An analysis of plant communities at Coomonderry Swamp with comparisons to other wetlands on the south coast of New South Wales

N.H. de Jong

de Jong, N.H. (Department of Biological Sciences, University of Wollongong, Wollongong, New South Wales, Australia 2522) 1997. An analysis of plant communities at Coomonderry Swamp with comparisons to other wetlands on the south coast of New South Wales Cunninghamia 5(1): *81–128.* Coomonderry Swamp (34°48'S, 150°44'E) is, at 670 ha, the largest freshwater, coastal wetland in southern New South Wales and represents a substantial percentage of wetland of this type. In this study the floristic composition and relationships between plant communities at Coomonderry Swamp are described. Comparisons are made with a diversity of other local wetlands in order to assess the value of Coomonderry Swamp as a reference site, to analyse those broad characteristics of the environment associated with changes in floristics in coastal wetlands of the region, and to assess the distribution and abundance of key indigenous plant species over a range of wetland conditions.

Seven communities were defined by cluster analysis at Coomonderry Swamp with 11 'local variants' recognized within these. Plant community differentiation at Coomonderry Swamp was considered to be related to the structure of vegetation, drainage and nutrient status of soils, and to the influence of anthropogenic disturbance.

Over 200 plant species were identified for Coomonderry Swamp and its humic soil margins. A number of these are of regional significance. However the greatest importance of Coomonderry Swamp lies in the diversity of its plant communities. Relatively undisturbed, permanent freshwater swamps are virtually non-existent in the Sydney region and are poorly represented on the south coast of New South Wales. Some communities, well represented at Coomonderry Swamp, such as native sedgeland and swamp mahogany open-forest, are regionally rare.

Cluster analysis of communities from eight other local wetlands resulted in the identification of a further four community types with salinity being the major additional environmental component differentiating these groups from those described for Coomonderry Swamp.

Introduction

Ninety percent of all coastal wetlands in New South Wales are found north of Sydney (Adam et al. 1985; Pressey & Harris 1988; ANCA 1996) and scientific focus has consequently been on the extensive dunal wetlands of the Central and North Coast (see Pressey & Harris 1988; Jacobs & Brock 1993 for review). Freshwater wetlands on the south coast of New South Wales have been poorly studied (but see Porter 1990). Yet their relative rarity enhances their worth; as habitat for fauna, as drought refuge for migratory and nomadic birds, and as sites harbouring rare species.

Although there has been a general recognition by authorities of these values, south coast wetlands continue to be under threat. Impacts of development on wetlands are regularly debated in the local media, although much damage to wetland margins and infilling of ephemeral and smaller permanent water bodies is seldom reported (pers. obs.). Debate often emphasises the need for information, not just about complex issues such as effects of disturbance, or methods of restoration, or so called 'wetland compensation', but often about the basic data - what animals and plants are present?

Despite being the largest freshwater wetland on the New South Wales south coast, Coomonderry Swamp has remained essentially unexplored, although bird surveys and inventories have noted its ecological significance (Goodrick 1970; Moss 1983; Lawler & Porter 1990). This recognition resulted in protection of the central third of the wetland within Seven Mile Beach National Park, but urban and agricultural impacts along some margins of the wetland have greatly increased in recent years.

This study describes in detail the plant communities at Coomonderry Swamp. These communities are then assessed in a broader context. Comparisons are made with eight other local wetlands which differ markedly in disturbance regime and geomorphology, and also with wetlands described in some other published reports. These include studies of: estuarine communities at Jervis Bay (Clarke 1993; Mills 1995) and the Minnamurra River (Carne 1989), foreshore vegetation of Lake Illawarra (Yassini and Clarke 1985; Yassini 1985), and upland swamp plant assemblages (Kodela & Hope 1992; Keith & Myerscough 1993; Stricker & Wall 1995; Kodela et al. 1996). Relationships are also examined between wetland environments of the Sydney region (Benson & Howell 1994) and with similar coastal environments of the central coast of NSW (Myerscough & Carolin 1986).

Comparison were made with other wetlands to allow: (i) better insight into the relationship between distributions of communities (or species) and environmental factors (cf. Grime et al. 1988); (ii) better determination of the distributions of species which may be poorly known e.g. those belonging to the Juncaceae, Cyperaceae and Poaceae (Adam 1981; Adam et al. 1988; Clarke 1993; Johnson 1993); and (iii) better evaluation of Coomonderry Swamp as a reference site.

In this paper the term 'community' is applied to vegetation assemblages in the sense described by Austin (1991) i.e. 'relatively homogeneous units within a continuum'. In response to the need to work towards a broader framework of community classification of wetlands in New South Wales (Adam et al. 1988), the terminologies suggested by Adam et al. (1988) and Zedler et al. (1995) for saltmarsh and adjoining communities; by Myerscough & Carolin (1986) for coastal sand and associated wetland communities; and by Goodrick (1970) for wetlands in general, are used, or at least referred to, where vegetation units are considered to be comparable.

Some communities described emphasise the dynamic nature of wetlands and the requirements for at least some temporal evaluation of vegetation. For example open water and ephemeral communities may occupy the same space, with their alternation being dependent on the particular regime of environmental conditions. In this report clustering and ordination techniques were used to correlate floristic patterns to environmental variables on the broader scale of differences found within and among the variety of wetlands surveyed. Hypotheses concerning the causes of finer scale temporal and spatial changes of vegetation within Coomonderry Swamp will be considered elsewhere (de Jong unpubl. data).

This report does not provide an exhaustive list of all community types found in the region. Many wetlands in the area cited in inventories (Adam et al. 1985; West et al. 1985; ANCA 1996), await ecological investigation, and to these must be added numerous ephemeral wetlands and periodically wet environments which have not been mapped or recorded. Omitted from the present report are examples of coastal wet heaths (coastal bogs, Goodrick 1970) which are located on the margins of Jervis Bay. Analogous communities on the central coast of NSW have been described by Myerscough & Carolin (1986). In addition, a number of saltmarsh assemblages known to occur in the region (see Adam et al. 1988; Clark 1993) are not included.

The objectives of this study were to: (i) provide a detailed survey of the plant species composition, distribution, abundance and structure at Coomonderry Swamp, (ii) give a first account of the floristics at a range of other south coast wetlands, and (iii) compare communities, species richness, and distribution and abundance of key species among local coastal wetlands.

Methods

Study sites

Coomonderry Swamp (34°48'S, 150°44'E) is equidistant between the large south coastal towns of Kiama and Nowra (Fig. 1) and has a catchment of 1530 hectares. It covers approximately 670 hectares, filling a depression stretching for more than five kilometres adjacent to the open-forest vegetation of Seven Mile Beach National Park. Coomonderry is a last vestige of once extensive areas of wetland associated with the Shoalhaven River and Broughton Creek. Almost all of these swamps were drained at various times for grazing purposes with consequent acid-soil problems recently becoming apparent (e.g. Department of Land & Water Conservation 1995). Immediately to the north of Coomonderry Swamp, a portion of what was once Foys Swamp is now a sand mine.

Coomonderry Swamp is a dune-contact wetland although the term 'lake', usually employed in the typology of dunal waterbodies, can hardly be applied to Coomonderry Swamp since it is uniformally shallow (<2 m depth) and rarely supports large areas of open water. Its geomorphology (between dunes and adjacent rock) and chemistry (salinity usually <500 mgL^{-1}) are typical and indicative of dune-contact systems (Timms 1982, 1986, 1988).

No obvious creeks feed into Coomonderry Swamp, yet the wetland responds rapidly to rainfall events and also to periods of drought (de Jong 1997). Inputs of water to Coomonderry Swamp are via: direct rainfall, surface run off and springs from bedrock, subsurface seepage from dune ridges, and groundwater from mounds in sand dunes and from sand-bed aquifers (Mitchell McCotter & Associates Pty Ltd

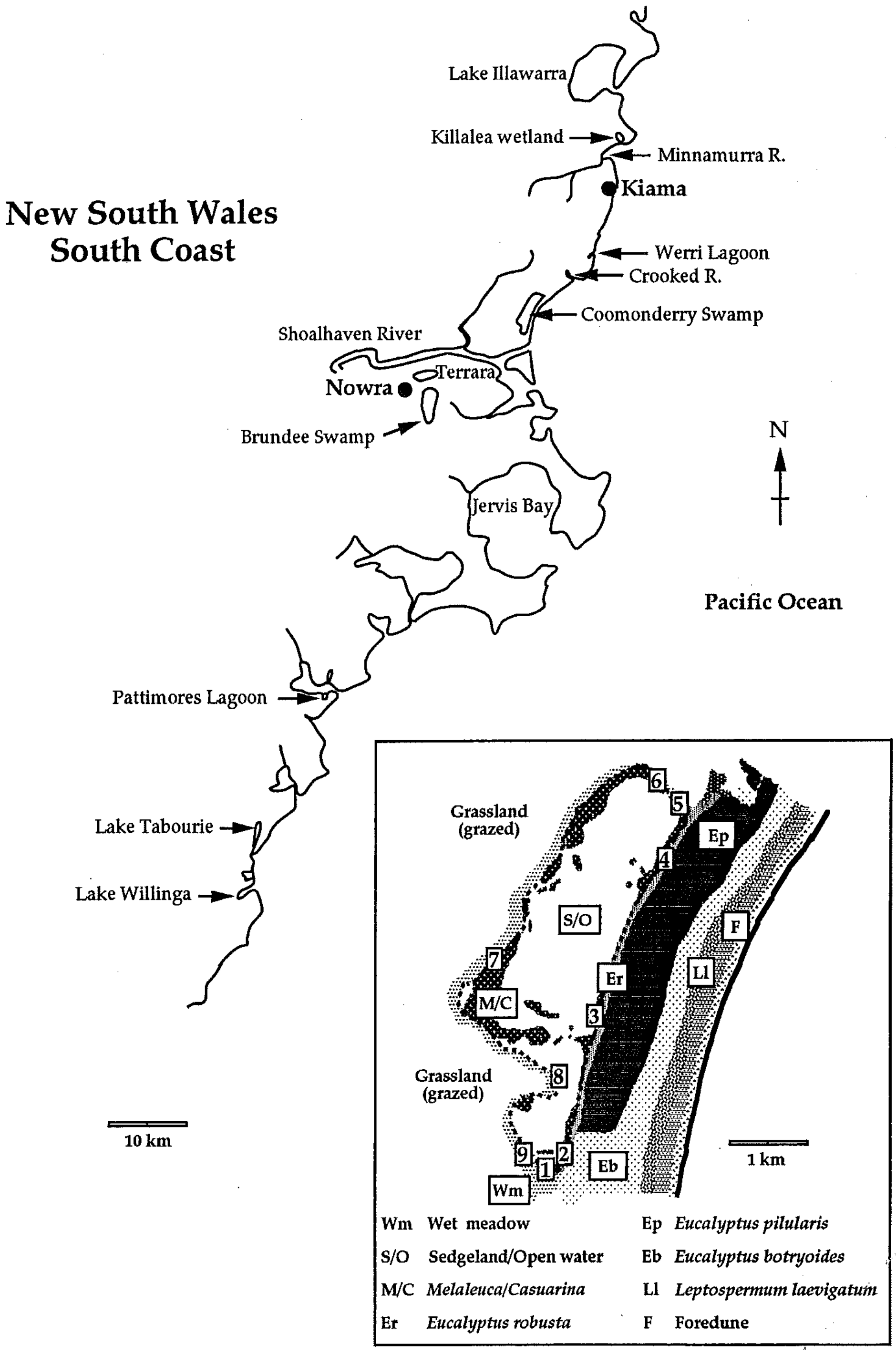

Fig. 1. Locations of wetlands surveyed and other coastal wetlands referred to in the text. Inset: Coomonderry Swamp indicating positions of transects 1–9, and major vegetation types. Based on Mitchell McCotter & Associates Pty Ltd (1991) and de Jong & Kodela (1995).

1991). Outflows occur via a southern drainage channel and by seepage into sand beds at the eastern margin. Hazelton (1992), described the wetland soils as composed of friable organic peat (30 cm) overlying acid peats of depths greater than 100 centimetres. Below the peat, various sandy subsoils overlie Quaternary marine sands.

The comprehensive botanical survey at Coomonderry Swamp involved investigation along nine transects (Fig. 1) supported by general description of floristics in and around the wetland over a three year period. Detailed descriptions of vegetation were also completed at Killalea (the nearest other freshwater wetland) and at a saline wet meadow site, Werri Lagoon (Fig. 1). Preliminary surveys were made at another six wetlands (Fig. 1 & Table 1). Wetlands were chosen to represent the three major geomorphological divisions: estuarine, floodplain and dunal (Adam et al. 1985). Difference among wetlands included salinity, hydrology, soil type, size, and the nature and degree of anthropogenic disturbance (Table 1).

Detailed maps, locations, management objectives, landform types, land tenure, wetland size, bird habitat and conservation status of the wetlands surveyed have variously been described in inventories and other publications (Blachford & Reeks 1976; Bell & Edwards 1980; Moss 1983; Adam et al. 1985; West et al. 1985; Gibson 1989; Lawler & Porter 1990; Porter 1990; Chafer & Marthick 1995; Shoalhaven City Council 1995; ANCA 1996; Young et al. 1996).

Survey design

Belt transects (1 m width) were generally situated along the elevation gradient, beginning on the landward side in visually homogeneous units of either woodland, meadow or sand dune and ending in the deepest part of the wetland, often in open water or homogeneous units of deep water vegetation. Discontinuities in vegetation commonly varied in response to changes along the elevation gradient and consequently transects varied in length (Table 1). At Terrara, a drained and grazed swamp, there was no obvious elevational change.

Estimates of percentage cover (0, < 10%, ≥ 10%) were made for all plant species in contiguous, 2 m × 1 m quadrats along each transect. Structural characteristics of the vegetation were recorded and the following classifications were used (after Specht 1981): (i) herbaceous layer: < 1 m, (ii) reed/sedge: 1–2 m, (iii) shrubland: 1–4 m, (iv) woodland: trees > 4 m.

Soils at c. 20 m intervals along each transect were visually classified as either 'peat' (almost completely organic), 'humic' (> 50% organic but with some sand), 'sandy' (< 50% organic), 'sand' (virtually no organic material) and 'lateritic' (a soil type found only on the western upper margin of Brundee Swamp). Where possible, water salinity and pH were recorded at c. 20 m intervals. Salinities were measured using a temperature—compensated salinity meter and pH using Universal Indicator paper or field pH meter. At Coomonderry Swamp, elevations along transects were recorded at 2 m intervals. These were determined using an autolevel and from water depths. At this site, elevations on all transects could be related. At other sites water depths were recorded at 2 m intervals along transects at the time of sampling and estimates were made of relative elevations above water level.

Table 1 Characteristics of wetland sites and extent of vegetation study.

Site	Size (km²)	Geomorphology	Disturbance history	Survey
Killalea Swamp (375) (SB009NS) 34°34'S, 150°52'E	0.2	Fresh-brackish, dunal swamp.	Probably cleared. Grazed until recently. Wholly protected within State Recreation Area.	Comprehensive: 3 transects and perimeter survey (110, 72, 56 m).
Werri Lagoon (371a) 34°44'S, 150°50'E	0.8–6.2 (17.0)	Estuarine lagoon.	Cleared and grazed freehold land. Drained regularly - intermittently open.	Comprehensive: 3 transects and perimeter survey (56, 50,104 m).
Crooked River 34°46'S, 150°49'E	0.2–0.5 (28.6)	Estuarine lagoon.	Degraded forest, cleared and grazed freehold land. Silted entrance - intermittently closed.	Preliminary: 2 transects: forest to saltmarsh (80, 222 m).
Coomonderry Swamp (370) (SB006NS) 34°48'S, 150°44'E	5.9–6.7 (15.3)	Fresh, dunal swamp.	Western margin: cleared and grazed freehold land. Eastern margin relatively undisturbed.	Comprehensive: 9 transects and perimeter survey (204, 210, 120, 130, 290, 72, 96, 120, 120 m).
Terrara Swamp 34°53'S, 150°39'E	1.7–2.0	Fresh, floodplain swamp.	Extensively drained, fallow or grazed freehold land.	Preliminary: 1 transect in wet meadow (60 m).
Brundee Swamp (344) 34°55'S, 150°39'E	4.0	Fresh–brackish, floodplain swamp.	Extensively drained, fallow or grazed freehold land. Some undisturbed, wooded wetland.	Preliminary: 2 transects: forest to wet meadow, dry meadow to tea-tree (110, 200 m).
Pattimores Lagoon (294) 35°16'S, 150°30'E	0.5	Saline, dunal swamp.	Largely undisturbed margin, but subject to periodic estuarine inflow via a canal.	Preliminary: 1 transect: forest to deep water (98 m).
Lake Tabourie (272) 35°27'S, 150°25'E (43.0)	1.4	Estuarine lake.	10–25% cleared, some revegetated. Uncleared margin in State Forest. Silted entrance.	Preliminary: 1 transect: sand dune regrowth-deep water (144 m).

Table 1 continued

Willinga Lake (260) 35°30'S, 150°23'E	0.3	Estuarine lake.	Increasing development on margins. Entrance intermittently closed. Some undisturbed margin.	Preliminary: 1 transect: forest to deep water (260 m).

Site: Wetland reference numbers (Adam et al. 1985; ANCA 1996) shown in brackets. Size: Ranges are given where maps and/or references differ. Variations indicate the arbitrary definition of wetland boundaries. Catchment size (if known) is shown in brackets. Survey: Length of transects shown in brackets in the order named (see Fig. 4). Sources: Bell & Edwards 1980; Moss 1983; Adam et al. 1985; West et al. 1985; Lawler & Porter 1990; Chafer & Marthick 1995).

Transect analyses at Coomonderry Swamp

TWINSPAN analysis (Hill 1979; Gauch 1982) was used to cluster quadrats along each of the nine transects at Coomonderry Swamp (Table 1) on the basis of plant species compositional similarity. A standard stopping rule for numbers of divisions was applied for all transects, identifying relatively homogeneous units of vegetation (termed community transect units). An example of how TWINSPAN defined these units along one transect at Coomonderry Swamp is shown in Fig. 2 (see also de Jong 1997). An alternative clustering strategy used for comparison (Jaccards coefficient with average linkage clustering) produced very similar results.

Community analyses at Coomonderry Swamp

The percentage frequency of occurrence in quadrats was calculated for all species within each of the 36 community transect units identified by TWINSPAN. Cluster analysis was performed on the resulting matrix to relate the floristics of the whole wetland (cf. Keith & Myerscough 1993). The Bray-Curtis measure of dissimilarity and flexible UPGMA (unweighted pair group arithmetic averaging) agglomerative clustering technique with ß = -0.1 (Belbin 1987) was chosen to analyse these data. Alternative methods again produced similar results.

Ordination using hybrid multi-dimensional scaling (HMDS) (Belbin 1987) was carried out on the Bray-Curtis association matrix derived from the initial TWINSPAN analysis of transects. Ordinations were performed in three and four dimensions with a 0.8 cut (Belbin 1987).

Following cluster analysis and ordination, hypotheses were generated regarding the relationship between floristics and soil-water characteristics, structural characteristics of the vegetation and disturbance factors. Each community transect unit was characterized by calculating values (*a posteriori)* for measures which could be indicative of each of these factors. These measures were means for: (i) relative elevation (cm); (ii) soils ranked: 1 - peat, 2 - humic, and 3 - sandy; and (iii) species richness at 10 m^2 scale (five quadrat interval). Other measures for each vegetation unit were: (i) vegetation height calculated from the formula: $[\Sigma(nh)]+q/[\Sigma n]+q$ (where 'n' = the number of quadrats with ≥ 10% cover for a given species, 'h' = ranked height class for each of these species, and 'q' is the number of quadrats having no species with ≥ 10% cover); (ii) proportion of introduced taxa and (iii) proportion of woody perennials together with longer-lived, non-woody species whose populations exhibited constancy (Putman 1994) over three years of seasonal and hydrological flux.

Pairwise correlations between each variable and each ordination vector were calculated using Pearson correlation coefficients. The significance of correlations was tested with t - tests with the level of significance reduced to $P = 0.001$ by the Bonferroni procedure to compensate for the number of correlations.

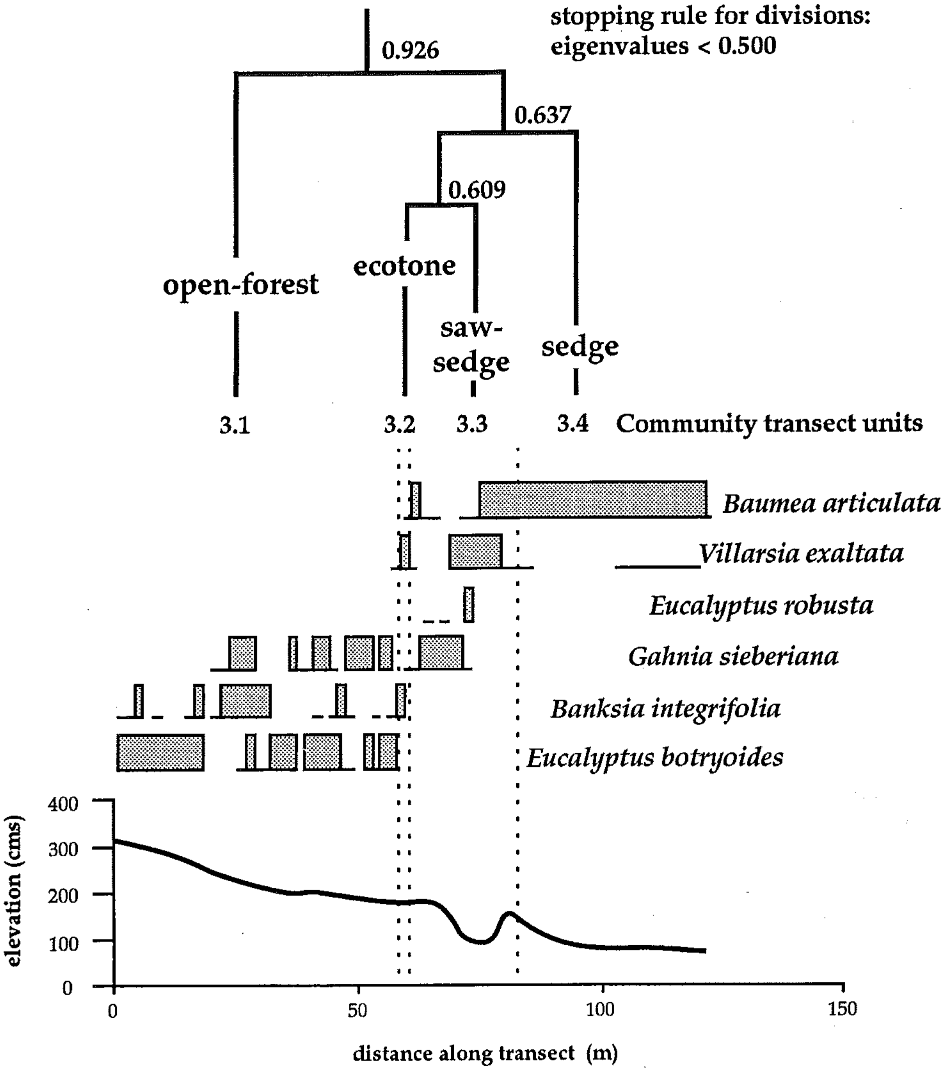

Fig. 2. Community transect divisions derived from TWINSPAN analysis of species composition in quadrats along Transect 3 at Coomonderry Swamp. Direct gradient analysis shows the distribution and abundance of some key indigenous species. Lines show presence of named species. Shaded bars show % cover ≥ ten. Transect divisions are numbered consecutively down the transect.

Comparisons with other wetlands

Community transect units were also identified along transects at other wetlands (Table 1) by using TWINSPAN. All community transect units (including those from Coomonderry Swamp) were compared by forming a percentage frequency occurrence matrix and then applying the clustering and ordination techniques in the way previously described. Once again correlations between vectors (three to five) and floristic and soil-water characteristics were calculated. Additional variables included two soil ranks: 4 - sand and 5 - laterite, pH and salinity. Correlations were not carried out for salinity and pH with community transect units above water level. The significance of correlations was tested with t - tests, with the level of significance reduced to $P = 0.001$ by the Bonferroni procedure, to compensate for the number of correlations performed. Soil-water and structural attributes of each community type derived from the clustering procedure were compared using single-factor ANOVA, with multiple comparison of means performed with Fisher PLSD tests. None of the appropriate transformations removed heterogeneity among variances and so ANOVAS were performed on the untransformed data.

Results

Community analyses at Coomonderry Swamp

Over 200 plant species were recorded within Coomonderry Swamp and along its margins (Appendix 1) and eleven communities were recognized (Fig. 3). For purposes of comparison with other wetlands, these were further reduced to seven: with fresh wet meadow, floating mat and ephemeral meadow being considered 'local variants' of wet meadow; *Melaleuca* and *Melaleuca–Casuarina*, local variants of *Melaleuca*; and *Marsilea* and *Utricularia–Eleocharis* complexes, local variants of deep freshwater communities. As indicated, arrangements of communities varied little among alternative clustering procedures. Discrepancies arose in the classification of 'mixed' communities, for example, disturbed and open *Melaleuca* scrub which contained understories dominated by short-lived herb and grass species. Such units could be grouped with other *Melaleuca* communities, or alternatively, with wet meadow communities.

The diversity of communities found at Coomonderry Swamp reflects the complexity of factors influencing floristics. The four dimensional ordination resulted in a 24% reduction in stress (to 0.1307) over three vector analysis, and better differentiated correlated variables, albeit with a corresponding increase in 'noise' (Table 2). The trend in negative to positive scores for vector 1 corresponded to an increase in elevation and decrease in organic content of soils. Vector 2 correlated strongly with structural components of the vegetation, the negative to positive sequence of vector values matching a general increase in canopy height with an associated decrease in proportions of introduced taxa. Vector 3 suggested the influence of human disturbance at Coomonderry Swamp (and disturbance and stress related to inundation changes lower on the elevation gradient). The negative to positive sequence of vector scores in this instance generally matched an increase in the proportion of introduced species and related decrease in woody perennials and longer-lived non-woody perennials. Vector 4 indicated the influence of soil characteristics with the trend from negative to positive vector scores correlated with a decrease in humic content of soil. More soil analysis is needed to define those characteristics that influence floristics in this wetland (cf. Keith & Myerscough 1993).

The categories of factors delineated by ordination: disturbance, structure and elevation; are superimposed on the dendrogram (Fig. 3) to indicate their relative importance to early divisions of the cluster analysis.

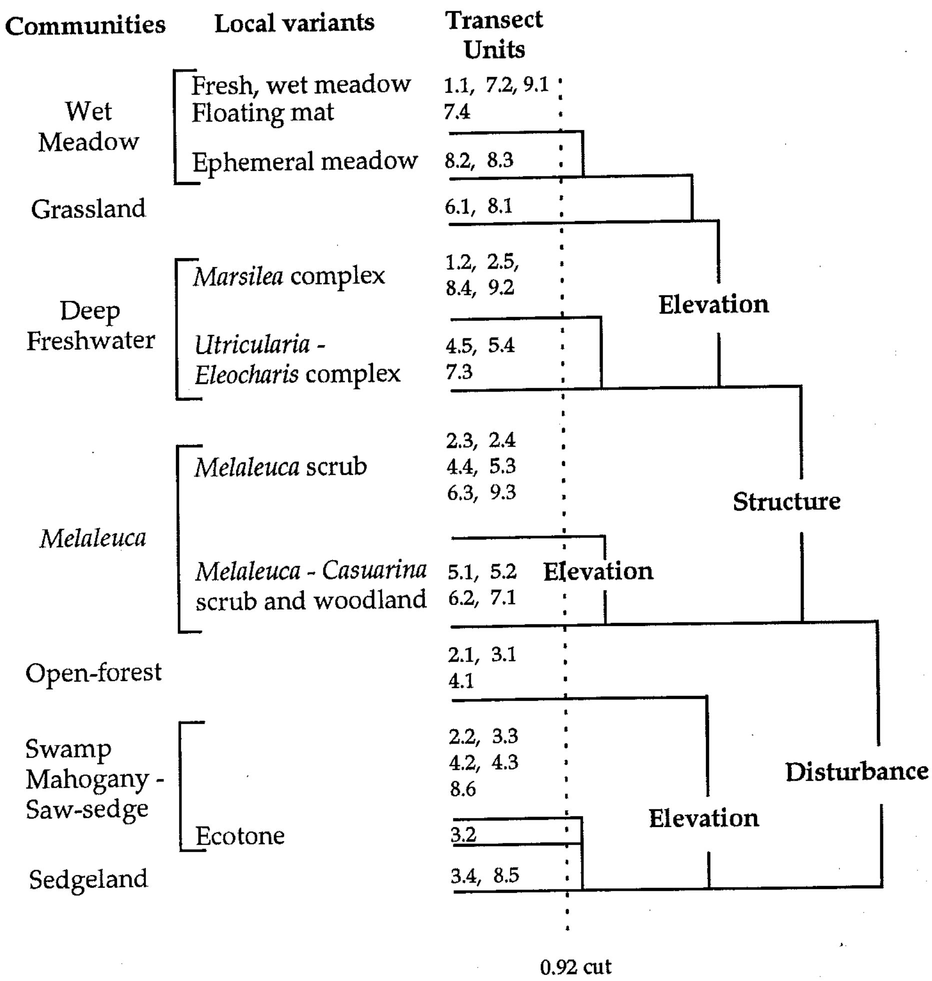

Fig. 3. Dendrogram derived from cluster analysis of all community transect units at Coomonderry Swamp. Correlations with ordination vectors indicated the importance of disturbance, structure and elevation in determining early divisions of the cluster analysis.

Table 2 Pearson correlation coefficients for four vector ordination of community floristics at Coomondery Swamp with elevation, soil and variables indicative of vegetation structure and disturbance.

	Vector 1	Vector 2	Vector 3	Vector 4	Veg. height	Elev.	Introd.	Peren.	Species rich.
Veg. height	0.049	**0.809***	-0.137	0.453					
Elev.	**0.581***	0.260	0.366	0.379	0.291				
Introd.	-0.292	**-0.640***	**0.663***	-0.177	**-0.599***	-0.057			
Peren.	0.249	0.495	**-0.539***	0.395	0.522	0.075	**-0.721***		
Species richness	0.353	0.127	0.448	-0.084	-0.031	0.316	0.025	-0.266	
Soil index	**0.545***	0.284	0.269	**0.610***	0.386	**0.763***	-0.077	0.258	0.185

Critical value: $P = 0.001$. $*P < 0.001$. See text for description of variables. 'n' = 36 community transect units.

Characteristics of communities at Coomonderry Swamp

Five communities at Coomonderry Swamp were found along margins subject to greatest anthropogenic disturbance and consequently high proportions of ruderal species predominated.

Fresh, wet meadow Areas of wet meadow occurred principally on the southern and south-western margins of the wetland where heavier, peaty soils were subject to frequent fluctuations in inundation (de Jong 1997). These areas have been consistently grazed in the past and cattle still enter the wet meadow during periods of greatest draw-down. Wet meadow is one of the more species-rich communities in the wetland, with more than 90 species recorded in proximity to Transect 1 alone (Fig. 1). Wet meadow at Coomonderry Swamp was dominated by species of Cyperaceae, Juncaceae and Poaceae. Key species included *Hydrocotyle peduncularis, Triglochin procerum, Isolepis prolifera, Juncus polyanthemus, Pseudoraphis paradoxa, Paspalum distichum* and *Persicaria decipiens. Cotula coronopifolia* and *Triglochin striatum*, species commonly associated with saline environments, periodically occurred.

Floating mat An unusual community transect unit clustered as wet meadow was a floating mat of vegetation of ≥ 50 cm thickness within a stand of *Melaleuca ericifolia* in water > 1 m depth.

Ephemeral meadow During periods of severe draw-down, extensive blooms of ephemeral and opportunistic species soon covered mud in areas of previously open water. Dominant species along the upper margins, trampled by cattle, included *Cynodon dactylon, Hydrocotyle peduncularis, Axonopus affinus, Paspalum dilatatum* and *Trifolium repens.* At lower elevations *Centipeda minima, Hydrocotyle bonariensis, Myriophyllum simulans* and *Juncus polyanthemus* were common — the latter two species probably present prior to draw-down.

Grassland Grazed areas above much of the western, southern and northern margins of Coomonderry Swamp were predominantly covered with *Pennisetum clandestinum*. Other species were *Axonopus affinus, Trifolium repens, Cynodon dactylon, Hypochaeris radicata* and *Carex appressa*.

***Marsilea* complex** Deep freshwater communities are the flooded counterparts of ephemeral communities. *Marsilea mutica* predominated beyond wet meadow, over the summer months, and in water generally less than 60 cm. Other key components included *Isolepis prolifera, Juncus polyanthemus, Triglochin procerum, Utricularia australis, Eleocharis sphacelata, Myriophyllum simulans, Pseudoraphis paradoxa* and *Paspalum distichum*.

***Utricularia–Eleocharis* complex** Deep water areas of the swamp, not dominated by *Melaleuca* spp. or *Baumea articulata* (but often occurring with these), principally supported *Utricularia* spp. interspersed with tall clumps of *Eleocharis sphacelata* and *Typha orientalis*. Other floating species included *Nymphaea* spp., *Potomogeton* spp., and *Persicaria* spp.

The aforementioned communities illustrate the dynamics often associated with systems subjected to frequent disturbance. Sedgelands however, and the undisturbed, wooded, eastern margin have remained robust in the face of these short term environmental and seasonal fluctuations (de Jong 1997). Cluster analysis delineated five resilient communities.

***Melaleuca* scrub** *Melaleuca ericifolia* is perhaps the most pervasive species in this wetland, occurring as thickets throughout the sedgland and almost continuously along the 5 km length of the undisturbed margin. Remnant pockets on the western margin suggest extensive clearing. Co-occurring species varied depending on water depth and disturbance within each *Melaleuca* community. *Azolla filiculoides, Spirodela punctata* and *Persicaria praetermissa* were common understory species in standing water.

***Melaleuca–Casuarina* scrub and woodland** *Casuarina glauca* was a dominant or co-dominant woody species, often occurring above stands of *Melaleuca ericifolia* along the elevation gradient. *Carex appressa, Gahnia sieberiana, Entolasia marginata* and *Viola hederacea* were common understory species of grazed, dryer ground at the northern end of the wetland. *Isolepis inundata, Isolepis prolifera, Eleocharis acuta* and *Persicaria praetermissa* were common members of *Melaleuca–Casuarina* communities at slightly lower elevations. *Melaleuca linariifolia* was a secondary wooded component of some *Melaleuca* and *Melaleuca–Casuarina* communities.

Sedgeland The extensive central body of Coomonderry Swamp is covered by sedge, principally *Baumea articulata*, but also *Baumea arthrophylla*. Within this continuous 2 m tall stratum, *Villarsia reniformis* was found with some of the typically open water species previously described. Isolated stands of *Typha orientalis, Phragmites australis* and *Eleocharis sphacelata* were scattered throughout the sedgeland. *Baumea juncea* with *Villarsia exaltata* became increasingly common with more shallow inundation or on moist soil.

Swamp Mahogany–Saw-sedge The transition between sedgeland and forest is typified by open *Eucalyptus robusta* (Swamp Mahogany) woodland with isolated *Casuarina glauca* and *Melaleuca* spp., an often very open shrub/sedge stratum of *Gahnia sieberiana* (Saw-sedge), *Leptospermum juniperinum* and *Baumea* spp., and a dense grass/herb substratum dominated by *Hemarthria uncinata, Villarsia exaltata, Lobelia alata* and *Goodenia paniculata.*

Open-forest *Eucalyptus pilularis* open-forest, on sandier soils to the north, and *Eucalyptus botryoides* open-forest on more humic soils to the south, were clustered together in this analysis on the basis of a strong similarity in understory components. Open-forest is a relatively species-rich community at Coomonderry Swamp. The usually dense small tree and shrub strata were composed of a broad range of species including *Glochidion ferdinandi, Elaeocarpus reticulatus, Banksia serrata, Banksia integrifolia, Breynia oblongifolia, Myoporum* spp., *Acacia* spp. and *Monotoca elliptica.* Understorey species included *Gahnia sieberiana, Entolasia* spp., *Oplismenus aemulus, Dianella caerulea, Pteridium esculentum* and *Lomandra longifolia.* Pockets of rainforest occurred throughout the open-forest and several species of vines (e.g. *Parsonia straminea, Smilax glyciphylla, Marsdenia rostrata* and *Cissus hypoglauca*) were a strong constituent of both the rainforest and open-forest vegetation.

Comparisons with other wetlands

In addition to the 36 community transect units from Coomonderry Swamp, TWINSPAN analysis identified a further 46 from transects at other sites. Cluster analysis, based on the total 82 units × species (% frequency occurrence in quadrats) matrix, defined some communities and several local variants not encountered at Coomonderry Swamp (Fig. 4). These included dry meadow, saltmarsh, mangrove and deep estuarine communities. Swamp Mahogany–saw-sedge, sedgeland and wet meadow communities of the type found at Coomonderry Swamp did not occur, or were poorly represented at these other sites.

HMDS ordination in four vectors was selected as best for differentiating floristics over the broad range of wetland sites (Table 3), although some variables themselves were strongly correlated and were thus poorly separated in the ordination. The factors correlated significantly were: salinity and introduced taxa (vector 1), vegetation height, species richness and pH (vector 2), disturbance (i.e. introduced taxa and the proportion of perennial species — vector 3) and a range of components related to the elevation gradient (elevation, vegetation height, soil and salinity — vector 4). Correlations should be treated with additional caution as the stress value in four dimensions was high (0.1843). However five vector ordination did not improve differentiation of variables although stress was reduced by 17% to 0.1533.

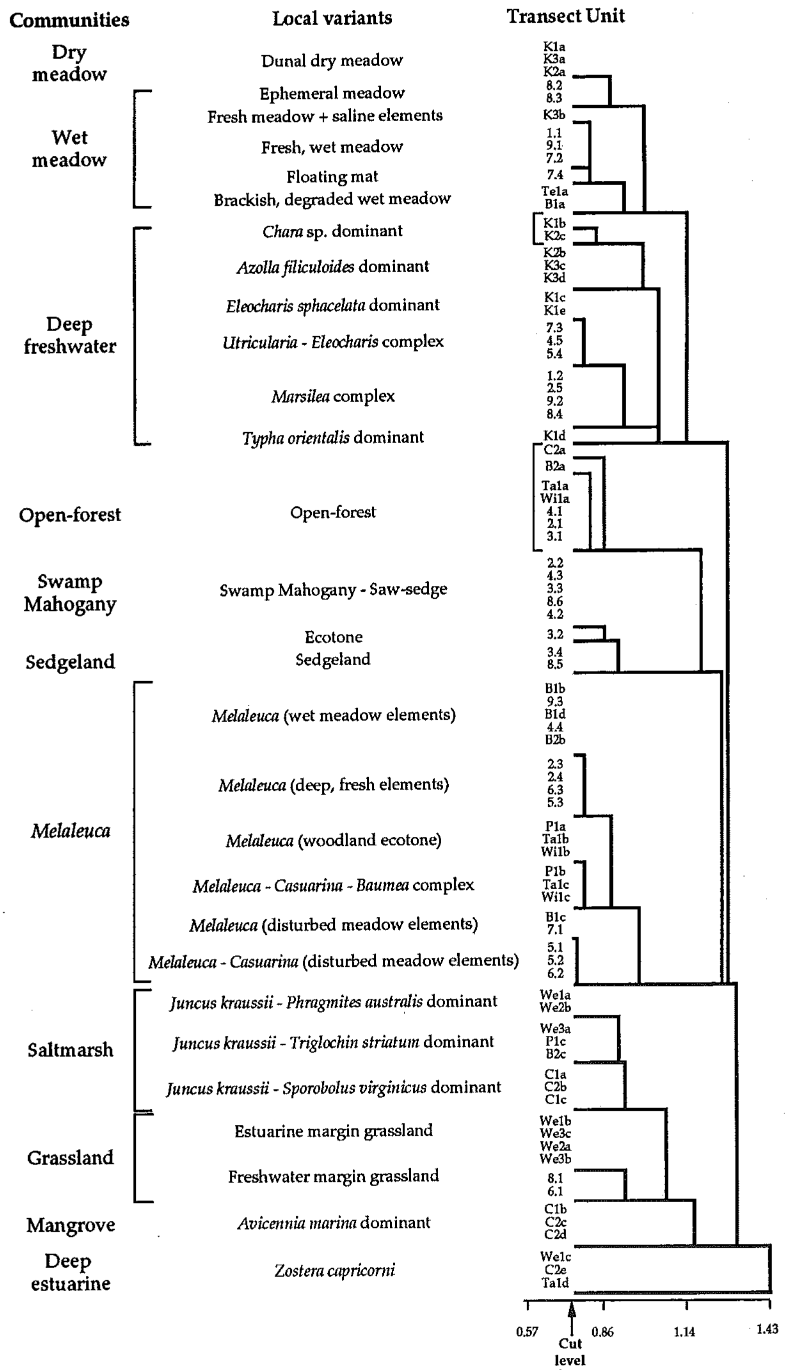

Fig. 4. Dendrogram derived from cluster analysis of all community transect units encountered at nine South Coast wetlands. Association values are shown along the bottom. Community names for Coomonderry Swamp are abbreviated as shown in Fig. 2. Abbreviations for other wetlands are initials: **K**illalea, **Te**rrara, **B**rundee, **C**rooked, **Ta**bourie, **Wi**llinga, **P**attimores and **We**rri; followed by transect number and section of transect ('a' uppermost) i.e. We3c is the 3rd community down the elevation gradient along Transect 3 at Werri Lagoon.

Table 3 Pearson correlation coefficients for four vector ordination of community floristics at nine South Coast wetlands with variables indicative of vegetation structure, disturbance and soil-water characteristics.

	Vector 1	Vector 2	Vector 3	Vector 4	Veg ht.	Elev.	Introd.	Peren.	Spec. rich.	Soil index	pH
Veg. ht.	0.006	**-0.494***	-0.348	**-0.494***							
Elev.	0.130	-0.109	-0.089	**-0.391***	0.276						
Introd.	**0.363***	0.203	**0.701***	0.218	**-0.401***	0.115					
Peren.	-0.015	-0.236	**-0.545***	-0.249	**0.530***	-0.049	**-0.601***				
Spec. rich.	0.163	**-0.367***	-0.006	-0.142	0.156	**0.494***	0.103	-0.168			
Soil index	-0.087	-0.109	-0.125	**-0.441***	0.306	**0.638***	0.038	0.126	**0.415***		
pH	-0.388	**0.549***	0.120	-0.438	-0.296	-0.279	-0.246	-0.182	-0.314	-0.066	
Sal.	**-0.522***	0.456	0.210	**-0.585***	-0.180	-0.146	-0.294	-0.159	-0.321	-0.229	**0.842***

Critical value: $P = 0.001$. *$P < 0.001$. See text for description of variables. 'n' = 82 community transect units except for salinity and pH where 'n' = 49.

Characteristics of communities at other wetlands

The floristics and structure of plant communities could be related to the particular sets of conditions operating in each wetland surveyed (Tables 4 & 5). In the following descriptions relationships between other wetlands surveyed, and communities and key species of Coomonderry Swamp are emphasised.

Wet meadow communities Ephemeral and wet meadow communities at Coomonderry Swamp were clustered with the brackish wet meadow communities of Brundee, Terrara and Killalea swamps. All these communities were similar in structure, disturbance regime and species richness, and shared a large common pool of short-lived, herbaceous species and Cyperaceae. However the abundance of *Bacopa monniera, Aster subulatus, Hydrocotyle bonariensis and Crassula peduncularis* at Killalea wetland indicated the distinctive saline and dunal influence at this site, while the importance of *Cotula coronopifolia, Aster subulatus* and *Triglochin striatum* at Brundee and Terrara was indicative of the brackish inundations experienced by these two wetlands.

Deep, freshwater communities Killalea Swamp was the only other freshwater wetland surveyed and many significant components of Coomonderry Swamp were also found to be important here. These included, *Eleocharis sphacelata, Baumea articulata, Schoenoplectus validus, Typha orientalis, Ludwigia peploides, Azolla filiculoides, Spirodela punctata* and *Myriophyllum simulans*. Notable absences were *Marsilea mutica* and *Melaleuca* spp., while *Chara* sp. was the dominant open water plant.

Table 4 Characteristics of plant communities

Community	Soils	Occurrence at sites	Structure	Main species
Dry meadow	Sand. Organic content increasing at wetland margin.	Degraded sand dunes adjacent to the eastern margin of Killalea Swamp.	Herb-field. Grassland.	*Hydrocotyle bonariensis* *Cynodon dactylon* *Pennisetum clandestinum* *Isolepis nodosa*
Wet meadow	Peat.	Periodically submerged, unwooded margins of Killalea Swamp and Coomonderry Swamp. Terrara Swamp and Brundee Swamp flats.	Herb-field.	*Isolepis prolifera* *Juncus polyanthemus* *Persicaria decipiens* *Juncus prismatocarpus* *Paspalum distichum* *Senecio madagascariensis*
Deep freshwater	Peat.	Killalea Swamp, Coomonderry Swamp.	Submerged, floating and emergent species of open water in sedgeland, rushland and reedland.	*Eleocharis sphacelata* *Azolla filiculoides* *Marsilea mutica* *Typha orientalis* *Utricularia australis* *Baumea articulata* *Ludwigia peploides* *Chara* sp.
Open-forest	Sandy soils with increasing humic content approaching wetland margin. Lateritic at Brundee.	Higher, dry ground above Crooked, Coomonderry, Brundee, Pattimores, Tabourie and Willinga wetlands.	Open-forest with upper, mid (shrub) and low (herb) layers. Closed-forest (rainforest) in patches at Coomonderry Swamp.	*Eucalyptus botryoides* *Eucalyptus pilularis* *Acacia longifolia* *Breynia oblongifolia* *Pterideum esculentum* *Entolasia* spp. *Lomandra longifolia* *Hibbertia scandens* *Kennedia rubicunda* *Imperata cylindrica*
Swamp mahogany –saw-sedge	Humic to peaty soils.	Eastern margin of Coomonderry Swamp - rarely inundated.	Open-woodland.	*Eucalyptus robusta* *Casuarina glauca* *Gahnia sieberiana* *Hemarthria uncinata* *Villarsia exaltata* *Leptospermum juniperinum*
Sedgeland	Peat.	Central body of Coomonderry Swamp.	Open sedgeland, sedgeland and reedland.	*Baumea articulata* *Baumea arthrophylla* *Villarsia reniformis* *Villarsia exaltata*
Melaleuca	Humic to peaty soils.	Coomonderry and Brundee Swamps. Upper tidal to dry margins of Pattimores, Tabourie and Willinga wetlands.	Scrub and woodland with herb understory.	*Melaleuca ericifolia* *Casuarina glauca* *Baumea juncea* *Persicaria praetermissa* *Viola hederacea* *Entolasia stricta*

Table 4 Continued

Saltmarsh	Saline, organic, sandy or silty loams.	Tidal margins of Werri Lagoon, Crooked River and Pattimores Lagoon. Brundee Swamp flats.	Reedland, open-herb-field and open-grassland.	*Juncus kraussii* *Phragmites australis* *Sporobolus virginicus* *Triglochin striatum*
Grassland	Humic, silty or sandy loams.	Grazed margins at Werri Lagoon and Coomonderry Swamp.	Grassland.	*Pennisetum clandestinum* *Stenotaphrum secundatum* *Casuarina glauca*
Mangrove	Saline, organic loams.	Tidal areas of Crooked River.	Low, open scrub, open herb-field.	*Avicennia marina* *Sarcocornia quinqueflora*
Deep estuarine	Saline, organic loams.	Werri, Crooked and Tabourie estuaries.	Attached, floating species.	*Zostera capricorni*

The various attributes distinguishing communities are shown in Table 5. Main species are ranked in a general order of importance in terms of distribution and abundance on transects within communities.

Grassland Areas of grazed paddock adjoined some parts of Killalea, Crooked River, Brundee and Terrara wetlands, but were only included in transect surveys at Werri Lagoon. At this site the dominant grass species was Kikuyu (*Pennisetum clandestinum*) although *Stenotaphrum secundatum* was also prevalent. Saline elements were interspersed throughout the grassland, particularly in the wettest areas. These included *Juncus kraussii, Leptinella longipes, Tetragonia tetragonoides* and remnant *Casuarina glauca*.

***Melaleuca* communities** *Melaleuca* scrub at the brackish wetland, Brundee, was similar to that described at Coomonderry Swamp. At both sites, this species continued into standing water forming a dense stratum often taller than 3 m. At Brundee *Melaleuca styphelioides* is a co-dominant woody species in addition to *Casuarina glauca*. Only a few *Melaleuca styphelioides* trees occur at Coomonderry Swamp. Understory species in wetter stands at Brundee were also similar to those found at Coomonderry Swamp despite salinities ranging up to 6 ppt. On drier margins there were numerous affinities with the open-forest vegetation of Coomonderry Swamp, even though parent soils here are lateritic.

Melaleuca ericifolia was the dominant transition species of all relatively undisturbed estuarine wetlands surveyed. As at Brundee, this species remained a significant component on humic soils, perhaps further into woodland than encountered at Coomonderry Swamp. *Melaleuca ericifolia* communities adjoining estuaries did not progress beyond the deeper water margins suggesting an intolerance to continuous saline inundation. The estuarine *Melaleuca ericifolia* communities surveyed formed a

Table 5. Attributes of communities encountered at nine coastal wetlands in southern NSW.

	Dry meadow	Wet meadow	Deep fresh	Open-forest	Swamp mahogany	Sedge	*Melaleuca*	Salt-marsh	Grassland	Mangrove	Deep estuary	*P*
Veg. height	1.18 (0.18) a	1.21 (0.11) a	1.48 (0.10) a	2.44 (0.21) c	2.28 (0.14) bc	1.57 (0.11) ab	2.32 (0.10) c	1.49 (0.13) a	1.61 (0.32) a	1.36 (0.28) a	1.00 (0.00) a	*
Elevation	126 (73) d	7 (4) bc	-47 (11) a	195 (60) d	31 (13) bc	-6 (6) abc	2 (7) bc	-11 (7) abc	41 (16) c	-47 (2) ab	-76 (30) a	*
Proportion introd. taxa	0.40 (0.03) c	0.37 (0.04) c	0.11 (0.04 ab	0.02 (0.02) a	0.01 (0.01) a	0.00 (0.00) ab	0.09 (0.02) ab	0.16 (0.06) b	0.65 (0.10) d	0.00 (0.00) ab	0.00 (0.00) ab	*
Proportion perenn. taxa	0.12 (0.03) ab	0.14 (0.03) ab	0.39 (0.08) c	0.43 (0.02) c	0.48 (0.04) c	0.54 (0.04) c	0.41 (0.05) c	0.28 (0.04) bc	0.12 (0.04) ab	0.31 (0.03) ac	0.00 (0.00) a	*
Species richness	9.5 (1.0) bcd	13.6 (1.6) ab	5.1 (0.8) cf	15.1 (1.4) a	9.2 (1.2) d	5.3 (0.7) cdf	8.3 (1.0) d	5.6 (0.8) cdf	6.8 (1.5) cde	2.6 (0.1) ef	1.0 (0.0) f	*
Soil index	3.0 (0.6) a	1.3 (0.2) cd	1.0 (0.0) d	3.3 (0.3) a	2.0 (0.0) b	1.0 (0.0) d	1.7 (0.1) bc	1.4 (0.2) cd	2.0 (0.0) b	1.0 (0.0) d	1.0 (0.0) d	*
pH	-	5.9 (0.1) a	6.0 (0.1) a	-	-	5.9 (0.1) a	5.9 (0.2) a	6.6 (0.2) b	-	7.0 (0.0) b	7.0 (0.0) b	*
Salinity	-	0.7 (0.6) ab	0.1 (0.0) a	-	-	0.0 (0.0) ab	7.6 (4.0) b	19.2 (4.1) c	-	31.2 (0.8) c	28.3 (8.0) c	*
n	3	9 (5)	15	7	6	2	20 (13)	8	6	3	3	

Data are means, with standard errors in parentheses, for 'n' replicates of community transect units clustered together within each community (Fig. 4). Salinity and pH calculated for inundated community transect units only ('n' in parentheses). Means in each row designated 'a - f' (Fisher PLSD - ANOVA) are not significantly different at $P=0.05$. Level of significance is * $P \leq 0.0001$. Elevations are in centimetres and salinities are in ppt. Other variables are described in the text.

dense 2 m high closed canopy. On drier, sandier soils *Melaleuca ericifolia* commonly occurred with *Eucalyptus botryoides, Acacia longifolia* and *Entolasia stricta.* On wetter, more humic soils *Leptospermum juniperinum, Leptospermum polygalifolium, Centella asiatica, Casuarina glauca, Baumea juncea, Cassytha pubescens, Selaginella uliginosa* and *Hemarthria uncinata* were important components. On peaty, wet soils *Baumea juncea, Phragmites australis, Juncus kraussii* and *Samolus repens* became increasingly more prevalent. Species richness decreased down the elevation gradient within these communities.

Open-forest communities *Eucalyptus botryoides* was the dominant canopy species on sandy soils at Lake Tabourie, Lake Willinga, Pattimores Lagoon and Crooked River. On lateritic soils at Brundee *Eucalyptus pilularis* was the dominant tall woody species. Mid-story and under-story strata were very similar in all these communities, although a number of species at Brundee—*Acacia falcata, Daviesia ulicifolia, Hibbertia diffusa* and *Eucalyptus ?imitans*—were not found elsewhere.

Dunal, dry meadow communities Disturbed, dryer communities adjacent to the eastern margins of Killalea wetland, supported a number of taxa commonly found on sand dunes. The dominant species found were *Hydrocotyle bonariensis, Cynodon dactylon, Pennisetum clandestinum, Isolepis nodosa, Zoysia macrantha* and *Spinifex sericeus.* Some typical wet meadow species from quadrats on the waterline were also clustered in these communities.

Saltmarsh communities There was considerable heterogeneity in saltmarsh within and between sites surveyed. *Juncus kraussii, Triglochin striatum* and *Phragmites australis,* were characteristic of grazed saltmarsh at Werri Lagoon and Brundee. *Sporobolus virginicus, Juncus kraussii* and *Phragmites australis* were important components of less disturbed margins. Quadrats containing saltmarsh species were classified with *Melaleuca ericifolia* where the latter made a sharp boundary with open water, while at other sites, saltmarsh formed an understory component of mangrove communities. Open saltmarsh flats at Crooked River were variously dominated by *Suaeda australis, Juncus kraussii* and *Sporobolus virginicus,* usually in shallower water, and *Sarcocornia quinqueflora* with *Avicennia marina* in deeper water.

Mangrove–saltmarsh communities *Avicennia marina* was only encountered at Crooked River where it occurred with *Sarcocornia quinqueflora, Suaeda australis* and *Sporobolus virginicus.*

Deep estuarine communities Transects at lagoonal sites were terminated in deep water where *Zostera capricorni* predominated.

Discussion

Plant communities at Coomonderry Swamp

A significant ecological feature of Coomonderry Swamp is its diversity of plant communities and the associated diversity of habitat available to avifauna (Blachford & Reeks 1976; Lawler & Porter 1990). Under Goodrick's (1970) general classification, six out of nine categories of freshwater wetland are represented at Coomonderry Swamp. Three of these — fresh meadow, seasonal fresh swamp and open fresh water — have been considered to be of high value to birds (Blachford & Reeks 1976). The extent and state of preservation of the sedgeland–swamp mahogany–woodland–dunal transition is of great value since similar stands are poorly represented south of Sydney. Floating mats are an unusual occurrence (but see Hill & Webb 1982; Mitch & Gosselink 1993).

Coomonderry Swamp is a geographically isolated example of a freshwater, dunal wetland and consequently it has major importance as a refuge for some plant species such as *Eucalyptus robusta, Villarsia reniformis, Lilaeopsis polyantha,* regionally uncommon members of the Juncaceae, and uncommon ephemerals such as *Cyperus odoratus* (Appendix 1).

While most plant communities (Fig. 3) defined in this analysis have remained structurally consistent over time (i.e. 50 years–aerial photographs, see de Jong 1997), wet meadow, ephemeral and open water complexes were highly dynamic. However, ephemeral and open water communities reoccurred in a consistent cyclic pattern while temporal monitoring over 3.5 years suggested that a finer resolution of wet meadow was not warranted (de Jong 1997).

The diversity of plant communities at Coomonderry Swamp appeared to be the consequence of a complex interaction of factors. Rates of change in the inundation regime, changes in soil characteristics and water status along the elevation gradient, and levels of anthropogenic disturbance varied between different margins of the wetland. In general terms, a toposequence: grassland–wet meadow–open water–sedgeland could be recognized on much of the northern, western and southern farmed margins. A 'hybrid' toposequence: grassland–(rarely Swamp Mahogany)–*Melaleuca* or *Melaleuca/Casuarina*–open water–sedgeland was found where grazed land abutted steeper margins. The toposequence: open-forest (sometimes littoral rainforest)–Swamp Mahogany woodland–*Melaleuca*–sedgeland was developed on the eastern undisturbed fringe.

Comparison of Coomonderry Swamp with wetlands of the Jervis Bay region

Wetlands associated with Jervis Bay were purposely omitted from the present study because of time constraints and because they had received more attention than other South Coast wetlands (Adam & Hutchings 1987; Clarke 1993; Clarke et al. 1995; Mills 1995). Mills (1995) provided a comprehensive overview of the natural vegetation of the Jervis Bay area in which he described a number of communities closely affiliated with those found at Coomonderry Swamp. Floristically and structurally, both *Eucalyptus botryoides* and *Eucalyptus pilularis* open-forest communities at Jervis Bay are similar to those found at Coomonderry Swamp. Mills (1995) commented on the usually distinct boundary between the two, and this is also a feature of their occurrence on sand above Coomonderry Swamp. At Jervis Bay littoral rainforest sometimes forms part of this coastal lowland complex. Equivalents of several other coastal communities described by Mills (1995) are found within Seven Mile Beach National Park, immediately east of Coomonderry Swamp, but were not described in the present study.

Casuarina glauca and *Melaleuca ericifolia* communities at Jervis Bay are most often associated with estuarine margins (Mills 1995). Many components of the *Melaleuca ericifolia* substrata are similar to those found at Coomonderry Swamp e.g. *Hemarthria uncinata* and *Entolasia stricta.* However *Casuarina glauca* communities at Jervis Bay indicate the saline influence, with species such as *Samolus repens, Juncus krausii* and *Apium prostratum* (Mills 1995). Sedgelands at Jervis Bay occur in depressions on sandstone soils (Mills 1995). These communities are floristically different to sedgeland at Coomonderry Swamp and are considered by Mills (1995) to resemble those described for upland swamps. *Eucalyptus robusta* forest–woodland is associated with floodplains and fresh swamps at Jervis Bay (Mills 1995) and is similar to the freshwater–open-forest transition at Coomonderry Swamp, though much less extensive (Braithwaite et al. 1995).

Comparison of Coomonderry Swamp with tableland and upland swamps

The toposequence described for the undisturbed margin of Coomonderry Swamp structurally equates, to some degree, with the *Eucalyptus* woodland–*Banksia* thicket–Restioid/Cyperoid heath–tea-tree toposequences described by Keith & Myerscough (1993) and noted by Stricker & Wall (1995) for upland swamps on tablelands south of Sydney, NSW. This is particularly so where *Melaleuca ericifolia* thickets are found interpersed in deeper areas of sedgeland at Coomonderry Swamp analogous to tea-tree thickets occupying the most waterlogged parts of upland swamps. Keith & Myerscough (1993) in their report also recognized general structural similarities with a related toposequence described by Myerscough and Carolin (1986) for coastal dune fields 200 km north of Sydney. Keith & Myerscough (1993) noted other floristic analogs, all related to a gradient in soil moisture, organic matter and nutrients, for a diversity of temperate heathlands along the eastern coast of Australia.

Despite these structural similarities, floristic composition and species richness at Coomonderry Swamp contrasted greatly with upland swamps. All communities surveyed for this report were much less species rich, and the only affinities in floristics occurred where undisturbed *Melaleuca* communities at Coomonderry Swamp shared some dominants (e.g. *Leptospermum juniperinum* and *Gahnia sieberiana*) with *Melaleuca* thickets of upland swamps. Upland swamps of the Boyd Plateau, Central Tablelands (Kodela et al. 1996) are even more floristically distinct.

Greater similarities in species composition were found between Coomonderry Swamp and some freshwater lagoons and reed swamps of 'the coastal division' described by Stricker & Wall (1995) and Ryan et al. (1996), although wetlands described by these workers are located further from the coast (>50 km), at intermediate elevations (100–500 m above sea level), and at least 100 km north of Coomonderry Swamp.

Comparison of Coomonderry Swamp with coastal wetlands of the Sydney region and central coast of NSW

As previously indicated, freshwater dunal wetlands such as Coomonderry Swamp are more commonly found north of Sydney. Structural and floral characteristics of the dune–woodland–fringe forest–swamp transition at Coomonderry Swamp and of the

Eurunderee system (Myerscough & Carolin 1986) are very similar. Dry sclerophyll forest communities described by Myerscough & Carolin (1986) have most dominant components in common with the *Eucalyptus pilularis* open-forest of drier, sandy ground above Coomonderry Swamp (Table 4), although species associated with heath ecotones at Eurunderee are not found at Coomonderry Swamp. Many dry sclerophyll members described by Myerscough & Carolin (1986) were also noted in the substrata of *Eucalyptus botryoides* open-forest at Coomonderry Swamp. Here also, a number of species listed by Myerscough & Carolin (1986) for vine thicket, headland thicket and rainforest occurred, particularly on more humic soils, and where littoral rainforest is developed within the woodland (see Mills & Jakeman 1995). Although not surveyed for this report, foredune and hinddune communities from both localities had much in common (de Jong pers. obs.)

More significant differences were apparent when communities of the swamp and immediate margins were compared. *Lepironia articulata* and *Melaleuca quinquenervia,* two species not naturally occurring on the south coast of NSW, dictate much of the structure of freshwater wetlands further north. *Melaleuca quinquenervia* within swamp forest of the Eurunderee sand mass appeared to provide a more dense tree stratum than was found in equivalent communities at Coomonderry Swamp. Myerscough & Carolin (1986) did not observe any differentiation of *Eucalyptus robusta* and *Melaleuca quinquenervia* on the basis of water depth. At Coomonderry Swamp *Melaleuca ericifolia* (and *Melaleuca linariifolia* where it occurs) often formed dense thickets in standing water while *Eucalyptus robusta* was generally restricted to the (fluctuating) water margin where fewer *Melaleuca* plants were located. Species common to Swamp Mahogany woodland at both sites included: *Leptospermum juniperinum, Baumea arthrophylla, Baumea articulata, Baumea juncea, Baumea rubiginosa, Gahnia sieberiana, Schoenus brevifolius, Villarsia exaltata and Callistemon citrinus.* Formation of hummocks by organic accumulation, with consequent ecotonal development to *Gahnia sieberiana,* was noted by Myerscough & Carolin (1986) and was also typical of undisturbed margins at Coomonderry Swamp (Fig. 2).

'Fringe forest' of the lake margins of the Eurunderee sand mass equated to some degree with *Casuarina–Melaleuca* woodland both at Coomonderry Swamp and at other south coast sites surveyed. Understory species in both regions were related to water depth, substrate and salinity. In this case also the dominant, *Melaleuca quinquenervia,* is replaced by *Melaleuca ericifolia* on the south coast of NSW.

The community termed 'swamp' by Myerscough & Carolin (1986) is structurally equivalent to sedgeland and open water communities at Coomonderry Swamp, but species composition differed substantially between the two locations. Only scattered *Melaleuca quinquenervia* and *Banksia robur* trees occurred in swamp at Eurunderree, whereas at Coomonderry, *Melaleuca ericifolia* formed large thickets within the sedgeland. However *Eucalyptus robusta* did not occur within the swamp proper at either location.

Dry sclerophyll communities often associated with coastal freshwater wetlands, such as *Eucalyptus botryoides* and *Eucalyptus pilularis* open-forest, are reasonably well represented in the Sydney region (defined by the Sydney 1:100 000 map sheet — see

Benson & Howell 1994). However, in the Sydney area, sedgelands (*Eleocharis–Typha* dominated) and wet meadow communities are poorly represented, while only remants of undisturbed freshwater wetlands (*Baumea* dominated) and swamp forest remain (Benson & Howell 1994). Where they are found, these communities closely resemble equivalent communities described in this report, but often contain greater numbers of introduced taxa (Benson & Howell 1994).

Comparison of Coomonderry Swamp with other wetlands surveyed

Ordination of transect data from a diverse range of other south coast region wetlands produced only one further variable correlated strongly with change in floristics, this being salinity. It is thus not surprising that both fresh wetland communities and estuarine communities (particularly *Melaleuca* and *Melaleuca/Casuarina* communities), above the influence of continuous inundation, are often similar.

Wet meadow, estuarine pastures and salt marsh Minor differences in wet meadow related to brackish incursions at Brundee Swamp and Terrara Swamp, and to disturbed dunal influences at Killalea. Adam et al. (1988) have attributed a decline in *Selliera radicans*, particularly in the Sydney region, to invasion by *Hydrocotyle bonariensis*. *Hydrocotyle bonariensis* is a dominant component in dry dunal and wet meadow communities at Killalea wetland where *Selliera radicans* is absent. The latter species is found at many nearby wetlands e.g. Lake Illawarra (Yassini & Clarke 1985) and Werri Lagoon and was plentiful in brackish meadow and saltmarsh at Brundee Swamp and in saltmarsh margins of estuaries surveyed further south where *Hydrocotyle bonariensis* was not encountered (Appendix 1) .

Triglochin striatum and *Cotula coronopifolia* occurred only sporadically in fresh, wet meadow at Coomonderry Swamp, but were prevalent in saline and brackish environments surveyed. These observations support the argument of Adam et al. (1985) that limiting effects in wetlands more often relate to competition among species rather than an inability to tolerate particular conditions of inundation or salinity. Zedler et al. (1995) have suggested that *Triglochin striatum* may have a competitive advantage in areas of saltmarsh where trampling by cattle provides waterlogged recesses. Numbers of this species observed in areas at Brundee Swamp (brackish) and Werri Lagoon (saline) subject to trampling by cattle support this contention.

Both *Triglochin striatum* and *Cotula coronopifolia* are facultative halophytes while other species (e.g. *Lilaeopsis polyantha* and *Villarsia reniformis*) might be considered to be facultative glycophytes (in the sense that they tolerate salinity, but appear to be more competitively limited at saline sites than at freshwater sites). A robust form (phyllodes > 30 cm) of *Lilaeopsis polyantha* was intermittently prevalent in wet meadow at Coomonderry Swamp and this uncommon species has also been recorded at Wingecarribee Swamp in the adjacent highlands (Kodela & Hope 1992) but also, in contrast, at the tidal margins of Werri Lagoon. Coomonderry Swamp supports perhaps the largest population of the uncommon running marsh flower, *Villarsia reniformis*, yet this species was also recorded in smaller numbers at some estuarine and brackish sites (Appendix 1).

Intensive sampling in a one hectare area at the southern edge of Coomonderry Swamp detected examples of complex hybridization in taller Juncaceae. Both *Juncus polyanthemus* and *Juncus procerus* (as well as the introduced *Juncus cognatus*) were found at this site beyond their previous known ranges. Hybrids between these two species, between *Juncus polyanthemus* and *Juncus usitatus*, and between *Juncus continuus* and *Juncus usitatus* were recorded (L. Johnson Nat. Herb. pers. comm.). Several *Juncus* spp. co-occurred at other sites, and more intensive sampling should elicit further examples of hybridization. For example at Brundee Swamp, *Juncus kraussii, Juncus continuus, Juncus polyanthemus* and *Juncus mollis* co-occurred and Johnson (1993) has previously found hybridization in the latter two species.

Several *Persicaria* spp. are co-dominants in wet meadow at Coomonderry, Brundee and Killalea swamps and an undescribed form of *Persicaria lapathifolia* was recorded for Coomonderry Swamp (P. Kodela Nat. Herb. pers. comm.). Co-occurrence, new forms and the potential for hybridization in this genus have also been noted for wetlands of the Nepean-Hawkesberry system (J. Howell & D. Benson Nat. Herb. pers. comm.) Interactions among co-occurring members of this genus require further examination.

Just as the dynamics of wet meadow precluded finer community divisions, transect analysis at saline sites also supported fewer rather than more divisions within saltmarsh. Cluster analysis of saltmarsh transects produced an erratic grouping of quadrats in response to the mosaic of dominant species encountered. Carne (1989) recorded similar patterns in estuarine vegetation at Minnumurra River (Fig. 1). He related these to 'geomorphology through the landform attributes of microtopography and substrate composition' which had consequential effects on salinity and waterlogging. Carne (1989) did not differentiate between saltmarsh communities in his work. Zedler et al. (1995) also proposed a single saltmarsh community which might be variously dominated by *Sporobolus, Sarcocornia* or *Triglochin*. Clarke (1993) preferred recognition of only five truly saltmarsh complexes (in addition to Mangrove, *Juncus* and associated complexes) even though his study at Jervis Bay (Fig. 1) found 16 'communities' analogous to the 25 'communities' described by Adam et al. (1988). The prevalence of *Juncus kraussii* in assemblages classified as saltmarsh in this report (Fig. 4) suggests that *Juncus kraussii* is often an integral member of saltmarsh communities rather than a dominant member of dryer, peripheral communities.

A relatively species-rich assemblage of estuarine pasture species (community transect unit We3a — Fig. 4), clustered as saltmarsh, has developed under a regime of continuous grazing and an inundation regime manipulated to mitigate local flooding. It supports an interesting mix of species (Appendix 1), including *Bacopa monniera* and *Isolepis platycarpa,* two species well beyond their previous known southern limits.

Undisturbed freshwater margin Woody species associated with the undisturbed eastern margin of Coomonderry Swamp — *Eucalyptus robusta, Melaleuca* spp., *Leptospermum juniperinum, and Casuarina glauca* were also encountered in varying combinations at a number of other wetlands (Appendix 1). However the *Eucalyptus robusta* stand at Coomonderry Swamp was by far the largest and least degraded of any site surveyed. Nor were other sites characterised by a meadow-like understory of *Hemarthria uncinata* and *Villarsia exaltata.*

Open-forest *Eucalyptus* open-forest was the predominant vegetation type on sandier soils above most wetlands surveyed. However the development of littoral rainforest within open-forest seen at Coomonderry Swamp is a rare occurrence (Mills & Jakeman 1995). The only similar stand adjacent to wetland can be found on Comerong Island at the mouth of the Shoalhaven River (Fig. 1), and at Jervis Bay on sand dunes where the water table is high (Mills 1995).

Conservation of Coomonderry Swamp

A part of Coomonderry Swamp is protected within National Park, the wetland is listed as an important wetland (ANCA 1996) and has recently been listed on the register of the National Trust of Australia (NSW) (de Jong & Kodela 1995). However increasing urban and agricultural development could result in an altered hydrological regime and diminished water quality, as well as increases in the incidence of fire, weeds and feral animal invasion. Comprehensive faunal surveys have not been carried out although various unpublished surveys and the report of Lawler and Porter (1991) indicated that Coomonderry Swamp forms, with other wetlands of the Shoalhaven River system, an extremely valuable avian environment and a significant refuge for migratory water birds in times of inland drought. While rigorous faunal assessment is overdue, the present study demonstrates the primary standing of Coomonderry wetland as a reference site for restoration of freshwater wetland plant communities in the southern region of NSW. As such, Coomonderry Swamp requires equivalent protection as its counterpart, Jervis Bay, which is now a recognized reference site for marine and estuarine communities (Clarke 1993).

Acknowledgments

I am indebted to officers of the National Parks and Wildlife Service of NSW, Land & Water Conservation and Shoalhaven City Council for their assistance. Botanical advice was provided by staff at the Janet Cosh Herbarium at the University of Wollongong and the National Herbarium of NSW, Royal Botanic Gardens, Sydney. In this respect, Belinda Pellow, Philip Kodela, Teresa James, Karen Wilson, Lawrie Johnson, Gwen Harden, Jocelyn Howell and Douglas Benson deserve particular mention. Pam Hazelton (Soil Conservation Service) provided initial advice on soils. Ken Russell, Andy Davis and Mick Gregory gave advice on analysis procedures. Thanks are also due to Rob Whelan for his helpful discussion and critical analysis. In this he was assisted by my colleagues, Jack Baker, Simon Bull, Justine Cox, Simon Haemstra, Eleanor Hannah, Gary Leonard and Juliet York from the School of Biological Sciences, University of Wollongong. Joy Zedler, Rob Whelan and Roger Carolin provided incisive comments on a draft of the manuscript. This paper is a contribution of the Australian Flora and Fauna Research Program, University of Wollongong.

References

Adam P. (1981) Saltmarsh plants of New South Wales. *Wetlands (Australia)* 1: 11–19.

Adam P. & Hutchings P. (1987) The saltmarsh and mangroves of Jervis Bay. *Wetlands (Australia)* 6: 58–64.

Adam P., Urwin N., Weiner P. & Sim I. (1985) *Coastal wetlands of New South Wales.* (Coastal Council of NSW; Sydney).

Adam P., Wilson N. C. & Huntley B. (1988) The phytosociology of coastal saltmarsh vegetation in New South Wales. *Wetlands (Australia)* 7: 35–57.

Austin M. P. (1991) Vegetation theory in relation to cost-efficient surveys. In: *Nature conservation; cost effective biological surveys and data analysis* (eds C. R. Margules & M. P. Austin pp. 17–22. (CSIRO: Canberra).

Australian Nature Conservation Agency (ANCA) (1996) *A Directory of Important Wetlands in Australia. Second Edition.* (ANCA: Canberra).

Belbin L. (1987) *PATN: Pattern Analysis Package.* (CSIRO: Canberra).

Bell F. C. & Edwards A. R. (1980) *An environmental inventory of estuaries and coastal lagoons in New South Wales.* (Total Environment Centre: Sydney).

Benson D. & Howell J. (1994) The natural vegetation of the Sydney 1:100 000 map sheet (with vegetation map of Ku-ring-gai National Park). *Cunninghamia* 3(4): 677–787.

Benson D. & McDougall L. (1993–95) Ecology of Sydney plant species (Parts 1-3). *Cunninghamia* 3(2): 257–422; 3(4): 677–787; 4(2): 217–431.

Blachford L. & Reeks N. (1976) *A Cartographic Survey of Wetlands of Coastal New South Wales.* (National Parks Association of NSW: Sydney).

Braithwaite L. W., Austin M. P. & Catling P. C. (1995) Forest and woodland communities. In: *Kowari 5: Jervis Bay. A Place of Cultural, Scientific and Educational Value* (eds G. Cho, A. Georges, R. Stoutjesdijk & R. Longmore pp. 91–98. (ANCA: Canberra).

Carne J. (1989) Relationships between geomorphology and vegetation in the Minnamurra estuary, NSW. *Wetlands (Australia)* 8: 61–68.

Chafer C. J. & Marthick J. (1995) *A Catchment Atlas for the Kiama Municipality.* (Minnamurra Environment Group Inc.).

Clarke P. J. (1993) Mangrove, saltmarsh and peripheral vegetation of Jervis Bay. *Cunninghamia* 3(1): 231–254.

Clarke P. J., Hutchings P. A. & Adam P. (1995) Mangroves and saltmarshes. In: *Kowari 5: Jervis Bay. A Place of Cultural, Scientific and Educational Value* (eds G. Cho, A. Georges, R. Stoutjesdijk & R. Longmore) pp. 133–136. ANCA, Canberra.

de Jong N. H. (1997) *The vegetation ecology of a coastal freshwater wetland.* (PhD thesis: Wollongong University).

de Jong N. H. & Kodela P. G. (1995) *Coomonderry Swamp: statement of significance.* (National Trust of Australia New South Wales, Sydney).

Department of Land and Water Conservation (1995) *Guidelines for the Use of Acid Sulphate Soil Risk Maps.* (Soil Conservation Service of NSW, Department of Land and Water Conservation, Sydney).

Gauch H. G. (1982) *Multivariate analysis in community ecology.* (Cambridge University Press, Cambridge).

Gibson J. D. (1989) *The Birds of the County of Camden, including the Illawarra Region. Second edition.* (Wollongong I.B.O.C.).

Goodrick G. N. (1970) *A survey of wetlands of Coastal New South Wales.* CSIRO Div. Wildl. Res. Tech. Mem. No. 5.

Grime J. P., Hodgson J. G. & Hunt R. (1988) *Comparative Plant Ecology. A functional approach to common British species.* (Unwin Hyman Ltd, London).

Harden G. J. (ed.) (1990–93) *Flora of New South Wales*, Volumes 1–4. (New South Wales University Press, Kensington).

Hazelton P. A. (1992) *Soil Landscapes of the Kiama 1:100 000 Sheet.* (Department of Conservation and Land Management (incorporating the Soil Conservation Service of NSW, Sydney).

Hill M. O. (1979) *TWINSPAN, A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes.* (Cornell University, Ithaca).

Hill R. & Webb G. (1982) Floating grass mats of the Northern Territory floodplains - an endangered habitat? *Wetlands (Australia)* 2: 45–50.

Jacobs S. W. L. & Brock M. A. (1993) Wetlands of Australia. Southern (temperate) Australia. In: *Wetlands of the world I: Inventory, ecology and management* (eds Whigham D. F., Dykyjová D. & Hejn´y S). pp. 244–304. Klewer Acad. Publ., Dordrecht.

Johnson L. A. S. (1993) New species of *Juncus* (Juncaceae) in eastern Australia. *Telopea* 5(2): 309–318.

Keith D. A. & Myerscough P. J. (1993) Floristics and soil relations of upland swamp vegetation near Sydney. *Aust. J. Ecol.* 18: 325–344.

Kodela P. G. & Hope G. S. (1992) *Wingecarribee Swamp: Statement of Significance.* (National Trust of Australia New South Wales, Sydney).

Kodela P. G., James T. A. & Hind P. D. (1996) Vegetation and flora of swamps on the Boyd Plateau, Central Tablelands, New South Wales. *Cunninghamia* 4: 525–530.

Lawler W. & Porter J. (1990) *Nowra District Wetland Survey, Preliminary Report: Birds.* (Internal Report, NPWS, Sydney).

Mills K. (1995) Natural vegetation. In: *Kowari 5: Jervis Bay. A Place of Cultural, Scientific and Educational Value* (eds G. Cho, A. Georges, R. Stoutjesdijk & R. Longmore) pp. 71–81. (ANCA, Canberra).

Mills & Jakeman J. (1995) *Rainforests of the Illawarra District.* (Coachwood Publ., Jamberoo, NSW).

Mitch W. J. & Gosselink J. G. (1993) *Wetlands. Second edition.* (Van Nostrand Reinhold, New York).

Mitchell McCotter & Associates Pty Ltd (1991) *Proposed Rezoning of Coomonderry Swamp: Environmental Assessment.* (Shoalhaven City Council, report No. 91051RPI, Nowra).

Moss J. (1983) *Illawarra Region Wetlands Study.* (Department of Environment and Planning, Sydney). 2nd edition.

Myerscough P. J. & Carolin R. C. (1986) The vegetation of the Eurunderee sand mass, headlands and previous islands in the Myall Lakes area, New South Wales. *Cunninghamia* 1(4): 399–466.

Porter J. (1990) *Impacts on wetlands of the NSW South Coast.* (Total Environment Centre, Sydney).

Pressey R. L. & Harris J. H. (1988) Wetlands of New South Wales. In: *The Conservation of Australian Wetlands* (eds A. J. McComb & P. S. Lake) pp. 35–57. (Surrey Beatty & Sons, Chipping Norton, NSW).

Putman R. J. (1994) *Community Ecology.* (Chapman & Hall, London).

Ryan K., Fisher M. & Schaeper L. (1996) The natural vegetation of the St Albans 1: 100 000 map sheet. *Cunninghamia* 4: 433–482.

Shoalhaven City Council (1995) *Tabourie Lake. Estuary Management Plan.* (Shoalhaven City Council, Nowra).

Specht R. L. (1981) Major vegetation formations in Australia. In: *Ecological Biogeography in Australia* (ed Keast A.) pp. 163–297. (W. Junk, The Hague).

Stricker J. S. & Wall C. A. (1995) *Wetlands of the Nepean - Hawkesbury Catchment.* (Sydney Water Corporation, Sydney).

Timms B. (1982) Coastal dune waterbodies of north-eastern New South Wales. *Aust. J. Mar. Freshwater Res.* 26: 1–13.

Timms B. (1986) The coastal dune lakes of eastern Australia. In: *Limnology in Australia* (eds P. De Deckker & W. D. Williams) pp. 421–432. (Dr. W. Junk, Dordrecht, The Netherlands).

Timms B. (1988) Conservation of central dune freshwater lakes and ponds of Eastern Australia. In: *Proceedings International Symposium on Wetlands* (eds B. Gilligan, M. Maddock & K. McDonald) pp. 399–409. (Shortlands Wetlands Centre, Newcastle).

West R. J., Thorogood C. A., Walford T. R. & Williams R. J. (1985) *An Estuarine Inventory for New South Wales.* (Dept. of Agriculture, Sydney).

Yassini I (1985) Foreshore vegetation of Lake Illawarra. *Wetlands (Australia)* 5: 97–117.

Yassini I. & Clarke A. (1985) *Foreshore Vegetation of Lake Illawarra.* (Lake Illawarra Management Committee, Wollongong).

Young A. R. M., Marthick J. K., Chafer C. J. & Allen T. P. (1996) *Illawarra Wetlands Project.* A report prepared for the Illawarra Catchment Management Committee. (NSW Government Environmental Trusts).

Zedler J. B., Nelson P. & Adam P. (1995) Plant community organization in New South Wales saltmarshes: species mosaics and potential causes. *Wetlands (Australia)* 14: 1–17.

Manuscript accepted 16 April 1997

Appendix 1 **Vascular plant species recorded from nine wetlands (and humic soil margins) on the south coast of NSW.**

*	introduced taxon	•	at, or near (< 20 km), limit of known range (Harden 1990-93)
◊	protected species in NSW (Harden 1990-93)	••	beyond limit of known range (Harden 1990-93)
##	rare or uncommon species in NSW (Harden 1990-93)	Δ	new record for ecogeographic region (Harden 1990-93)
#	regionally rare, uncommon or poorly conserved species (after Benson & McDougall 1993-95)		
?	insufficient material for positive identification at that wetland		
	Bold type denotes abundance: ≥ 10% cover in any quadrat within a representative community		

Nomenclature follows Harden (1990-93) and recent revisions accepted by the National Herbarium of NSW.

Communities (see Fig. 4)

DM:	dry meadow	WM:	wet meadow	DF:	deep freshwater	ME:	*Melaleuca*	SS:	Swamp mahogany - saw-sedge
SE:	sedgeland	OF:	open forest	GL:	grassland	SM:	saltmarsh	MA:	mangrove

Wetlands (see Fig. 1 & Table 1)

K:	Killalea Lagoon	We:	Werri Lagoon	C:	Crooked River	B:	Brundee Swamp	Te:	Terrara Swamp
P:	Pattimores Lagoon	Ta:	Tabourie Lake	Wi:	Willinga Lake	Co:	Coomonderry Swamp		

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
PTERIDOPHYTA										
AZOLLACEAE										
Azolla filiculoides var. *rubra*	K	Co	**Co**K	Co						

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
BLECHNACEAE										
● ◊ *Blechnum indicum*					Co					
B. cartilagineum							Wi			
Doodia asperata							Co			
DENNSTAEDTIACEAE										
Hypolepis muelleri		Co								
Pteridium esculentum				**P** Ta Wi	**Co**		**Co B** P **Ta Wi**			
GLEICHENIACEAE										
Gleichenia dicarpa					Co		Wi			
MARSILEACEAE										
Marsilea mutica		Co	**Co**							
SELAGINELLACEAE										
Selaginella uliginosa				Ta Wi			Ta			
GYMNOSPERMAE										
ZAMIACEAE										
Macrozamia communis							Co			
ANGIOSPERMAE										
- MONOCOTYLEDONS										
ALISMATACEAE										
Alisma plantago-aquatica		Co	Co							
Sagitaria graminea subsp. *platyphylla*	K		Co **K**							

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
ASPARAGACEAE										
**Protasparagus aethiopicus*								We		
ASPHODELACEAE										
*••*Trachyandra divaricata*	**K**									
COMMELINACEAE										
Commelina cyanea				Co			Co	We	We	
CYPERACEAE										
••*Baumea arthrophylla*			**Co**	**Wi**	**Co**	**Co**				
B. articulata			**Co** K	**Co**	**Co**	**Co**				
B. juncea				**P Ta Wi**	Co		Co		**P**	
B. rubiginosa					Co					
Bolboschoenus ?caldwellii		Te B	K							
B. fluviatilis		**Co**	Co							
Carex appressa		Co		Co				**Co**		
C. inversa	**K**									
**Cyperus brevifolius*		**Co**								
•*C. laevis*							Co			
Δ##••*C. odoratus*		Co								
C. polystachyos	**K**	Co **K** B		Co						
C. sanguinolentus		Co								

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
Eleocharis acuta	**K**	**Co** K **Te B**	**Co**	B				**B**		
*•*E. minuta*		Co								
E. sphacelata		**Co**	**Co K**							
•*Fimbristylis velata*		CoK								
Gahnia sieberiana			Co	**Co P**	**Co**		**Co** C			
				Ta Wi			**Ta Wi**			
Isolepis cernua		Co **K**								
I. fluitans		Co B	**Co**	Co	Co	Co				
I. inundata		Co B		**Co Wi**						
I. nodosa	**K**						Ta			
Δ#*I. platycarpa*									**We**	
**I. prolifera*	**K**	**Co B**	**Co**	**Co**						
Lepidosperma laterale							Wi			
Schoenoplectus validus		Co **B** Te	**Co K**							
Schoenus brevifolius				**Ta** Wi	Co		**Ta**			
S. maschalinus		Co			Co					
S. nitens				Wi						
HYDROCHARITACEAE										
Ottelia ovalifolia			Co							
Vallisneria gigantea			K							

Communities	DM	WM	DF	ME	SS	SE	OF	GL	SM	MA
JUNCACEAE										
Juncus continuus		Co		B Wi	Co					
##*J. continuus* X *usitatus*							Co			
**J. cognatus*		Co						Co		
J. kraussii subsp. *australiensis*				**B** P **Ta Wi**			C	**We**	**We C** **B P**	
J. mollis				B					B	
J. planifolius		Co	Co	Wi						
••Δ*J. polyanthemus*		**Co Te B**	**Co**	B ?Wi					B	
J. polyanthemus X *usitatus*		Co								
##*J. polyanthemus* X *procerus*		Co	Co							
J. prismatocarpus		**Co K**	**Co**	**Co**	**Co**					
J. procerus		**Co**	**Co**	Co						
#*J. subsecundus*			Co							
J. usitatus		**Co**						Co		
JUNCAGINACEAE										
Triglochin procerum s. lat.		**Co** B	**Co** K	Co						
T. striatum	K	Co K Te B			Co				**We B P**	
LEMNACEAE										
•*Lemna ?disperma*			Co							
Spirodela punctata	K		Co K	**Co**						

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
LOMANDRACEAE										
Lomandra ?confertifolia subsp. *rubiginosa*							Wi			
L. longifolia				Wi			**Co** C**B** **Ta Wi**			
?Lomandra sp.							**C**			
LUZURIAGACEAE										
Eustrephus latifolius							Co Ta			
Geitonoplesium cymosum							Co C			
ORCHIDACEAE										
Acianthus ?fornicatus							Co			
Caladenia carnea var. *carnea*							Co			
Cryptostylis subulata					Co					
Dipodium ?punctatum							Co			
Spiranthes sinensis subsp. *australis*		Co		Wi						
PHILYDRACEAE										
Philydrum lanuginosum		Co B	**Co**	Co						
PHORMIACEAE										
Dianella caerulea var. *caerulea*					**Co**		Co Wi			
POACEAE										
Agrostis avenacea var. *avenacea*	**K**	**Co K**							**B**	
**Andropogon virginicus*		Co					Co			
**Axonopus affinus*		Co		Co	Co			Co		

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
**Bromus cartharticus*		Co						We		
Cynodon dactylon	**K**	Co		**Co**				We	We C	
Deyeuxia quadriseta				Ta Wi						
Dichelachne inaequiglumis							Co			
**Digitaria ciliaris*		Co								
**Echinochloa crus-galli*		Co **Te**						We		
Echinopogon caespitosus var. *caespitosus*				Ta			Co C			
Entolasia marginata				Co	**Co**		**Co C Wi**			
E. stricta				**B** Ta **Wi**	**Co**		**Co** C **Ta Wi**			
**Eragrostis mexicana*							Co			
Hemarthria uncinata				Ta **Wi**	**Co**					
**Holcus lanatus*	K	Co								
Imperata cylindrica var. *major*				**B Ta Wi**			**Co** C **B** Ta **Wi**			
**Lolium ?multiflorum* and hybrids		Co								
**L. perenne*	K									
Microlaena stipoides var. *stipoides*							Co			
Oplismenus aemulus				Co P Ta	**Co**		Co			
Panicum simile -		Co					B			
**Paspalum dilatatum*		Co								

Communities	DM	WM	DF	ME	SS	SE	OF	GL	SM	MA
P. distichum		**Co** K **Te B**	**Co**	Co	Co					
*•*P. urvillei*		Co								
P. ?vaginatum	K								**We**	
**Pennisetum clandestinum*	**K**	**Co** Te		**Co**				**Co We**	**We** C	
**Phalaris angusta*		Co								
**P. aquatica*		Co ?K								
Phragmites australis				P **Ta Wi**	**Co**			We	**We** C **B** P	
**Polypogon monspeliensis*		Co							We	
Pseudoraphis paradoxa		**Co**	**Co**	**Co**	Co					
Sacciolepis indica		Co								
**Setaria gracilis*								We		
**S. pumila*								Co		
Spinifex sericeus	**K** Ta									
**Sporobolus indicus* var. *capensis*	K									
S. virginicus var. *virginicus*				**Ta**					**C**	**C**
**Stenotaphrum secundatum*							C	**We**	**We C**	
Themeda australis							Co			
Zoysia macrantha	**K**		**K**							

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
POTAMOGETONACEAE										
Potamogeton ochreatus			Co							
P. tricarinatus			**Co**							
Potamageton sp.				**Co**						
RESTIONACEAE										
◊••*Restio tetraphyllus* subsp. *meiostachyus*				**Wi**			**Co**			
SMILACACEAE										
Smilax glyciphylla					Co		**Co**			
SPARGANIACEAE										
Sparganium subglobosum		Co								
TYPHACEAE										
Typha orientalis	K	Co **K** B	**Co K** Te							
ZOSTERACEAE										
Zostera capricorni: deep estuarine at **We C Ta**										
ANGIOSPERMAE										
– DICOTYLEDONS										
AIZOACEAE										
Tetragonia tetragonoides								**We**	We C B	
AMARANTHACEAE										
Alternanthera denticulata	K	Co K		Co						

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
APIACEAE										
Apium prostratum var. *filiforme*									We	
Centella asiatica		Co		P						
**Hydrocotyle bonariensis*	**K**	Co K	K	Co						
H. peduncularis		**Co**								
##Lilaeopsis polyantha		K							We	
L. polyantha large phyllode form		Co								
APOCYNACEAE										
Parsonia straminea		Co		**Co**	**Co**		**Co**	**We**	C	
ASCLEPIADACEAE										
**Araujia sericiflora*								We		
Marsdenia rostrata							**Co**			
Tylophora barbata							C			
ASPARAGACEAE										
**Protasparagus aethiopicus*								We		
ASPHODELACEAE										
*••*Trachyandra divaricata*	**K**									
ASTERACEAE										
**Aster subulatus*	K	Co **K** **Te B**						We	We **B**	
**Bidens pilosa*								We		

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
**Bidens tripartita*		**Co**								
Centipeda minima var. *minima*		**Co**	Co	**Co**						
**Chrysanthemoides monilifera* subsp. *rotundata*								We		
**Conyza albida*	K	Co		Ta			C			
**Conyza parva*		Co								
**Cotula coronopifolia*	K	Co **B**	**K**	B					**We B**	
Euchiton involucratum		Co								
**Facelis retusa*		Co								
**Hypochaeris glabra*		Co		Wi				**We**	**We**	
**H. radicata*	K	**Co** K Te							We	
Lagenifera gracilis							Co			
#*Leptinella longipes*				Wi				**We**	**We**	
**Onopordum acanthium* subsp. *acanthium*			Co Te					We		
Ozothamnus diosmifolius				P			Co Wi			
Pseudognaphalium luteoalbum		Co K								
**Senecio madagascariensis*	K	Co K Te	Co					We	We	
**Sonchus asper* subsp. *glaucescens*		Co								
**S. oleraceus*		Co **K**	K							
Vernonia cineria var. *cineria*							Ta			
*••*Xanthium occidentale*		Te								

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
AVICENNIACEAE										
Avicennia marina var. *australasica*									C	**C**
BRASSICACEAE										
#*Cardamine paucijuga*		Co								
*##*Lepidium bonariense*								We		
CALLITRICHACEAE										
**Callitriche ?stagnalis*		Co								
CARYOPHYLLACEAE										
**Silene nocturna*	K									
*••*Spergularia marina*									We B	
CASUARINACEAE										
Allocasuarina littoralis							**Co**			
Casuarina glauca	**K**	Co **B**	**Co**	**Co B P** **Ta** Wi	**Co**	Co	C	**We**	**We C**	
CHENOPODIACEAE										
**Atriplex prostrata*									**We** C	
Chenopodium glaucum		K								
Suaeda australis									**C**	**C**
Sarcocornia quinqueflora subsp. *quinqueflora*								We	**We** C **P**	**C**
CLUSIACEAE										
Hypericum gramineum					Co					

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
CONVOLVULACEAE										
Dichondra repens							Co C		C	
#Polymeria calycina					Co					
CRASSULACEAE										
#Crassula peduncularis		**K**								
C. sieberiana	K									
DILLENIACEAE										
Hibbertia diffusa							B			
H. ?obtusifolia							Wi			
#H. scandens	**K**			Co P Ta			**Co C** **Ta** Wi			
DROSERACEAE										
Drosera spatulata				Wi	Co					
ELAEOCARPACEAE										
Elaeocarpus reticulatus					Co		**Co Wi**			
ELATINACEAE										
#Elatine gratioloides		Co		Co	Co					
EPACRIDACEAE										
Leucopogon lanceolatus var. *lanceolatus*							**Co** Wi			
Monotoca elliptica							**Co** Ta			

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
ESCALLONIACEAE										
Polyosma cunninghamii							C			
EUPHORBIACEAE										
Breynia oblongifolia				P			**Co** C Ta Wi			
##*Chamaesyce sparrmanii*	K									
#*Glochidion ferdinandi* var. *ferdinandi*					Co		**Co**			
Poranthera microphylla							Co			
FABACEAE - FABOIDEAE										
Daviesia ulicifolia							**B**			
Desmodium brachypodum							Co			
•*D. rhytidophyllum*							Co			
D. varians				Ta			Co C			
Glycine clandestina species complex				Ta Wi			Co C B Wi			
Hardenbergia violacea							Wi			
Kennedia rubicunda				B Wi			Co C **B** **Ta** Wi			
Pultenaea daphnoides							Wi			
P. retusa				B Wi			B			
**Trifolium repens*	K	**Co** B						**Co**		
FABACEAE–MIMOSOIDEAE										
Acacia falcata							B			
A. implexa							**Co** P			

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
A. longifolia	K			**B P** **Ta** Wi	Co		Co ?C **B** Ta **Wi**			
A. mearnsii							Co			
A. suaveolens							Co			
A. ulicifolia							Co			
FUMARIACEAE										
**Fumaria* sp.		Co								
GOODENIACEAE										
•*Goodenia heterophylla* subsp. *eglandulosa*							Co			
G. ovata				**P** Wi			Wi			
G. paniculata		Co		B Wi	**Co**					
Selliera radicans				**P** Wi				We	**We B P**	
HALORAGACEAE										
Gonocarpus micranthus subsp. *micranthus*					Co					
G. teucrioides							Co Ta Wi			
?*Haloragis heterophylla*							Wi			
*•*Myriophyllum ?aquaticum*		B								
•*M. simulans*	?K	**Co** ?K ?B	**Co**	Co	**Co**					
•*M. verrucosum*		K								

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
HYDROCHARITACEAE										
Vallisneria gigantea			K							
LAMIACEAE										
*•*Plectranthus ?ciliatus*								We		
LAURACEAE										
Cassytha pubescens				**B P** Ta **Wi**			C Ta			
*•*Cinnamomum camphora*				**Co**						
LENTIBULARIACEAE										
Utricularia australis			**Co**	Co	**Co**					
U. dichotoma					Co					
LOBELIACEAE										
Lobelia alata		Co		**Co**	Co					
Pratia purpurascens				B **P**			Wi			
LYTHRACEAE										
Lythrum hyssopifolia		Co							B	
MALVACEAE										
**Sida rhombifolia*				Co						
MENISPERMACEAE										
Stephania japonica var. *discolor*							Co C			
MENYANTHACEAE										
Villarsia exaltata		Co	**Co**	Co	**Co**	**Co**				
V. reniformis		Co	**Co**	Co	Co	**Co**				

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
MYOPORACEAE										
Myoporum acuminatum							Co			
M. boninense subsp. *australe*							**Co C**			
MYRTACEAE										
Angophora floribunda							Co			
Callistemon citrinus					Co					
Eucalyptus botryoides				**P Ta Wi**	Co		**Co C Ta Wi**			
E. botryoides × *saligna*							Co			
•*E. ?imitans*							B			
E. pilularis				**B**			**Co B** Wi			
#*E. robusta*				**Co B** ?Wi	**Co**	Co	**Co**			
#*Leptospermum juniperinum*		Co		**Wi**	**Co**	Co	Co Ta			
L. laevigatum	Ta									
L. polygalifolium subsp. *polygalifolium*				Wi						
Melaleuca ericifolia		**Co B**	**Co**	**Co B P Ta Wi**	**Co**		**C Wi**		**C**	
•*M. linariifolia*			**Co**	**Co**	**Co**		Co Wi			
•Δ*M. styphelioides*				Co **B**						
Syzigium australe							**C**			

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
NYMPHAEACEAE										
*Δ*Nymphaea alba* and hybrids		Co	**Co**	**Co**						
*•*N. capensis*			**Co**							
?•*Nymphoides geminata*				Co						
OLEACEAE										
Notelaea venosa							**C** Ta Wi			
ONAGRACEAE										
Ludwigia peploides subsp. *montevidensis*	**K**	Co	Co **K**	**Co**						
OXALIDACEAE										
*•*Oxalis corniculata*		Co								
O. perennans	K									
PASSIFLORACEAE										
#*Passiflora herbertiana* subsp. *herbertiana*							Co			
PHYTOLACCACEAE										
**Phytolacca octandra*				B						
PITTOSPORACEAE										
Billardiera scandens var. *scandens*				P			Co Ta Wi			
B. scandens var. *scandens/sericata* intergrade							Co B			
Pittosporum revolutum							Co **C**			
P. undulatum							**Co** C P			

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
PLANTAGINACEAE										
**Plantago lanceolata*	K									
POLYGONACEAE										
**Acetosella vulgaris*		Co								
Persicaria decipiens	K	**Co B**	Co	**Co**						
P. hydropiper		**Co**								
P. lapathifolia		Co **Te**								
P. lapathifolia (form with hairy underleaf)		Co								
P. orientalis		Co								
P. praetermissa		**Co**	**Co**	**Co** B				We		
**Polygonum aviculare*		**Te**							Te	
**Rumex crispus*		Co								
PRIMULACEAE										
**Anagallis arvensis*	K									
Samolus repens				Ta Wi					**We** C	
PROTEACEAE										
Banksia integrifolia subsp. *integrifolia*					**Co**		**Co Ta**	We		
B. serrata							**Co Ta**			
B. spinulosa var. *spinulosa*							Wi			
Persoonia linearis							**Co** ?B			

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
RANUNCULACEAE										
Clematis aristata							Co Wi			
Ranunculus inundatus	K	**Co** K **B**	K	B						
R. ?lappaceus				B						
ROSACEAE										
**Rubus* complex		Co						**Co**		
Rubus parvifolius							Co C			
RUBIACEAE										
Galium propinquum				Ta						
Opercularia aspera							Wi			
O. ?varia							Co B			
RUTACEAE										
##•*Melicope micrococca*							Co			
Zieria smithii subsp. A							Co			
SALICACEAE										
**Salix alba*		Co								
SANTALACEAE										
Choretrum candollei				Wi						
Exocarpus cupressiformis					**Co**		**Co**			
SCROPHULARIACEAE										
••*Bacopa monnieri*		**K**							**We**	
Gratiola pedunculata		Co								

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
Mimulus repens		K							**We**	
Veronica plebeia							Co			
SOLANACEAE										
**Lycium ferocissimum*								We		
Solanum americanum		Co								
**S. nigrum*								We		
**S. pseudocapsicum*									C	
STACKHOUSIACEAE										
Stackhousia viminea					Co					
STYLIDIACEAE										
Stylidium graminifolium							Co			
THYMELAEACEAE										
Pimelia linifolia subsp. *caesia*							B Wi			
Pimelia linifolia subsp. *linifolia*							Wi			
VERBENACEAE										
**Lantana camara*	**K**						**Co C**			
VIOLACEAE										
Viola caleyana		Co								
V. hederacea		Co		**Co** B Wi	Co		**Co** B Wi			
VITACEAE										
#*Cayratia clematidea*							Co			
Cissus hypoglauca							Co			