AUSTRALIAN SALTMARSHES

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Introduction

Studies of Australian intertidal wetlands are very much in their infancy. In recent years mangrove ecology has begun to receive much needed attention but saltmarshes seem destined for a cinderella role with, however, no sign of the fairy godmother. Basic questions such as the extent of the resource, the nature of its flora and fauna, geographical variation and the relationships between saltmarshes and other ecosystems cannot be answered with any degree of certainty. The coastal zone, particularly in south eastern Australia, is under persistent pressure for development. Many saltmarshes have probably already been destroyed or heavily modified and in many areas the future of remaining sites is bleak. At least in the vicinity of urban development it seems that the most likely seral climax in saltmarsh development is, as elsewhere in the world, a garbage tip. It is instructive to compare Hamilton's (1919) account of the fringing saltmarsh vegetation of the Cook's river with the current barren state of what is one of the most modified and polluted estuaries in Australia.

For most of the Australian coast what information we have about saltmarshes is provided by geomorphologists rather than ecologists. However, a few, widely scattered, saltmarsh systems have been studied in detail. The study of the saltmarshes on the south side of Botany Bay (the most extensive saltmarsh system in central New South Wales), and of the factors influencing individual species by Clarke and Hannon (1967, 1969, 1970, 1971 and Kratochvil, Hannon and Clarke 1973) is one of the most intensive carried out on any marsh system. The Blackwood Estuary in Western Australia provides the first example of studies on nutrient pools and productivity of Australian marshes (Congdon and McComb 1980a,b). Bridgewater's (1975) phytosociological account of the marshes around Westernport Bay was the first detailed description of Australian saltmarsh vegetation.

Much of the Australian coastline is unsuitable for the development of saltmarshes. In the north of the continent, most saltmarshes occurrences are on the landward side of mangrove stands. In some instances bare tidal flats are found above the mangroves with only limited development of saltmarsh. The relationships between mangroves, tidal flats and saltmarsh in the macrotidal Cambridge Gulf region of north west Australia are discussed by Thom, Wright and Coleman (1975).

In more temperate regions there is generally some development of saltmarsh behind locally extensive mangrove stands.

From about Sydney southwards the distribution of mangroves becomes more erratic and at some sites only saltmarsh is found. West of Melbourne the development of intertidal plant communities is limited but extensive stands of both saltmarsh and mangrove occur in South Australia in the St. Vincent and Spencer Gulfs and around Ceduna. In temperate Western Australia mangroves are absent, with the exception of the isolated and phytogeographically puzzling *Avicennia* population at Bunbury; saltmarshes occur in the estuaries but most are small. Mangroves are absent from Tasmania but saltmarshes are widespread (Goldin, 1980).

A feature of the coasts of both south east and south west Australia is coastal lagoons (Bird 1967). These vary in size and hydrology. In some, conditions are essentially estuarine; in others tidal action is absent or negligible. Some are periodically open to the sea; in others conditions are stable. In some lagoons hypersalinity may develop (even to the extent of complete drying out to give transient saltflats) while others are permanently only slightly brackish. The vegetation fringing lagoons varies depending on prevailing salinity conditions but in many instances may be described as saltmarsh. The influence of man on the present vegetation of the Gippsland Lakes and Lakes Alexandrina and Albert is discussed by Bird (1967).

The saltmarsh flora

The saltmarsh floras worldwide are characterised by a high degree of floristic resemblance, usually at the generic level although a number of species are found in several continents (e.g., *Sporobolus virginicus).* In early studies of Australian saltmarsh the reported number of species in common with northern hemisphere marshes was fairly high; more recent investigations and taxonomic revisions have reduced the apparent similarities. Nevertheless in vegetation structure and overall floristics Australian saltmarshes have much in common with those on other continents.

The saltmarsh environment is inimical to most plants and seemingly only relatively few have evolved the necessary adaptations to survive. The majority of halophytes belong to a small number of families (notably, Chenopodiaceae, Gramineae and Cyperaceae). The Australian saltmarsh flora conforms to this pattern. On the basis of flora and vegetation Chapman (1960) classified the saltmarshes of the world into nine major groups. In this scheme the marshes of temperate Australia and New Zealand are classified into one group characterised by species such as *Sarcocornia (Salicornia) quinqueflora, Halosarcia* and *Sclerostegia* spp. *(Arthrocnemum), Triglochin striata* and *Samolus repens.* Bridgewater (1975) suggests that Australasian marshes may be further distinguished by the presence of *Wilsonia* spp. (Convolvulaceae) and *Selliera radicans* (Goodeniaceae). Floristically and physiognomically southern Australian marshes are similar to those of mediterranean regions (the Mediterranean, California) and lack the extensive dominance of grasses found in north temperate regions.

Saenger *et al.,* (1977) report an inverse relationship between the number of mangrove species in an area and the number of saltmarsh species. Mangrove species diversity is greatest in north east Queensland with only one species *(Avicennia marina)* extending to the southern most mangrove occurrences. Only seven species have been recorded from saltmarshes in tropical northern Australia compared with more than thirty in the south. Saenger *et al.,* (1977) provide species lists for different regions of the coast and Bridgewater (1974) gives a key to the majority of species found on southern Australian marshes. It is not possible to provide a completely comprehensive list of the saltmarsh flora, partly because so few sites have been examined and partly because of the difficulty of defining the upper limits of saltmarsh vegetation.

Extensive areas of salt flats dominated by chenopodiaceous shrubs are found in the inland. The majority of species found in these inland sites also occur in coastal saltmarshes.

Fragmentary assemblages of saltmarsh species occur widely on seacliffs, particularly in poorly drained microsites.

Given the specialised and restricted nature of the saltmarsh flora it might perhaps be imagined that the habitat would be free from the invasion by alien species which has occurred in so many Australian vegetation types. This is not the case and a number of saltmarsh communities may be characterised by well established aliens.

Probably the only alien to invade successfully the lowest regions of the saltmarsh is *Spartina anglica.* This species is one of the classic examples of hybrid vigour. It was first recorded in Southampton Water in southern England in 1870 and is assumed to be the natural hybrid between the American *S. alterniflora* and the European *S. maritima.* The species proved to be extremely vigorous and more tolerant of frequent tidal inundation than other European saltmarsh species. The first introduction into Tasmania was in 1927 but definite establishment was not reported until 1947 from the Tamar estuary where large stands now occur. *Spartina* is also found in other estuaries in northern Tasmania. A number of introductions to the Australian mainland were made from 1930-1935 (Ranwell 1967) but it is only in Victoria that *Spartina* has become established. The extreme flooding tolerance of *Spartina* suggests that it poses a threat of invasion of the uppermost part of seagrass beds, as has occurred locally in the northern hemisphere. In general, *Spartina* has become most aggressively established in the cooler temperate regions of the world suggesting that its capacity for future spread in Australia will be limited. However, this cannot be guaranteed, and changes in the distribution of the species should be monitored.

Few aliens have invaded established native mid and lower marsh vegetation. A wide range of introduced species occur in the upper marsh and in the transition between saltmarsh and the hinterland. The total number of species concerned is large but the more widespread species are listed in table 1. The richness of the alien flora, particularly of annuals, in open, seasonally hypersaline upper marsh fringes suggest a possible lack of native species adapted to this niche.

The aliens on Australian saltmarshes come from both Old World (often with Mediterranean affinities) e.g., *Plantago coronopus, Parapholis incurva)* and New (e.g., *Hydrocotyle bonariensis, Aster subulatus).* It is difficult to envisage how many of the species reached Australia but whatever their route they have been established on saltmarshes for a long time. Hamilton (1919) records *Parapholis incurva, Plantago coronopus* and *Aster subulatus* as components of saltmarsh vegetation around Sydney more than sixty years ago.

A species of damp upper saltmarsh communities, the yellow composite *Cotula coronopifolia,* is one of the few plants native in Australia (and also in South Africa) which has returned the compliment and become an established alien in European saltmarshes.

TABLE 1

Some widespread alien species on Australian saltmarshes

Plantago coronopus	*Parapholis incurva*
Limonium binervosum	*Hordeum marinum*
Trifolium fragiferum	*Lagurus ovatus*
Melilotus indica	*Gastridium ventricosum*
Sonchus oleraceus	*Polypogon monspeliensis*
Aster subulatus	*Stenotaphrum secondatum*
Hydrocotyle bonariensis	*Puccinellia* spp.

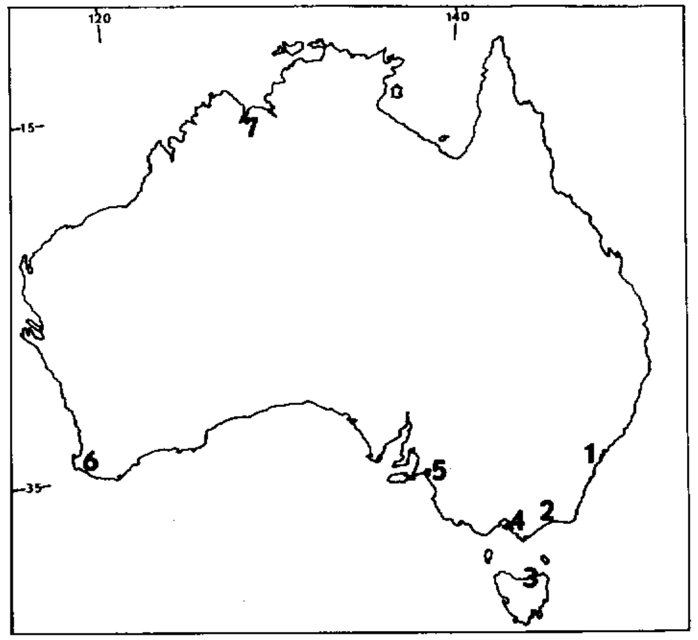


Fig. 1
Location of some sites mentioned in this article: 1 — Botany Bay (Clarke & Hannon, 1967-71), A.L.S., 1978); 2 — Gippsland Lakes (Bird, 1967); 3 — Tamar Estuary; 4 — Westernport Bay (Bridgewater, 1975); 5 — Lakes Alexandrina and Albert (Bird, 1967); 6 — Blackwood Estuary (Congdon and McComb (1980a,b); 7 — Cambridge Gulf (Thom, Wright & Coleman, 1975).

Vegetation:

The vegetation of saltmarshes is usually zoned parallel to the shoreline, although within each zone there may be a mosaic of communities. This zonation is frequently interpreted as the spatial expression of succession in time. This interpretation has not been backed up by other evidence. In the Sydney region, where saltmarsh occurs behind *Avicennia* woodland, evidence of active succession from mangrove to saltmarsh is lacking and whatever the historical explanation for the zonation it is best regarded at the present as a static zonation of a complex environmental gradient.

Saltmarsh communities may be somewhat crudely assigned to three main groups; shrublands, sedge and rush swamps, and grasslands. The shrublands are mainly dominated by chenopods although communities of *Frankenia pauciflora* would also be included here. The best development of chenopod shrub communities is on sites which are fairly well drained but which may become hypersaline between tidal inundations. A range of species and communities is found at different localities, but widespread species would include *Sclerostegia arbuscula* and *Halosarcia* spp. (all formerly in *Arthrocnemum) Sarcocornia (Salicornia)* spp., *Suaeda australis* and *Enchylaena tomentosa.*

Sedge and rushswamps are usually found in the upper marsh fringe but in more permanently brackish situations may occupy most of the saltmarsh zone. The most widespread community dominant is *Juncus kraussii* (in earlier accounts *J. maritimus* var. *australiensis)* but other frequent species include *Baumea (Cladium) juncea, Scirpus* spp., *Fimbristylis* spp., *Schoenus* spp. and *Cyperus* spp. In sites with a persistent freshwater influence species rich swamp communities with a well developed herb understorey may occur but such communities have not been investigated in detail.

In southern Australia grassland is poorly developed on many saltmarshes but in northern Australia extensive *Sporobolus virginicus* meadows, of importance for cattle grazing (Anning 1980), are found. *S. virginicus* is the most widespread saltmarsh grass in Australia although in the south (Tasmania, parts of Victoria and South Australia) it is replaced by *Distichlis distichophylla.* In more brackish habitats *Sporobolus* may be replaced by *Paspalum vaginatum.* Other grasses which may form swards in the upper marsh zone are *Zoysia macrantha* and *Cynodon dactylon.*

In addition to these major classes of community, a number of herbs which occur as minor species in a number of saltmarsh communities may locally become community dominants (for example, *Triglochin striata, Samolus repens).*

Most saltmarsh communities are species poor and may be defined in terms of dominance by one or two species. The most species rich communities occur in the upper marsh fringe in the ecotone between saltmarsh and inland vegetation. This zone is flooded by the tide infrequently (certainly less than twenty and often less than ten times a year). Nevertheless it is an extremely variable habitat and this is reflected in the range of communities that can be found there. At one extreme there is the open vegetation type of annual aliens, at the other species rich, virtually fresh swamps. The composition of plant communities and the zonation of communities are controlled by a set of interacting factors which Clarke and Hannon (1969) have called the holocoenotic complex. In terms of plant response the most important factors seem to be soil salinity and its variation in time and soil drainage both of which are strongly influenced by frequency of tidal submergence and climatic factors.

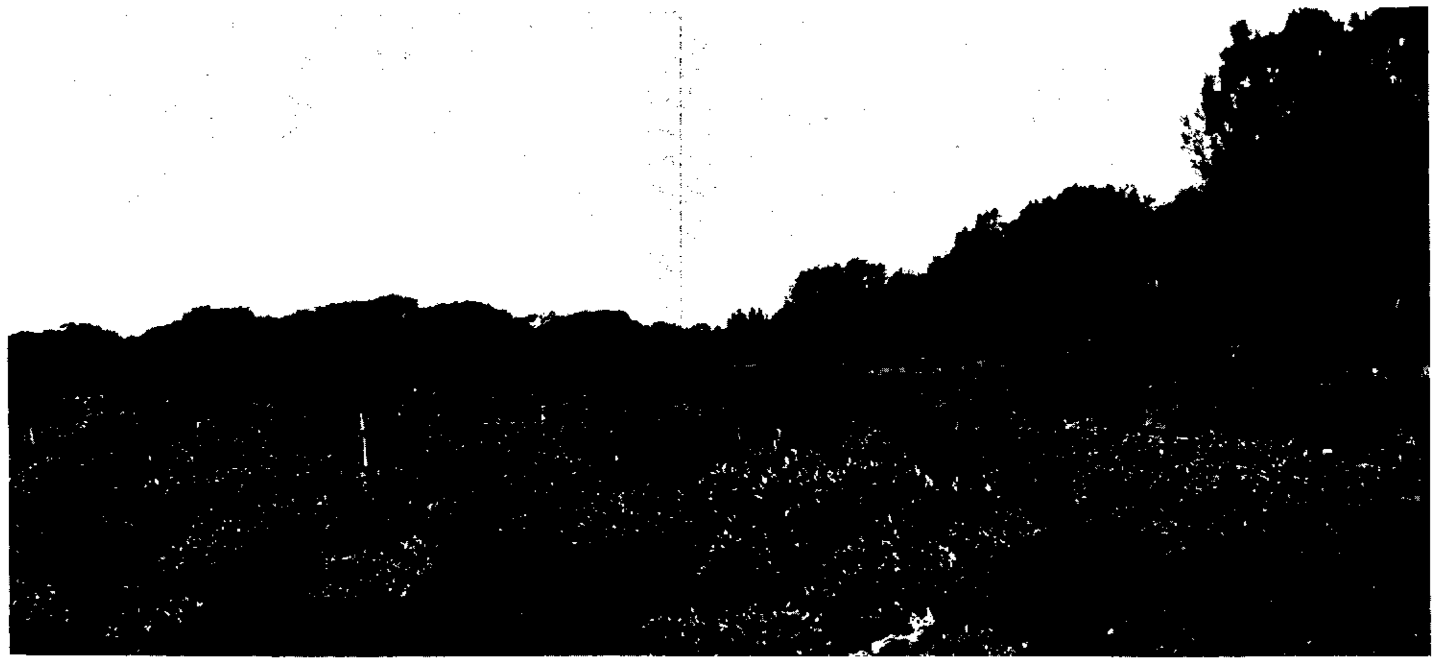
Insufficient data are available for discussion of variation in saltmarsh vegetation between sites. However, it is clear that some plant communities are relatively restricted while others are widespread suggesting that it may be possible to distinguish a number of saltmarsh types around the coast. Within southern Australia it appears that there is a difference between the marshes of NSW and those of Victoria, South Australia and Western Australia. Along the southern coasts a variety of chenopod shrub communities occupy extensive areas of the marshes, in NSW the chenopod zone is less extensive and largely dominated by one species, *Sarcocornia quinqueflora.* Possibly this difference is climatically determined; the NSW coast being subject to more evenly distributed rainfall and greater runoff than the drier southern coasts with pronounced seasonality in rainfall.

As mentioned earlier there is great variation in the vegetation around coastal lagoons from chenopod shrub communities to virtually freshwater reedswamp. In some lagoons mangroves are well developed (e.g., Lake Macquarie, Wallis Lake). Around many lagoons sedge and rush communities pass upwards to either *Melaleuca* or *Casuarina glauca* woodland. Very few studies of the fringing vegetation of lagoons have been undertaken.

Saltmarsh plant communities are generally defined in terms of vascular species but many algae are also characteristic of the habitat. King (1981) lists the algae recorded to date from saltmarshes in eastern Australia. Algae are assumed to play an important role in saltmarsh ecology but this has not been studied in Australia. Nitrogen fixing bluegreen algae are presumed to provide a major contribution to the nitrogen budget of saltmarshes.

The value of saltmarshes

Recent studies overseas have emphasised the relationships between saltmarshes and estuarine and coastal waters. It is argued that saltmarshes are a major source of organic material for detrital food chains. There is no doubt that some saltmarshes in the eastern United States are amongst the most productive natural ecosystems but the full details of the fluxes of material between saltmarshes and estuaries remain to be elucidated. It would be dangerous to extrapolate production figures for Australian marshes from the American figures given the differences in floristics, vegetation structure and climatic regime between the two regions.



NSW coastal saltmarsh, predominantly *Sarcocornia quinqueflora* with scattered *Avicennia marina*. The change through rush swamp to *Casuarina* woodland can be seen on the right.

A better basis for extrapolation would be from Mediterranean communities but suitable data are not available. It seems likely that productivity of chenopod shrub saltmarshes is much lower than that of American *Spartina* marshes. The only estimates of productivity for Australian saltmarsh are given by Congdon and McComb (1980a) for *Juncus krausii* marsh in the Blackwood estuary. Their estimates for net above ground production range from 0.3-1.3 kg dry $wtm^{-2}yr.^{-1}$, the higher figures being in the mid to upper range of estimates for saltmarshes and freshwater macrophytes but well below the maximum recorded from American marshes.

Given the relatively small extent of coastal saltmarsh and the nature of the vegetation it seems likely that their potential contribution to detritus food chains will be small but there is a need for actual data from Australian marshes rather than reliance on overseas estimates. While quantitative exchanges between saltmarshes and estuaries may be small, quality may be important. Exchanges of nutrients (for example nitrogen and phosphorus) could be essential for the function of estuarine ecosystems but again research is urgently needed.

While it is difficult at this stage to justify generalisations about exchanges between saltmarshes and estuaries our ignorance in the face of their possible importance ought to lead to counsel of caution in any proposed development. In other respects, we can be more certain of the importance of saltmarshes. They are an important habitat for birds, particularly waders and to many people are an intrinsically attractive part of the coastal scene (despite Hamilton's [1919] description of a marsh as a "monotonous stretch of dull green, stunted herbage").

The saltmarsh biota is superbly adapted to its environment. We are only just beginning to understand the details of the processes by which these adaptations are achieved. Greater knowledge of the species, of interest in its own right, may prove to be of wider applicability. For example, it has been suggested that understanding of the mechanisms of salt tolerance of wild plant species may lead to the development of new crop species and varieties for salinised semi-arid agricultural lands. This speculation may be overly optimistic but saltmarshes will provide natural laboratories for such research. The relative species paucity of saltmarsh plant communities makes them ideal for teaching purposes. Saltmarshes provide good demonstrations of zonation and offer opportunities for the study of succession.

Before we can fully appreciate the value of saltmarshes, much research is required. However, before this is likely to occur, many marshes will have changed. In addition to the obvious reclamation, some forces acting on marshes may be less apparent. Pollution, both chronic and acute, affects many marshes, little is known of its effects. Regulation of the flow of rivers into estuaries will reduce the range of conditions experienced by the marshes. It is impossible to predict what effect this will have but it emphasises the difficulty of accounting for the effects man has on ecosystems. Few, if any marshes, are still in a completely natural state, true control sites probably do not exist and our base line for comparison is continually changing.

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SALTMARSH PLANTS OF NEW SOUTH WALES

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The flora of saltmarshes is, when compared with that of other habitats, small. In the Sydney region the bulk of the biomass on saltmarshes is provided by about half a dozen species. The total saltmarsh flora is much larger but imperfectly documented.

This paper provides a Key to saltmarsh species in NSW — using it, it should be possible to identify at least the most common and widespread species on saltmarshes around Sydney. However, the Key makes no pretentions to completeness; many more species will be present on some saltmarshes. To identify these the user is advised to turn to a more comprehensive flora such as Beadle, Evans and Carolin (1972); the extensively illustrated guide by Galbraith (1977) will also prove useful.

Peter Bridgewater (1974) provided a Key to saltmarsh species in all the southern states which should be consulted for information of the wider distribution of species. This Key included a number of species which are absent from NSW coastal saltmarshes; interestingly many of these species are found in saline habitats in western NSW. A striking suite of species absent in NSW marshes are the succulent shrubby chenopods in the genera *Sclerostegia* and *Halosarcia* (both formerly in *Arthrocnemum* — see Wilson 1980) which are important community dominants in the other mainland states.

All species likely to be found in the mid and lower marsh zones in NSW are included in the current Key. (A possible exception is *Puccinellia stricta* (Hook.f.) C. Blom a loosely tufted grass locally common in the other southern states: as it occurs just south of the NSW border it may well be found on the south coast of NSW. A number of introduced *Puccinellia* spp. have been used in soil conservation projects and might also be found in coastal saltmarshes). The species of the upper margin of the saltmarshes are less well covered in the Key although all widespread dominants in these communities should be included.

The number of species potentially capable of occurring in the upper marsh is large but the actual flora of the habitat is poorly documented.

A number of different marginal assemblages can be recognized:—

Open vegetation on dry well drained sand: The majority of species are introduced, *Parapholis incurva* and *Plantago coronopus* are most frequent but many other introduced annual grasses and herbs may occur.

Drift line of rotting organic material (often washed up seagrasses and algae): The vegetation in this habitat tends to consist of small discontinuous patches dominated by single species with great variation in species composition between sites. The most frequent species are annual, or short-lived perennial, members of the family Chenopodiaceae. In addition to those species in this group covered in the Key other *Atriplex* spp. and *Chenopodium* spp. are likely to occur. Species from the drift line of sandy beaches might also be found and a number of alien species (including several composites) also occur.

Areas flushed by freshwater supporting low growing vegetation: These communities are often fairly open, a number of small sedges and rushes are found, *Cotula* spp. and other herbs also occur. Around Sydney one of the most frequent species is a diminutive sedge *Scirpus cernuus*, 3-5cm tall, but other superficially similar species in the same and related genera also occur. Recorded herbs included the creeping white flowered *Bacopa monniera* and the bluish purple flowered *Mimulus repens*. It would be difficult to include many species from this habitat in the Key without a full species list being available — the user is referred to Beadle *et al.* (1972). One genus represented in this habitat, but also found in dry open places, is *Centrolepis*, superficially like a small sedge some 3-5cm high, but in fact a member of a small family, the Centrolepidaceae.

Tall swamps: In the more saline marshes the two major dominants of these communities are *Juncus krausii* and *Baumea juncea*, around brackish lagoons a number of members of the Cyperaceae may be important. A number of other *Juncus* spp. also occur but these are difficult to identify using currently available floras. A rich understorey of small sedges and a variety of creeping herbs may also be present but has been little investigated. At least around Sydney members of the family Restionaceae do not seem very common in the more saline swamps. They may be distinguished when vegetative from the superficially similar sedges of the Cyperaceae by looking at the leaf sheath. In the sedges when the leaves are reduced to scales the sheathing leaf base around the stem is entire and tubular, in the Restionaceae where all leaves are reduced the leaf sheath is split on one side.

The majority of species on saltmarshes are also found in other habitats — sand dune, sea cliffs, swamps. Many species from inland habitats may, where populations are found close to the sea, locally invade the upper marsh. Thus, despite the basic similarity in terms of major community dominants between all saltmarshes, there may be great diversity when the total floras of sites are compared.

Throughout the Key scientific (Latin) names are used in preference to vernacular names. Unfortunately many saltmarsh species do not have a common name and even those common names that do exist are not unambiguous; for example, both *Sporobolus virginicus* and *Paspalum vaginatum* have been called "saltwater couch".

ARTIFICIAL KEY TO SPECIES OF COASTAL SALTMARSHES IN NEW SOUTH WALES

Plants with definite woody stems at least at bases (generally of shrubby appearance but may be prostrate) — 1
Plants herbaceous but not graminoid (a number of species will key out under both 1 and 2) — 2
Plants graminoid (grass-like — grasses, rushes, sedges) — 3

1 Plants with woody stems

1. Stems prostrate, with erect apparently leafless succulent branches. *Sarcocornia quinqueflora*
   Stems leafy 2
2. Leaves small 'heath'-like, dark green or grey green with recurved margins, lower leaves opposite, upper leaves often whorled. Flowers pale pink or white. *Frankenia pauciflora*
   Not as above 3
3. Leaves linear, alternate fleshy 4
   Leaves with flattened laminae 8
4. Leaves with sharp point at tip. Plant normally up to 50cm — sometimes to 1m. Leaves softer and up to 3cm on younger parts, harder and up to 1cm on older. Flowers sessile, axillary. *Salsola kali*
   Leaves lacking sharp points 5
5. Plant shrubby, up to 1m 6
   Plant procumbent, rarely more than 25cm high. 7
6. Erect shrubby plant up to 1m tall, glabrous, stems generally rather soft and only woody towards base. Leaves 1-4cm long, new growth often a rather bright yellowish green, older growth becoming reddish or purple *Suaeda australis*
   Shrub to 1m, leaves, and often stem, tomentose (densely covered with short hairs). Leaves 0.5-1.5cm long. Flowers solitary, axillary, perianth enlarging and becoming fleshy after flowering — red or yellow in colour, going black on drying. *Enchylaena tomentosa*