | h | | 1 | | | | | | garden escape | S Africa |
| Poac | *Chloris virgata** | i | p | | 1 | | | | | | widespread | Asia, Africa, America |
| Poac | *Sporobolus indicus* var. *capensis** | i | w | | 2 | | | | | | widespread | Africa |
| Poac | *Rostraria cristata** | i | w | | 1 | | | | | | widespread | Mediterranean, SW Asia |
| Cary | *Polycarpon tetraphyllum* | i | w | | | 2 | 1 | | | | widespread, gardens | Eur., Mediterr., SW Asia |
| Poac | *Poa annua* | i | w | | | 1 | 1 | | | | widespread | Europe |
| Cary | *Cerastium glomeratum** | i | w | | | 2 | | 1 | | | widespread | Europe, Mediterranean |
| Port | *Portulaca oleracea* | n | | | | 2 | | | 2 | | widespread | |
| Faba | *Medicago minima** | i | w | | | 2 | | | | | widespread | Eur., Mediterr., SW Asia |
| Port | *Portulaca pilosa* | i | h | | | 1 | | | | | coastal sand NC | tropics, prob. S America |
| Aste | *Cotula australis** | n | | | | 2 | | | | | widespread | |
| Poac | *Lolium perenne** | i | p | | | | 2 | 3 | | | widespread, pasture | W Europe, Mediterr. |
| Poac | *Ehrharta erecta** | i | w | | | | 1 | 2 | | | widespread | Africa |
| Aste | *Sonchus oleraceus* | i | w | | | | 2 | 1 | 1 | | widespread | Europe, Asia |
| Sola | *Solanum nigrum* | i | w | | | | 2 | | 1 | | widespread | Eur., Mediterr., SW Asia |
| Cact | *Opuntia stricta* | i | h | | | | 1 | | | | widespread, Hunter valley | America |
| Cras | *Crassula sieberiana* | n | | | | | 2 | | | | widespread | |
| Poac | *Ehrharta longiflora** | i | w | | | | 1 | | | | widespread | S Africa |
| Amar | *Crinum pedunculatum* | n | | | | | | 1 | 1 | | coastal N from Jervis Bay | |
| Poac | *Pennisetum clandestinum* | i | p | | | | | 2 | 2 | | pasture, roadsides etc. | E Africa |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Poac | *Lolium loliaceum** | i | p | 3 | 2 | uncommon | Mediterranean |
| Fuma | *Fumaria bastardii** | i | b | 1 | | widespread | Europe |
| Cary | *Silene nocturna** | i | w | 1 | | waste areas | Mediterranean |
| Aste | *Bidens pilosa* | i | w | 2 | | widespread | S America |
| Poac | *Chloris gayana** | i | p | 1 | | pasture | Africa |
| Poac | *Avena fatua** | i | w | 3 | | widespread | Europe, Asia, Africa |
| Poly | *Polygonum arenastrum** | i | w | | 2 | widespread | Europe |
| Bras | *Cakile edentula* | i | b | | 1 | 1 coastal | N America |
| Faba | *Melilotus indicus* | i | w | 4 | | widespread | Mediterr., SW Asia |
| Aste | *Senecio crassiflorus** | i | b | 1 | | natural. Stockton-Berowra | S America |
| Sola | *Calibrachoa parviflora** | i | b | 2 | | unco., Newcastle, Boggabri | S America |
| Conv | *Calystegia soldanella* | n | | | 2 | coastal | cosmopolitan |

*n: native in, but usually not restricted to, the Port Hunter area*
*i: introduced from overseas or from elsewhere in Australia*
*r: planted for dune rehabilitation*
*b: species introduced with ballast*
*h: species used in horticulture*
*p: species used for pastures*
*w: 'weed' (mode of introduction unknown)*

* species represented by one or more voucher specimens
4: common; 3: rather or locally common; 2: several; 1: few
Botanical Subdivisions of New South Wales:
NC, CC, SC: North, Central and South Coast
NT: Northern Tablelands NWS and NWP: North Western Slopes and Plains

have appeared from time to time are *Myoporum parvifolium*, **Ursinia speciosa*, **Commelina benghalensis*, **Cotula turbinata* and **Nothoscordum borbonicum*.

At Barrie Crescent the shade cloth fence separating the lawn from the terrace was set back several metres after the repeated heavy erosion of the foreshore. It now links up with the seaward side of the high fence around the Child Care Centre (Fig. 3). The lawn still has an amazing mix of introduced species, even after mowing has recently intensified and resulted in the disappearance of **Portulaca pilosa* and **Trachyandra divaricata*. A particularly memorable occasion was when the **Cotula turbinata* population 'exploded' and covered the lawn with flowers (Fig. 3a). On other occasions this annual species can be absent from the assemblage which, among the predominant *Cynodon dactylon*, includes **Gazania rigens*, *Portulaca oleracea*, **Heliotropium amplexicaule*, **Ambrosia artemisiifolia*, **Medicago truncatula* and **Medicago minima*.

The vegetation on the narrow terrace comprises a mosaic of patches dominated by a single species such as **Gazania rigens*, **Lobelia maritima*, **Ambrosia artemisiifolia*, **Panicum racemosum* or **Stenotaphrum secundatum*, with a row of **Chrysanthemoides monilifera* subsp. *rotundata* shrubs along the southern seaward edge (Fig. 3b and c). Lately, the scree slope has become larger and is locally colonised by a mix of *Spinifex sericeus*, **Panicum racemosum* and some **Cakile maritima* or by large patches of **Tetragonia decumbens* (Fig. 3d). Other species on the terrace include *Cynodon dactylon*, **Trachyandra divaricata*, **Oenothera drummondii* and very succulent *Senecio pinnatifolius* var. *pinnatifolius*. Noteworthy are a sporadic **Ammophila arenaria* tussock and occasionally, **Ursinia speciosa* and **Solanum tuberosum*.

In October 2005 the dune terrace between Corroba Park and the beach was still dominated by **Chrysanthemoides monilifera* subsp. *rotundata*, here as elsewhere now markedly infested by the tip moth **Comostolopis germana*, the result of releases for biological control. However, on a narrow strip along the playing fields **Chrysanthemoides monilifera* subsp. *rotundata* was poisoned and cut and replaced with *Lomandra longifolia* and *Westringia fruticosa*. *Cynodon dactylon* has become common here amid other species such as **Carpobrotus edulis*, **Heliotropium amplexicaule*, **Oxalis pes-caprae*, **Hebenstretia dentata* and **Galenia pubescens*.

### *Stockton: Little Park Beach*

The narrow foredune is dominated by *Spinifex sericeus* with **Hydrocotyle bonariensis* and backed by a shrubbery of *Acacia longifolia* subsp. *sophorae* and **Chrysanthemoides monilifera* subsp. *rotundata* which merges with the taller scrub fringing the Reserve (Fig. 4a). The main species in this restored vegetation are *Melaleuca armillaris* and *Leptospermum laevigatum* with some *Banksia integrifolia* and a few *Casuarina equisetifolia*. **Panicum maximum* var. *maximum* and its cultivar 'Embu' are dominant among an array of grasses along the park fringe.

Open areas in the *Acacia* scrub, especially near the parking area at the foot of the breakwater, carry a large population of **Heterotheca grandiflora*, rather spectacular when in full flower in late summer and autumn (Fig. 4b). Other species common here are **Oenothera drummondii* and **Oenothera mollissima*, **Tetragonia decumbens* and **Hebenstretia dentata*. The low dune front is often eroded by wave action and occasionally large amounts of timber flotsam are thrown onto the beach. The propagule for the one very healthy *Crinum pedunculatum* plant on the foredune would have arrived in a similar way.

### *Newcastle: the surroundings of Macquaries Pier*

The vegetation of Nobbys Beach is dominated by *Spinifex sericeus*, interspersed with **Hydrocotyle bonariensis* and some **Cakile maritima* (Fig. 5c). Patches of **Tetragonia decumbens* and **Oenothera drummondii* are common, and *Carpobrotus glaucescens* and **Gladiolus gueinzii* are present. Many **Chrysanthemoides monilifera* bushes line the southern side of the pier, all of them infested by tip moth. In the 1990s a single **Senecio crassiflorus* plant dominated a large sand accumulation close to Nobbys Head, but in 2003 it was reduced to a few runners and by 2005 it had disappeared (Fig. 5d). Several ruderal species can be found along the pavement of the pier, for instance **Polygonum arenastrum*, but the most notable is **Calibrachoa parviflora*. It also established in the recently landscaped patch around the monument where **Carpobrotus edulis* appears to be the main species used, although flowering **Oenothera drummondii* provides dramatic highlights to this small triangular area (Fig. 5a, b).

At Horseshoe Beach the older planted sections have a 2 m high shrubbery of *Acacia longifolia* subsp. *sophorae*, *Leptospermum laevigatum* and some *Banksia integrifolia*. In the area more recently planted with these species *Spinifex sericeus*, **Cakile maritima*, **Hebenstretia dentata*, **Oenothera drummondii*, **Hydrocotyle bonariensis* and **Carpobrotus edulis* are conspicuous elements in the mostly ruderal species assemblage.

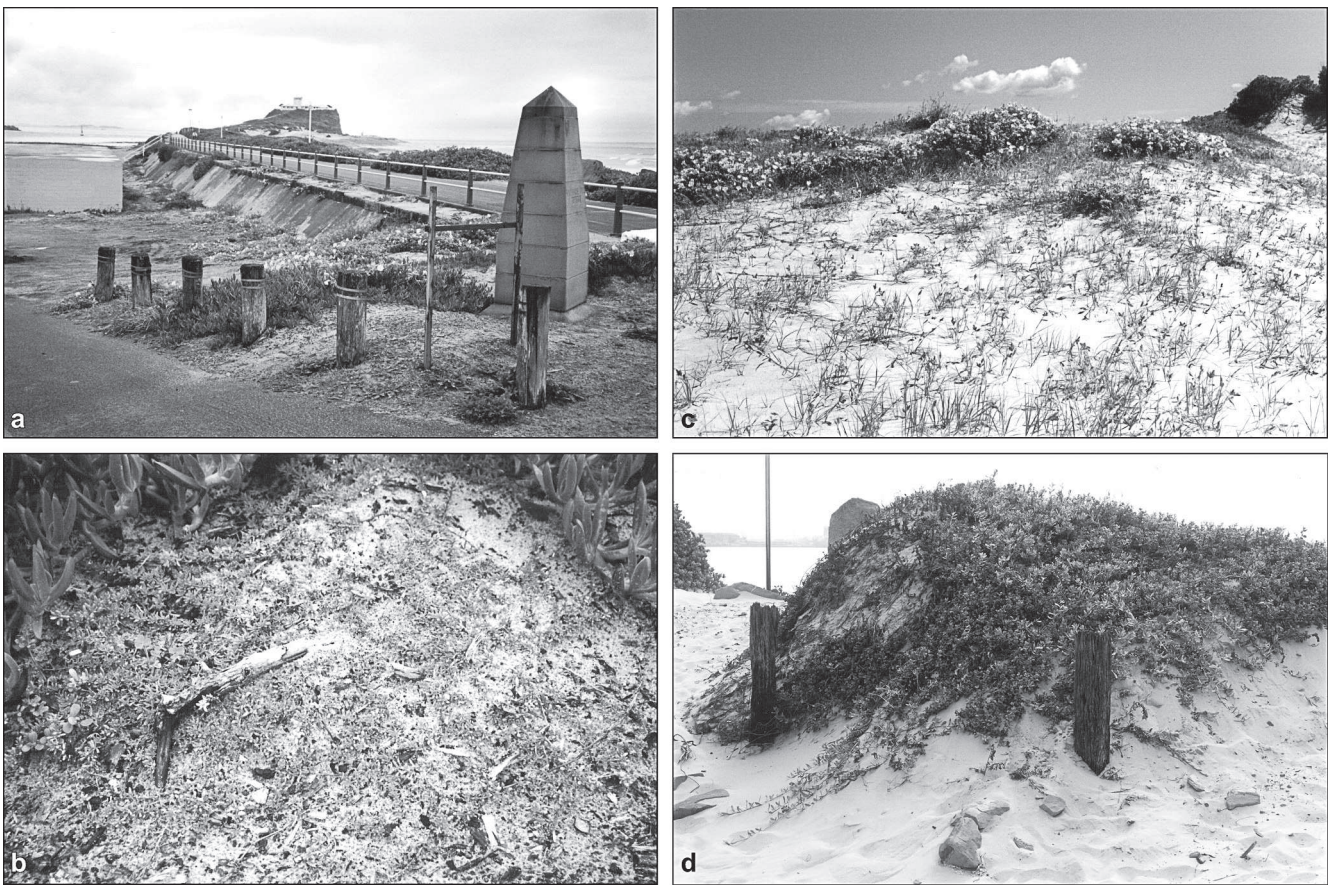


**Fig. 5.** Macquaries Pier and Nobbys Beach; **a)** the monument at the base of the pier in April 2003, surrounded by **Carpobrotus edulis*, **Oenothera drummondii*, **Arctotheca calendula*, some *Spinifex sericeus* and, near the posts, **Calibrachoa parviflora*; **b)** the open patch of **Calibrachoa parviflora* among the third and fourth post; **c)** a dune on Nobbys Beach sparsely covered by flowering male *Spinifex sericeus* with **Oenothera drummondii* dominant on the crest; **d)** a mound with **Senecio crassiflorus* and **Tetragonia decumbens* along the pier near Nobbys Head in March 1994. This was the only plant of **Senecio crassiflorus* in my study area; it declined in vigour over the years and had disappeared in 2005.

**Table 2. Composition of the Stockton/Port Hunter flora**

**a) Overall composition**

21 Native species: 14 coastal, 7 widespread (including 8 planted species of which 3 or 4 are also speading naturally).
78 Introduced species: 75 exotic and 3 Australian but not native in the Port Hunter area;(4 or 5 species used for dune restoration, including 2 Australian and 2 or 3 exotics; 27 species coastal or predominantly coastal in distribution, 51 more widespread)

**b) Composition of the exotic flora**

22 European species: including 18 extending around the Mediterranean and into south-west Asia;
23 African species not included in previous category, of which 18 South African;
20 American species: of which 14 South American;
10 Species with a wider distribution over two or more continents:

**c) Composition of the flora on the Stockton/Port Hunter sites**

| | Number of species per site | | | Percentage of native species (%) |
|---|---|---|---|---|
| | native | introduced | total | |
| North Stockton | | | | |
| Corroba Park | 7 | 20 | 27 | 26 |
| Eames Avenue | 11 | 48 | 59 | 19 |
| Barrie Cr., terrace | 6 | 36 | 42 | 14 |
| Barrie Cr., lawn | 4 | 21 | 25 | 16 |
| Port Hunter | | | | |
| Little Park Beach | 7 | 31 | 38 | 18 |
| Macquaries Pier | 11 | 28 | 39 | 28 |
| Nobbys Beach | 3 | 8 | 11 | 27 |

**Table 3. Stockton/Port Hunter foreshore species composition by likely mode of introduction**
-numbers are best guesses based on literature and circumstantial evidence.

| | |
|---|---|
| **Volunteer native species** - includes *Cynodon dactylon* | 13 species |
| **Planted native species** | 8 |
| **Planted introduced species** -includes 2 species native elsewhere in Australia | 4 or 5 |
| **Species introduced with ballast** | 18 |
| **Species used in horticulture**, ornamentals, two vegetables, one also used in restoration | 21 |
| **Species used for pastures** | 8 |
| **Mode of introduction unknown** - many are so-called 'camp followers' | 29 |
| Total | 102 |

**Table 4. Dune vegetation in the 1930s; dune plants reported by Hamilton (1917), Osborn & Robertson (1939) and Pigeon (1940) from the NSW Central and Lower North Coasts**. Species arranged roughly according to their abundance.

**Strand**

**Cakile edentula*

**Foredune slope**

*Festuca littoralis*
*Spinifex sericeus*

**Foredune crest and rear**

*Spinifex sericeus*
*Festuca littoralis*
*Scaevola calendulacea*
*Senecio anacampserotis*
*Stackhousia spathulata*
*Chamaesyce psammogeton*
*Actites megalocarpa*
*Carpobrotus glaucescens*
*Isolepis nodosa*
*Senecio pinnatifolius* var. *pinnatifolius*
*Pelargonium australe*
*Hibbertia scandens*
*Calystegia soldanella*
*Apium prostratum*
*Zoysia pungens*
*Cynodon dactylon*
*Carex pumila*

**Dune scrub** (also scattered on foredune)

*Acacia longifolia* var. *sophorae*
*Banksia integrifolia*
*Leptospermum laevigatum*
*Leucopogon parviflorus*
*Correa alba*
*Kennedia rubicunda*
*Clematis glycinoides*
*Lomandra longifolia*
*Oxalis corniculata*
*Commelina cyanea*

**Older scrub and dune forest** (in addition to most of the above)

*Cupaniopsis anacardioides*
*Monotoca elliptica*
*Breynia oblongifolia*
*Myoporum insulare*
*Angophora costata*
*Stephania japonica* var. *discolor*
*Dianella caerulea*
*Pomax umbellata*

**Myall Lakes** (in addition to list given above)

*Banksia serrata*
*Acmena smithii*
*Myrsine variabilis*
*Notelaea longifolia*
*Clerodendron tomentosum*
*Dodonaea triquetra*
*Pandorea pandorana*
**Arctotheca populifolia*

**Sydney, early introductions** (Hamilton 1917)
**Ammophila arenaria*
**Hydrocotyle bonariensis*
**Stenotaphrum americanum*
**Tetragonia decumbens*

**Foreign species at Myall Lakes** (seen by author in 1994)
**Arctotheca populifolia*
**Cakile maritima*
**Chrysanthemoides monilifera* subsp. *rotundata*
**Eryngium maritimum*
**Gazania rigens*
**Gladiolus gueinzii*

## Discussion

### *The original flora and what is left of it*

What would the dune vegetation have been at the time of European settlement? Unfortunately, Robert Brown, who in the spring of 1804 was the first botanist to visit the area, did not provide a description of the local vegetation. At the end of his visit he summarised his collections and from this list it is clear, that he did not find species new to him on the dunes (Vallance *et al*. 2001). More than a century later, Hamilton (1917) described the coastal flora of the Port Jackson district (Sydney harbour) and his lengthy paper is the earliest record of some relevance to the Port Hunter area. Other valuable information about the dune flora before foreign species, especially **Chrysanthemoides monilifera* subsp. *rotundata*, made their mark, are Osborn and Robertson (1939) on the Myall Lakes area, about 75 km north-east of Stockton, and Pidgeon (1940) on the Central Coast of NSW, of which the Hunter River forms the northern boundary. The floristic information from these papers is summarised in Table 4.

In the first half of the twentieth century the foredune vegetation was dominated by *Festuca littoralis* and *Spinifex sericeus*. *Festuca littoralis* was the first species to establish on new sand deposits along the dune while *Spinifex sericeus* stolons descended from the dune crest. *Scaevola calendulacea*, *Senecio anacampserotis*, *Stackhousia spathulata*, *Hibbertia scandens*, *Chamaesyce psammogeton* and *Actites megalocarpa* were often common and the other species occurring on the foredune crest and back slope were apparently not rare either. As far as introduced species are concerned, the only one which was widespread in the 1930s was **Cakile edentula*, a strand-line plant from the east coast of North America. However, Hamilton (1917) reports it from only one beach near Sydney. This species is now rare and has largely been replaced by **Cakile maritima*. Hamilton also found **Tetragonia decumbens* and **Hydrocotyle bonariensis* at a few locations and mentions that **Ammophila arenaria* had been used for dune stabilisation. However, because of unsuitable climatic conditions, establishment was poor and it had almost died out where it had been planted. Osborn and Robertson (1939) found **Arctotheca populifolia*, native to southern Africa, on the drift sands at Myall Lakes, but no other foreign species of any consequence were present in the dune vegetation.

Now, in the early twenty-first century, several of the native species mentioned above are rare and even *Festuca littoralis* is uncommon. It certainly does not fulfil its pioneering role on the dune face any longer. **Hydrocotyle bonariensis* has spread far and wide and is common among the *Spinifex sericeus* vegetation. Of the more recent arrivals **Gladiolus gueinzii* is now widespread, too, but unless in flower, often goes undetected (Heyligers 1998, 1999a). In contrast, and in no small measure due to the sand stabilization activities of the Soil Conservation Service, **Chysanthemoides monilifera* subsp. *rotundata* became common along most of the NSW coast with dire consequences for the native flora (McDonald 1971, Weiss *et al*. 1998). After many eradication campaigns and biological control measures, it still forms a threat due to its ability to establish on the foredunes among *Spinifex sericeus* and young *Acacia longifolia* subsp. *sophorae* vegetation.

In our study area only the dune vegetation along Nobbys Beach is still dominated by *Spinifex sericeus* but it is rather low in species diversity, both native and foreign (Tables 1 and 2). The flora and vegetation on the other sites has been very much modified through human activities. The dunes at Corroba Park are dominated by **Chysanthemoides monilifera* subsp. *rotundata*, but the vegetation of the rehabilitated dunes along Eames Avenue has a rather natural appearance, despite the fact that the species which determine the groundcover physiognomy are predominantly foreign. Native species common in the 1930s, namely *Spinifex sericeus*, *Scaevola calendulacea*, *Carpobrotus glaucescens* and *Kennedia rubicunda*, are now of secondary importance. Only *Senecio pinnatifolius* var. *pinnatifolius*, being an annual, is more common as it tends to thrive on areas disturbed by rehabilitation maintenance.

### *Arrival and spread of foreign species*

Many of the foreign taxa in the Stockton area would have arrived through shipping, either directly from overseas or via other Australian ports. At Port Hunter, ships discharged unwanted ballast at Stockton before loading at the Newcastle wharves. The practice stopped in the twentieth century when solid ballast was replaced by seawater. This had important consequences for aquatic ecosystems, but diminished the chance of introducing terrestrial plants. Unless these had buoyant propagules, they could now only arrive via cargo.

In Stockton, at the southern end of town, there is an area named ‘Ballast Ground.’ However, the ballast dumps are gone and the area is now a grassed public reserve. Plants that I noticed there along the harbour foreshore, for instance *Tetragonia tetragonioides*, *Atriplex semibaccata*, **Fumaria bastardii*, **Malva parviflora*, **Foeniculum vulgare, *Verbena bonariensis* and **Senecio madagascariensis*,

are all widespread and mostly introduced species. For a number of species the early collection dates in the Newcastle area, e.g. 1908 for **Chrysanthemoides monilifera* subsp. *rotundata*, 1910 for **Senecio crassiflorus* and **Calibrachoa parviflora*, and 1915 and 1923 for **Hebenstretia dentata*, could be indicative of arrival in ballast, but only a note with the **Hebenstretia dentata* specimen from 1923 refers to 'ballast tips.' The early history of **Heterotheca grandiflora*, collected on grain loading wharfs in 1964, is recounted in the Appendix as one of the few, if not the only, example of information which provide an insight into the way a species arrived in the Port Hunter region.

Nearly 20 foreign species on the Stockton dunes are garden escapes. **Gazania rigens*, **Lobularia maritima* and **Hebenstretia dentata* form some of the more conspicuous elements through their large numbers, with **Ipomoea cairica* and **Carpobrotus edulis* providing local highlights. Other species, **Cotula turbinata*, **Ursinia speciosa*, **Commelina benghalensis* and **Nothoscordum borbonicum*, I also suspect of being garden escapes. **Trifolium repens* and a number of grasses, namely the *Chloris* and *Lolium* species as well as **Panicum maximum* and **Pennisetum clandestinum*, were introduced for pasture improvement. The occurrences of the latter in Africa, its introduction into Australia in the earlier decades of the twentieth century and its subsequent cultivation has been described in detail by Cameron (1960).

Most of the remaining foreign species, about 40, have been accidentally introduced, either as contaminants of produce or cargo, on livestock or on people. This could have happened at any port in Australia and internal transport, mainly by ship in the early days of European settlement and later also via roads and railway lines, would have substantially contributed to further dispersal. Almost without exception these are ruderal species: they thrive in disturbed habitats and could be characterised as 'camp followers.' Many of these would have come with the early colonists. As an example, Robert Brown lists 29 introduced species seen in the Port Jackson area in 1802–1804 and mentions species such as **Plantago major*, **Euphorbia peplus*, **Anagallis arvensis*, **Poa annua* and **Lolium perenne* (Britten 1906). Many species labelled as 'weeds' in Table 1 would fall in this category. Hence it is no surprise that such species find an ideal habitat at the restoration sites and much-used beaches at Stockton and, consequently, form the dominant group in the flora of these areas.

### *Growth habit diversity: is the new foredune vegetation more stable than the old?*

Floristically, the vegetation of the North Stockton foredunes appears to be more diverse than the one presumably present in the 1930s (Tables 1 and 4). Would this be important for foredune ecology? Would the present vegetation contribute to greater dune stability? In Table 5 the growth habits of the herbaceous foredune species present in the 1930s are compared with those now present on the North Stockton dune terrace and frontal slope. For the latter group only the 26 species on the Eames Avenue and Barrie Crescent sites which had an abundance score of 2 or higher on at least two of the sites are used. The two groups have only five native species in common, three of which are grasses.

**Table 5. Comparison between the functional groups of herbaceous species in the dune vegetation of the 1930s (strand and foredune species in Table 4) and in the vegetation of the three rehabilitated sites at Eames Avenue and Barrie Crescent (species with an abundance score of 2 or higher on at least two of the sites).**

| | 1930s vegetation | | Present vegetation | | Species in common |
|---|---|---|---|---|---|
| | native | foreign | native | foreign | |
| **Total number of species** | 16 | 1 | 5 | 21 | |
| **Annual species** | 1 | 0 | 1 | 7 | *Senecio pinnatifolius* var. *pinnatifolius* |
| with bushy habit[1] | 0 | 1 | 0 | 1 | |
| **Perennial species** | 15 | 0 | 4 | 14 | |
| with spreading habit | 9 | 0 | 4 | 6 | *Carpobrotus glaucescens* |
| graminoids | 3 | 0 | 3 | 3[5] | *Spinifex sericeus, Zoysia micrantha, Cynodon dactylon* |
| with bushy habit[2] | 5 | 0 | 0 | 3 | |
| with storage organs[3] | 0 | 0 | 0 | 6 | |
| others[4] | 1 | 0 | 0 | 5 | |

[1] the two **Cakile* species.
[2] include species such as**Stackhousia spathulata*, **Actites megalocarpa* and **Oenothera drummondii*.
[3] include **Cyperus conglomeratus*, **Trachyandra divaricata* and the **Oxalis* species; some of those species are also included in the previous groups.
[4] for instance *Senecio pinnatifolius*, **Gazania rigens* and **Hebenstretia dentata*.
[5] **Panicum racemosum*, **Cyperus congestus* and **Stenotaphrum secundatum*.

A major difference between the 1930s flora and the present one is the large number of annuals now present, mostly foreign species, e.g. **Medicago* spp., **Cotula turbinata*, **Lobularia maritima* and **Arctotheca calendula*. However, the number of perennials is rather similar, with the exception of species with underground storage organs, which were lacking in the 1930s vegetation. Interestingly, the total number of spreading species, whether they are rhizomatous or sprawl over the surface, is almost the same, but there is now a higher proportion of graminoids compared with other herbaceous species. This is an important difference because the graminoids (in this case five grasses and **Cyperus congestus*), fulfil a major ecological function in the vegetation by trapping windblown sand, a function strengthened by the subsequent establishment of shrubs which are initially decumbent (namely *Acacia longifolia* subsp. *sophorae* and, in the present vegetation, **Chrysanthemum monilifera* subsp. *rotundata*). These growth-forms are well suited to catch windblown sand and would be major contributors to building larger, more stable dunes. Bushy species, be they native or foreign, are also sandcatchers and, if present in sufficient numbers, could be equally effective in stabilisation. Hence, when one compares the ecological functioning of the 1930s vegetation with that of the present vegetation, it would appear that, due to presence of more graminoids and the fact that **Panicum racemosum* produces a denser sward than *Spinifex sericeus*, the present vegetation is more effective in sand-catching and dune stabilisation than the vegetation in the 1930s would have been.

In view of this conclusion, is the present dune terrace at North Stockton less liable to erosion? Unfortunately, along this stretch of the coast, little sand is available because of breakwaters at the entrance to Port Hunter. Sand carried by northerly longshore currents is diverted too far out to sea, and is not be returned to the beach north of the breakwaters. The storm attacks experienced in 1995 and 1997 resulted in dramatic erosion of the existing foredune. In view of the increasing influence of climate change, e.g. a rise in sea level and more extreme weather events, there is no indication that the present terrace, notwithstanding the increased density of the rhizomatous species **Panicum racemosum* and **Cyperus congestus,* and a sprawling shrubby vegetation along the crest, will endure such attacks any better than in the 1990s.

## Conclusion

The exploration of the flora around the sandy foreshores at Port Hunter has revealed the presence of a large number of foreign plant species. Since the first coal exports in the 1850s the Newcastle wharves and ballast ground at Stockton became points of entry for foreign species, either directly, or via stopovers at other Australian ports. Some of these, **Panicum racemosum*, **Tetragonia decumbens*, **Ursinia speciosa,* **Hebenstretia dentata* and until recently, **Heterotheca grandiflora* remained restricted to the Newcastle region, while others, **Chrysanthemum monilifera* subsp. *rotundata*, **Hydrocotyle bonariensis*, **Gladiolus gueinzii* and **Oenothera drummondii*, spread further afield, but only colonised their preferred coastal habitat. Many more species spread far and wide, their port of introduction no longer recognisable.

Foreign species have made their mark on the local vegetation to varying degrees. At Nobbys Beach the general aspect of the dune along the pier is still determined by *Spinifex sericeus*, but closer look will reveal the widespread occurrence of **Hydrocotyle bonariensis* among the grass, while apart from *Carpobrotus glaucescens*, introduced species such as **Tetragonia decumbens* and **Oenothera drummondii* occur on some low crests. But on the whole, the dune vegetation is similar to that of the other dunes in the region. In contrast, the North Stockton dune terrace is dominated by foreign species. **Panicum racemosum* and **Cyperus congestus* dominate the ground cover at Eames Avenue, **Gazania rigens*, **Stenotaphrum secundatum* and **Galenia pubescens* do so at Barrie Crescent, while **Chrysanthemoides monilifera* subsp. *rotundata* is still conspicuous.

I recorded 51 species in the Eames Avenue section (disregarding planted species), and 44 species at Barrie Crescent. In both cases, only 6 are native to Australia (*Spinifex sericeus*, *Carpobrotus glaucescens* and *Senecio pinnatifolius* var. *pinnatifolius* are the more important), while a seventh, *Cynodon dactylon*, is regarded as a cosmopolitan species. The foreign species have come from the four corners of the globe. If there ever was a multinational thriving vegetation assemblage, this one surely must have pride of place!

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## Appendix 1 Comments on 15 notable introduced species of the Port Hunter area

(arranged in family order of Harden (1990–1993, 2002).

### 1**Galenia pubescens* (Aizoaceae; Fig. 3c)

This low, sprawling species from southern Africa has a widespread but scattered distribution in southern Australia. Kloot (1986) reports it from ballast dumps at Port Germein, South Australia, in 1916. In NSW it is 'not very common but often locally abundant around mining areas' (Jacobs & Highet 1990). There is probably a connection here as ore mined at Broken Hill, in far western NSW, is processed at Port Pirie, close to Port Germein. Hence, **Galenia pubescens* could have travelled inland via the railway line. Similarly, it is also common along roads and in disturbed areas in the lower Hunter Valley with its numerous coal mines.

In the early 1940s Mort (1949) found **Galenia pubescens* on the Central Coast and lists it as a 'strand species' possibly useful for dune restoration. In Victoria, Walsh (1996) reports it to be 'common in coastal areas in the Melbourne and Geelong areas, growing on beach sand and the hinterland, occasional in dryish, often somewhat saline areas in the north and north-west, scattered on open wasteland (railyards, roadsides etc.) elsewhere.' In the Flora of South Australia **Galenia pubescens* is mentioned as occurring 'especially near the sea' from the Adelaide area to the Eyre Peninsula as well as near the Flinders Ranges (Jessop & Toelken 1986). In Western Australia **Galenia pubescens* has been found in disturbed areas in Perth and Bunbury and also in Kalgoorlie (Hussey *et al*. 2007). These distribution patterns point to introductions in contaminated ballast and subsequent transportation inland via railway lines and roads. Adaptable to dry and somewhat saline conditions, **Galenia pubescens* occurs among the rocks of Macquaries Pier, and in patches at North Stockton, where it also climbs the windbreak fence.

### 2**Tetragonia decumbens* (Aizoaceae; Fig. 3d)

The history of this species as well as that of **Trachyandra divaricata* has been analysed by Heyligers (2002) and only a few aspects relevant in the context of this paper will be mentioned. The first Australian specimen of **Tetragonia decumbens*, a species native to South Africa, was collected in 1908 on Coode Island, the ballast ground for Port Melbourne (Tovey 1911). It 'covered the ground in a thick mass, the branching stems trailing out in all directions.' However, it has not persisted on the island, nor is there any evidence that it spread along the shores of Port Phillip Bay.

Early records of **Tetragonia decumbens* in NSW are from the Sydney area where it was collected at Maroubra in 1917 and Camp Cove, on the southern shore of Port Jackson, in 1919 but at both locations the species has disappeared (Heyligers 1999b). In 1947 Mort collected **Tetragonia decumbens* on Stockton Beach and lists it as a mat-forming plant possibly useful for dune restoration. I do not know whether it has been used for that purpose, but it is rather common at Stockton where, like **Galenia pubescens*, it may cover sand-stilling fences, as well as on the dunes at Nobbys Beach, where individual plants accumulate broad mounds in the *Spinifex sericeus* vegetation. It also occurs near Anna Bay, at the north-east end of Stockton Beach.

### 3 **Oenothera drummondii* (Onagraceae; Fig. 5c)

In 1929 the first specimen of **Oenothera drummondii* in NSW was collected at Waratah, now a suburb of Newcastle, followed by a second specimen from Newcastle in 1940 and a third from Coffs Harbour in 1941. At that time this species was already widespread along the beaches and islands of southern Queensland where, between 1924 and 1933, it had been collected five times in the Moreton Bay area and once, in 1937, at Maroochydore on the Sunshine Coast.

After their coastal survey of NSW in the mid to late 1940s, Mort and Hewitt (1953) commented that the distribution of **Oenothera drummondii* was limited, but that it was plentiful in the Coffs Harbour district 'where its lemon yellow flowers produce a very attractive display in the late spring and summer months. Its use as a sand stabilising species is very limited, but its free-seeding habit assists, together with the other species on the sand, to produce a dense growth which is quite an effective barrier to all but the severest gales.'

At Nelson Bay *Oenothera drummondii was collected in 1961 but not until 1966 at Stockton. It is not listed by Bodkin (1986) among the eleven Oenothera species available at nurseries. In Western Australia *Oenothera drummondii is common on the dunes near Perth, which Smith (1985) assumes is due to its introduction as a garden plant. Nevertheless, the early occurrences in Western Australia, NSW and Queensland point to introduction through shipping, although its apparently late appearance at Stockton is puzzling.

### 4 **Heterotheca grandiflora* (Asteraceae; Figs. 4b and 6)

This striking species is native to the south-western United States of America and northern Mexico. Specimens and accompanying correspondence at NSW indicate that the first colonies of **Heterotheca grandiflora* in Australia were discovered in 1964 at Carrington and Lee Wharf on the southern shore of Port Hunter. A. J. Beck, the East Maitland Agronomist, in a letter dated 20 April 1966, described these occurrences as follows: 'The colony at Newcastle is located on a sandy footpath directly opposite the rock phosphate unloading equipment, which is situated at No.5 Lee wharf. The plants ranged from seedlings to mature plants, tallest of which is included in the specimens to be sent to you. The colony population consisted of some 360 plants and extended over an area of some 40 to 50 yards. At Carrington a smaller colony was located on some waste land behind the Wheat Terminal Wharf and directly adjacent to the silos. The plants here consisted of 20 in number ranging from seedlings to mature plants 4 feet high. The more vigorous growth of these plants is probably due to a better environment.'

Later **Heterotheca grandiflora* was found to be common at the grain terminal on Kooragang Island. The identity was checked by H. K. Sharsmith, a Californian taxonomist, who on 29 March 1966, after confirming the identification, wrote 'This species is a native in California and, although weedy from the standpoint of favoring disturbed waste ground, it is not an economically significant weed and does not invade agricultural lands.' She also mentions its introduction in Hawaii before 1920 and that it was reported to be a noxious weed of pineapple fields.

A related species, found in the south-eastern United States of America, *Heterotheca latifolia*, was used for experiments to determine the ecological consequences of achene dimorphism (Venable and Levin 1985). The ray and disc flowers of this species, like those of *Heterotheca grandiflora* and the other species in the section *Heterotheca*, produce markedly different achenes. The results of one of the experiments showed that wind dispersal was more effective for disc achenes, which have a well-developed pappus of capillary bristles, than for ray achenes, which lack a pappus. *Heterotheca latifolia*, just like **Heterotheca grandiflora*, is an annual and grows on sandy or rocky ground, on disturbed soils, in pastures and on wasteland. Since the 1930s it has enlarged its territory, frequently following railways and roads.

Attempts were made to eradicate **Heterotheca grandiflora* when it first appeared in 1966, but were apparently not successful. The occurrence at Raymond Terrace was first documented by a collection made in 1976. Subsequently, **Heterotheca grandiflora* became widespread between Hexham and Raymond Terrace in pastures and wasteland (Porteners 1992). It was collected in 1993 along the Tomago-Nelson Bay Road and a year later I found it at Stockton. Although not uncommon in the area north of Port Hunter, it would appear that, as observed in California, these occurrences are not economically important. Recent occurrences in northern NSW and south-eastern Queensland would indicate that spread to other areas, just like the expansion of **Heterotheca latifolia*, has already started.

### 5 ***Cotula turbinata* (Asteraceae; Figs. 3a, 7a and 7b)**

Until found at Stockton, **Cotula turbinata*, a species native to South Africa, was only known to occur in Australia in the south-west of Western Australia, at mostly coastal locations between Perth and Albany. Marchant *et al*. (1987) describe it as a 'weed of sandy soils, particularly in lawns.' This applies to the conditions at Stockton, where I have found it at Barrie Crescent and Eames Avenue, in the park along the foreshore and on the small oval in the centre of Beeston Street, off Eames Avenue. It is possible that we are dealing here with two independent introductions, one to the the west coast and another one to the east coast of Australia. In New Zealand Kirk (1896) found this species on a ballast heap near Wellington, dumped by a vessel arriving from Buenos Ayres, South America, together with **Calibrachoa parviflora* and many other species. Apparently, it has a way of getting around!

The inflated peduncle under the flowerhead makes **Cotula turbinata* stand apart from other *Cotula* species and it may have a wider distribution along the NSW Central Coast than has been recognised. *Cotula australis* grew among the* *Cotula turbinata* plants. This native species, often common in open grassy situations, is found throughout temperate Australia and has spread far and wide overseas: not only does it occur in New Zealand and South Africa, but Jörgensen & Ouren (1969) also mention Sri Lanka, the Canary Islands and the Pacific States of the United States of America, while Jörgensen also found it on the grain import quay in Oslo, Norway, where it is presumed to have come in with Australian wheat. **Cotula coronopifolia* is another species that has spread far and wide. Its status in Australia is unclear; it could have arrived here with the First Fleet from South Africa, where it is regarded as a native species. However, Brown mentions ?*Cotula coronopifolia* in his list of introduced species at Port Jackson (Britton 1906). It is not clear whether Brown queried the introduced status or that he was not sure of the identification, as he collected quite a few specimens from the local area. Whatever the case, the species has now spread to the far corners of the globe (Heyligers 1995).

### 6 ***Senecio crassiflorus* (Asteraceae; Fig. 5d)**

This species is a dune plant, native to the Atlantic coast of South America where it occurs in the company of **Panicum racemosum*, **Hydrocotyle bonariensis* and **Cakile maritima*, among others (Eskuche 1973, Costa *et al*. 1996). In Australia **Senecio crassiflorus* is 'cultivated as an ornamental, sometimes naturalised in coastal districts from Stockton to Berowra district' (Harden 1992a). However, Mort and Hewitt (1952) assume that 'due to the fact that it appears to be localised in the Newcastle district it is thought that it may have been brought in with ballast from South America in the sailing days. This plant is now naturalised in Australia and has spread fairly extensively from Belmont to Stockton, where it was recorded as early as 1910.' There are only a few collections of this species at NSW; the earliest being one from Newcastle made in 1912. In 1918 **Senecio crassiflorus* was collected at Swansea, followed by one at Stockton in 1925. The occurrence in the Berowra district appears to be based on a 1924 collection made between Cowan and Berowra on the west side of Kuringai Chase, well away from the coast and could have been a garden escape.

**Senecio crassiflorus* was tested by the Soil Conservation Service for dune restoration at The Entrance North with the result that 'this plant will prove invaluable for vital exposed areas, particularly in close proximity to the beach, where a small quantity of sand is collected from time to time. This has the effect of a light topdressing; however, with six inches accretion of sand or more the plant is often completely inundated and destroyed' (Mort & Hewitt 1952). As it had been known in the Newcastle district for about 40 years and had not spread beyond other beach areas, Mort and Hewitt advocated 'its encouragement on areas of coastal sand drift ... particularly in situations of extreme exposure and in close proximity of the beach.' Apparently, this advice has not been taken to heart, although the label of a collection at CANB from Sawtell Beach (south of Coffs Harbour) made in 1967 states that it was planted for the prevention of soil erosion. There is no other evidence of occurrences outside the area originally outlined by Mort and Hewitt and the only plant seen at Macquaries Pier is no longer present.

### 7 ***Ursinia speciosa* (Asteraceae; Fig. 7 c and d)**

There are only two collections of this South African species at NSW; one made in 1967 at Fullerton Cove north of Stockton, the other my collection from North Stockton made in 1996. At Fullerton Cove it was rare and found on a sandy knob over about 1.5 ha. The collector, O. Wykes, added to the label that this occurrence 'appeared to be the only area of infestation [sic!] in the Port Stephens Shire.' After receiving the Fullerton Cove specimens K. Mair, Director of the Sydney Royal Botanic Gardens, in providing the identification, writes 'This species was recorded by Ewart in Flora of Victoria 1931 in a list of plants which "occasionally appear spasmodically, mostly as garden escapes". It has, to my knowledge, not been recorded as naturalized in other States.' He then refers to Mort (1949) where an '*Ursinia* sp.' is mentioned as possibly suitable for planting on windward aspects of foredunes on the Central Coast. On this basis Mair surmises that the Fullerton Cove occurrence could either have originated through sand stabilisation work or from windblown seed and advises the District Agronomist to watch this species 'for indications of spreading to native bushland.' However, the occurrences of **Ursinia speciosa* have remained spasmodic and certainly have not lead to further 'infestations.'

**Fig. 6**.* *Heterotheca grandiflora* at Little Park Beach in September 2005 just coming into flower. It is a biennial species that 'overwinters' in the rosette stage and flowers in spring and summer. Previous season's dead plants are out of focus in the background.

It is of interest to go to the earliest known occurrence of this species in Victoria. In 1908 and 1909 Tovey (1911) found **Ursinia speciosa* on Coode Island, on the south bank of the Yarra River near its mouth, and was sure that it had come in with ballast dumped on that particular side of the island. Tovey, a Senior Assistant at the National Herbarium of Victoria, writes '... is only known in this State from this locality. It was growing in great profusion ... I brought away some of the young plants of the Ursinia [no italics], and planted them in my garden: but they seeded so freely and spread so rapidly that I had to pull them up, or they would have taken possession of the garden.' The species is not mentioned by Walsh and Entwisle (1999) and, Tovey's fear notwithstanding, one may assume that it did not become naturalised in Victoria. However, Hussey *et al*. (2007) report that in south-western Western Australia **Ursinia speciosa* 'is a garden escape that has naturalised in peppermint woodland at Hamelin Bay.' No *Ursinia* species are listed in Bodkin (1986), and hence one may assume are not available from plant nurseries.

The short-lived occurrence of **Ursinia speciosa* at North Stockton does not stack up with assumptions about an invading exotic nor about suitability for dune stabilisation. We can only wonder where the seeds of the small Stockton population came from. As I have been informed that it still is present on a few hectares near Fullerton Cove, it could have come from that location.

## 8 **Chrysanthemoides monilifera* subsp. *rotundata* (Asteraceae)

This subspecies of **Chrysanthemoides monilifera* is restricted to littoral habitats in the south-east of southern Africa. In eastern Australia its occurrences are also predominantly coastal, but it is also known from some inland locations where it was used for sand drift control (Weiss *et al*. 1998). The first herbarium specimen of **Chrysanthemoides monilifera* subsp. *rotundata* was collected in June 1908 at Stockton (Gray 1976). Cooney *et al*. (1982) mention that it had become particularly well established in the Stockton area by the early decades of the twentieth century and could have been introduced with ballast dumped on the north bank of the Hunter River.

In the early 1950s its 'naturalised' distribution was still limited to the Newcastle area, where it was proclaimed a noxious weed (Mort & Hewitt 1953). However, at that time the subspecies was already used in other locations for dune reclamation by the NSW Soil Conservation Service because of its excellent sand-stilling and sand-binding qualities. After its disastrous influence on the native vegetation was recognised, this practice was stopped and replaced by control programs.

After its release in 1989 the bitou tip moth has become established at many locations along the NSW coast. Especially where plants are directly exposed to coastal winds, the moth can cause significant reductions in flower and fruit production (Weiss *et al*. 1998). But on the

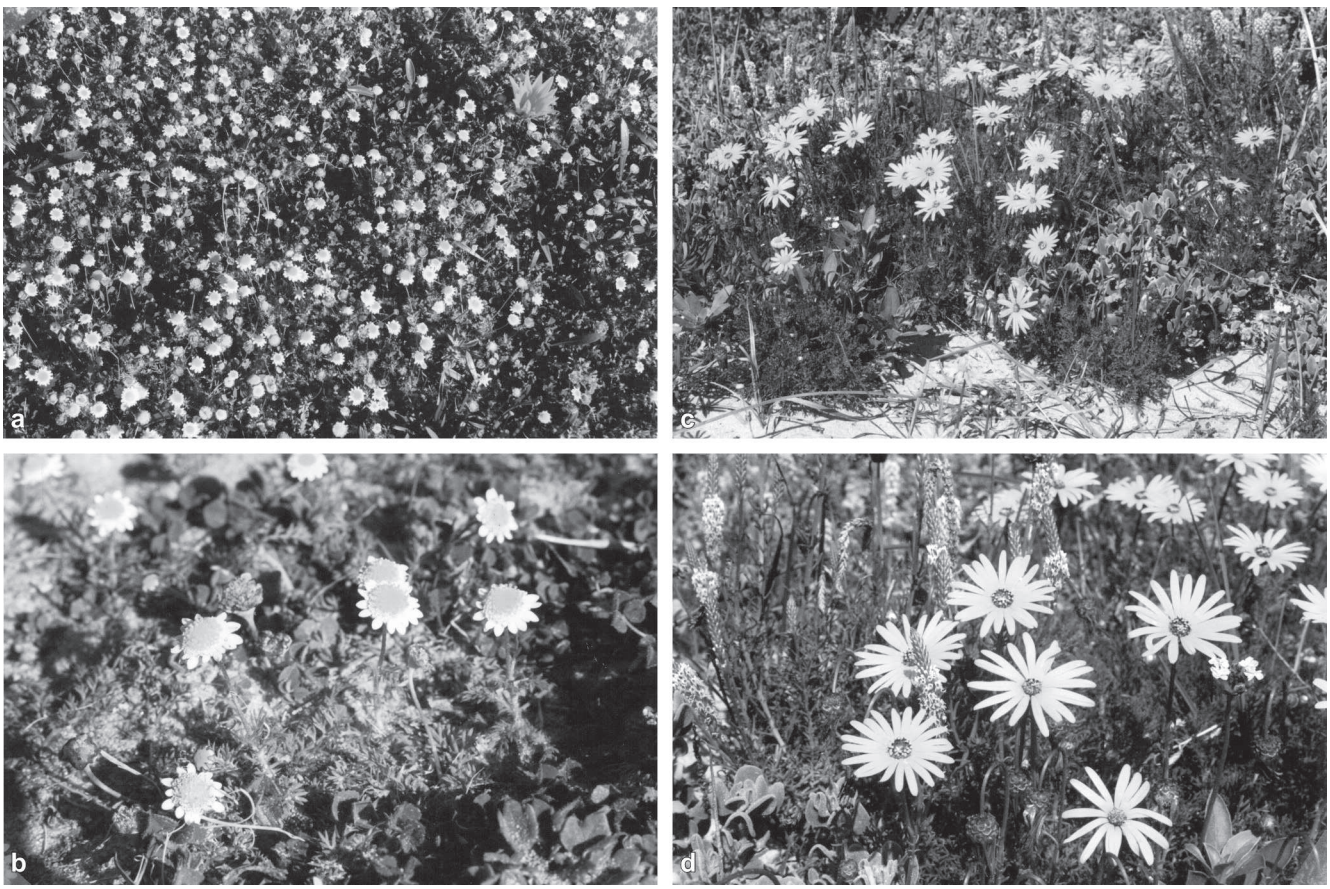


**Fig. 7**. **Cotula turbinata* and **Ursinia speciosa* at Barrie Crescent; **a)** a closer view of the **Cotula turbinata* 'lawn' shown in Fig. 3a; **b)** **Cotula turbinata* in flower and fruit in August 1997; note the funnel-shaped swelling of the peduncle under the fruiting head at left; **c)** and d. **Ursinia speciosa* among **Hebenstretia dentata* and **Tetragonia decumbens*; on **d)** towards the right a fruiting head showing the scarious pappus scales.

foreshores at Stockton this is not severe enough to keep regeneration of **Chrysanthemoides monilifera* subsp. *rotundata* in check and at Eames Avenue hand-pulling of young plants is still necessary.

### 9 **Solanum tuberosum* (Solanaceae; Fig. 8d)

In 2003 I found about twenty plants of a *Solanum* species in a grassy area close to the beach cliff at Barries Crescent. B. Lepschi (at CANB) provisionally identified them as **Solanum tuberosum* and D. Symon who confirmed the identification. He said, however, that '…the style is markedly longer and the calyx lobes shorter than any specimens we [i.e. at the State Herbarium of South Australia] have.' Despite trying to dig up some plants, I could not find tubers, although these may have remained out of reach among the dense roots of **Stenothaphrum secundatum* and *Cynodon dactylon*.

### 10 **Calibrachoa parviflora* (Solanaceae; Fig. 5b)

**Calibrachoa parviflora*, native of South America, is an 'uncommon weed, chiefly from Newcastle and Boggabri districts, also doubtfully naturalized in the Narrabri area' (Conn 1992). The earliest specimen at NSW was collected in November 1910 at Stockton Beach, the next two specimens in January 1941, one from the 'Newcastle District,' the other from Nobbys Head military camp. This points to introduction in ballast, an assumption supported by evidence from Kirk (1896), who found it near Wellington, New Zealand, on a heap of ballast dumped by a ship coming from South America. There were no further records from the Newcastle area until 1999 when I found a plant growing next to the pavement of Macquaries Pier. The specimen from the Boggabri district, the first of the four inland collections, dates from 1948. Disturbed grassland, a lawn of Buffalo Grass and riparian vegetation are mentioned on the labels of the other specimens, the latest one collected at Myambat on the Central Western Slopes in 1998.

### 11 **Hebenstretia dentata* (Selaginaceae; Fig. 8 a and b)

Harden (1992b) gives the status of this species, native to South Africa, as follows: 'Cultivated as an ornamental, occasionally naturalized in the Newcastle to Nelson Bay district.' Several labels of the nine herbarium records on which the naturalised distribution is based mention that the plants were found in disturbed areas, with one collection, made in 1970, coming from Stockton where it was 'frequent on disturbed, flattened sandy area behind beach.' This sandy area could well have been the foreshore at Eames Avenue. The earliest collection, also at Stockton, was made in 1915, well before any dune restoration work was mooted. The most interesting information was provided by W. M. Steinbeck with a specimen collected in June 1923: 'This plant grows freely on the foreshores at Stockton and it seems to be spreading back from ballast tips and is probably introduced.' **Hebenstretia dentata* is, or has been, sold by plant nurseries, as it is listed by Bodkin (1986) and I think it likely that this species was taken into cultivation for its ornamental qualities after its accidental arrival at Port Hunter. Mort (1949) listed *Hebenstretia dentata* in his suggestions for plants that may be useful in dune stabilisation.

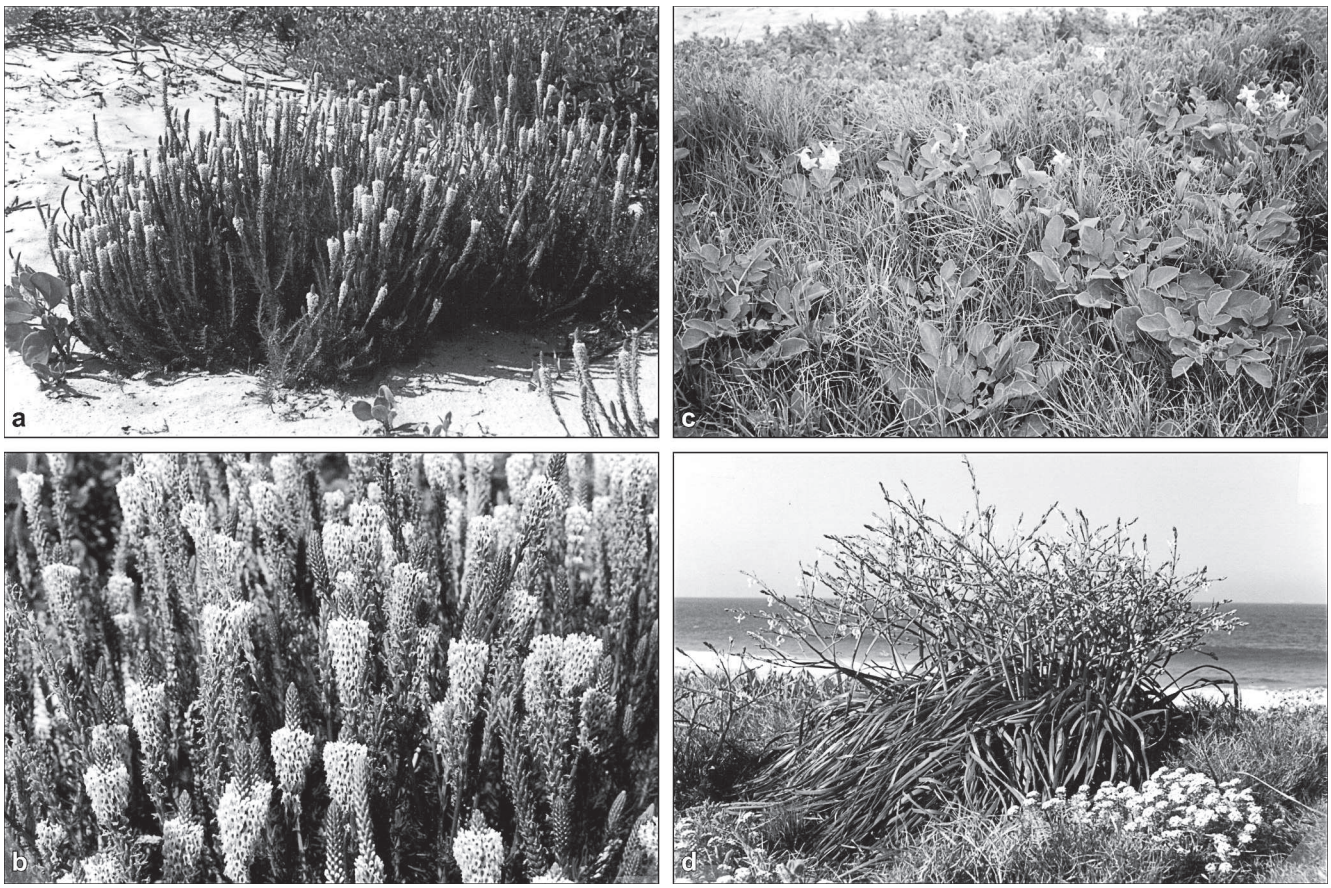


**Fig. 8. a)** **Hebenstretia dentata* on an open patch in the **Chrysanthemoides monilifera* subsp. *rotundata* vegetation near Corroba Park in August 1997; **b)** a close-up showing how the tightly closed **Hebenstretia dentata* buds almost literally burst into flower; **c)** the puzzling **Solanum tuberosum* on the same terrace in April 2003, puzzling because of some anomalies in its flower structure and the apparent absence of tubers; **d)** **Trachyandra divaricata* and **Lobularia maritima* on the terrace at Barrie Crescent in August 1997.

### 12 **Trachyandra divaricata* (Asphodelaceae; Fig. 8c)

There are no herbarium specimens from the Port Hunter area. The closest documented occurrence is a collection made in 1993 at Birubi Point at the far north-eastern end of Stockton Beach. When I began my observations, **Trachyandra divaricata* was present at North Stockton and Little Park Beach, but not around Macquaries Pier, a situation that did not change over the ensuing years, although it has become more numerous.

Native to South Africa, **Trachyandra divaricata* was collected in 1912 on Coode Island (Heyligers 1999) but, like **Ursinia speciosa*, it did not persist in the area. In the early 1930s **Trachyandra divaricata* became naturalised in the Fremantle area and spread north and south apparently aided by cars and boats (Heyligers 1999a, 2002). In NSW **Trachyandra divaricata* was first reported from Fairy Meadows, north of Wollongong, in 1968. The Wollongong-Shell Harbour area is still the major centre of its occurrence with scattered occurrences in the Sydney region and at Stockton. At most, if not all, of these sites dune restoration has been carried out, often including planting of *Acacia saligna*, a species endemic to Western Australia. Therefore, it seems likely that **Trachyandra divaricata* arrived and has been spread as a contaminant of *Acacia saligna* planting stock.

**Fig. 9.** **Panicum racemosum* in fruit on Eames Avenue terrace in October 2005. Flowering is stimulated by fresh sand accumulating in the sward.

### 13 **Gladiolus gueinzii* (Iridaceae)

This species, native to south-eastern South Africa, was first collected at Stockton in 1950 and in 1953 at Palm Beach at the entrance to Broken Bay, north of Sydney (Heyligers 1999a). It has since spread along the coast of NSW north as far as South West Rocks, where it was collected in 1964, and to the Eden area in the south where I found it common in 1984. Recently, it has also been collected in Victoria in far East Gippsland close to Cape Howe (Australian Virtual Herbarium information).

### 14 **Cyperus congestus* (Cyperaceae)

This species, native to South Africa, has spread rapidly on the dune terrace at Eames Avenue. In 1993 it occupied a small area at the entrance to the central path across the terrace, but five years later dominated the groundcover on the street side of the terrace. Rhizome growth has been the main means of dispersal as most flowering stems carry depauperate inflorescences and flowering, during winter and spring, appears to be sporadic. K. L. Wilson (NSW, in lit. 1996) who identified my specimens remarked that 'This is a new record for the North Coast – previously known from New England and from Sydney southwards.'

### 15 **Panicum racemosum* (Poaceae; Figs. 1 and 9)

This species is native to the Atlantic coast of South America where it is a common, often dominant, foredune plant in the company of **Senecio crassiflorus*, **Hydrocotyle bonariensis* and **Cakile maritima*, among others (Eskuche 1973, Costa *et al.* 1996). On the foredune slope to east of Corroba Park **Panicum racemosum* mingled with *Spinifex sericeus*.

It is not known how **Panicum racemosum* arrived in the Stockton area but it has been present for some time and was regarded by the local population as another kind of marram grass (D. Conway, pers. comm. 1994). However, Mort who in the 1940s surveyed the NSW coast for suitable dune restoration species and was familiar with the Stockton area, does not mention it in his 1949 paper. The other known Australian occurrence of **Panicum racemosum* is near Geelong, Victoria, where it 'has persisted for some years as a troublesome weed around grain storage areas ... but does not appear to have become naturalized elsewhere' (Walsh 1994).

When I began my observations at the Eames Avenue area in 1993 I was puzzled by a 25 m by 7 m patch of a coarse sprawling grass. Being vegetative it defied identification until in December some fertile specimens were obtained, which were keyed out by M. Lazarides as **Panicum racemosum*.

Eight months later the patch at Eames Avenue had expanded to 70 m by 30 m, a clear indication of this species' vigour. Over the following years it became the dominant grass over much of the area, especially in the shoreline section. Flowering only occurs during spring, especially where there has been a fresh supply of sand, and does not appear to produce sufficient seed to explain the rapid expansion. Apparently here, as in its native habitat, it mainly spreads through prolific rhizome growth (Cordazzo and Davy 1999).