# THE VEGETATION OF KOORAGANG ISLAND, NEW SOUTH WALES

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## INTRODUCTION

Kooragang Island lies in the mouth of the Hunter River estuary, and is flanked by the North and South Channels of the River (Fig. 1). It has an area of 2592 ha vegetated mainly by mangrove and saltmarsh communities with some pasture development on the western end.

Plans to reclaim the Island for industrial development met with opposition and the future of the Island became the subject of a public inquiry (Coffey, 1973) which recommended that a part of the Island and Fullerton Cove to the north be preserved as a wetland habitat, particularly for migratory wading birds.

A study was commissioned by several New South Wales Government Departments to make recommendations about the boundaries of the proposed reserve. That study is currently being assessed by the Departments concerned. This paper outlines the techniques used in, and the main results of, the vegetation survey which formed the foundation for the overall study.

The specific objectives of the vegetation survey were

i) to map and compare the vegetation in areas which might be included in the reserve;
ii) to assess the status of these areas with respect to weed infestation and the impact of past, present and possible future developments in the area;
iii) to identify probable causes, direction and rate of change of vegetation structure and composition;
iv) to search for rare or endangered species;
v) to provide base line data; and
vi) to provide a foundation for the overall study.

In particular, it was intended to identify vegetation types which could be regarded as 'habitat types' for subsequent faunal and ecophysiological studies.

## MATERIALS AND METHODS

The study was conducted between July 1981 and June 1982. Colour and black and white aerial photographs were examined to identify major structural and canopy species variations in the vegetation. The photographs and a preliminary reconnaissance of the study area led to the selection of 72 representative sites for the collection of quantitative data: 57 on Kooragang Island and 15 around Fullerton Cove. At each site a 243 $m^2$ square quadrat comprising eight concentric subquadrats was marked out. Subquadrats increased geometrically in area by a factor of three, the smallest being $\frac{1}{9}$ $m^2$ (see Fig. 2).

This design enabled differences in abundance between locally very plentiful species to be registered (in terms of presences or absences in the smaller subquadrats), and for the less abundant species to be detected in the larger subquadrats.

For each subquadrat a list was compiled of all species with at least one representative rooted in the subquadrat. In order to obtain structural information, mangroves were subdivided into pseudo-species based on height, stem diameter and crown diameter classes. The lowest height classes were further divided according to whether the individual was 'mature' (branched) or a seedling (unbranched). Other pseudo-species included stumps (divided into diameter classes) and pneumatophores.

Other information noted at the sample site included cover estimates, soil type and faunal notes. A soil sample was usually collected for subsequent salinity analysis.

## ANALYSIS

The species-composition data from each site were reduced to sets of species scores on a 0 to 8 scale, the score for a species equalling the number of the eight quadrats from which it was recorded. The sites were then classified using Indicator Species Analysis (ISA) (Hill *et al.*, 1975).

The computer analysis grouped the 72 sites into 14 'habitat types'. A fifteenth type, open water (w) was included subsequently. The habitat types and their relationship are shown in the dendrogram (Fig. 3). The analysis also generated an indicator-species key which could be used in the field for identification of habitat types. This key is presented in the Appendix.

Vascular plant species found in the quadrats are listed in Table 1 with abundance scores for the various habitat types. Table 2 lists species occurring in the study area but not encountered in quadrats. Nomenclature follows that of Jacobs and Pickard (1981). None of the species found is considered rare or endangered.

FIGURE 1: MAP OF THE STUDY AREA

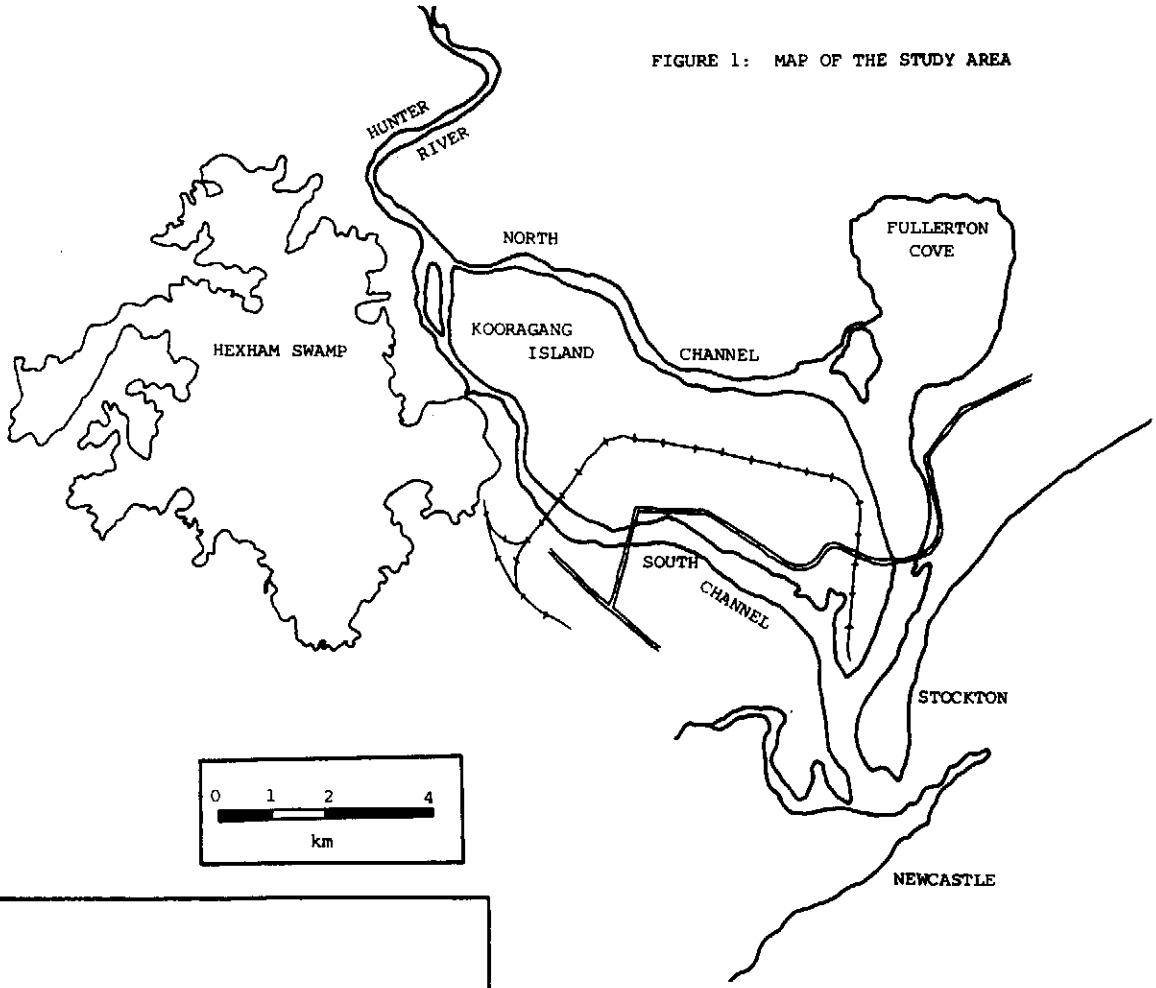



FIGURE 2: DIVISION OF QUADRATS INTO EIGHT CONCENTRIC SUBQUADRATS

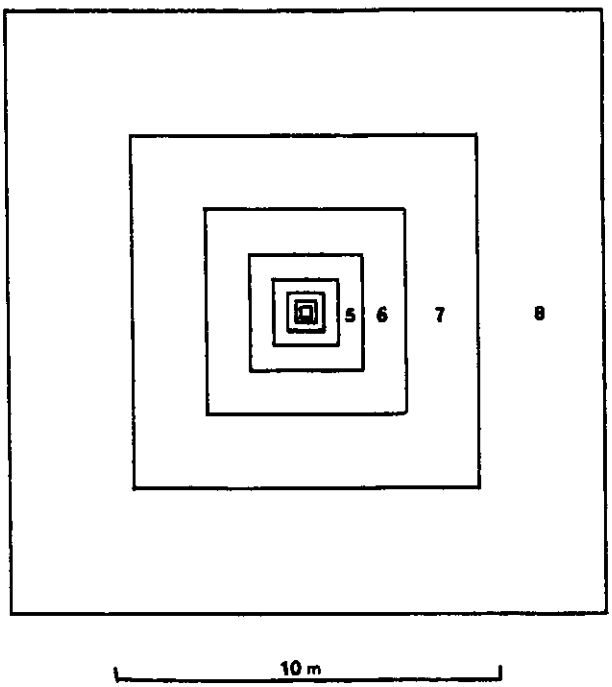


TABLE 1

Abundances of the vascular plant species at the vegetation sampling sites grouped according to habitat type. Each number is equal to 10 times the mean score achieved by the species in sites of the designated habitat type (on a 0-80 scale). Tree species have been subdivided into size classes as follows: Height classes - H+ <50cm; H* 50-100cm; H1 1-2m; H2 2-5m; H5 5-10m; HX 10-20m: Stem diameter classes (measured 1.5m from ground) - D+ <5cm; D* 5-10cm; D1 10-20cm; D2 20-50cm; D5 50-100cm: Crown diameter classes - C+ <1m; C1 1-2m; C5 2-5m. Pseudo-species listed here include stumps (of *Avicennia marina*, divided into diameter classes) and pneumatophores.

| | HABITAT TYPE | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MM1a | MM1b | MM2a | MM2b | SMM1a | SMM1b | SMM2a | SMM2b | SMM3 | SP | Cas | Pc | Ps | Sw |
| **Aegiceras corniculatum** H+(Seedling) | 70 | 1 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Aegiceras corniculatum** H+(Mature) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Aegiceras corniculatum** H*(Seedling) | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Aegiceras corniculatum** H*(Mature) | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Aegiceras corniculatum** H1 | 65 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Aegiceras corniculatum** H2 | 35 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Agrostis avenacea** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 3 | 55 | 10 | 9 | 8 | 0 |
| **Ambrosia tenuifolia** | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 13 | 0 | 3 | 23 | 78 | 0 |
| **Amyema cambagei** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 |
| **Anagallis arvensis** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 8 | 0 | 9 | 20 | 0 |
| **Apium leptophyllum** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 9 | 0 | 0 |
| **Apium prostratum** | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Aster subulatus** | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 16 | 13 | 62 | 28 | 6 | 10 | 9 |
| **Atriplex australasica** | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Atriplex hastata** | 0 | 0 | 0 | 0 | 0 | 0 | 27 | 8 | 0 | 7 | 28 | 9 | 10 | 7 |
| **Avena barbata** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |

| | M1a | M1b | M2a | M2b | SM1a | SM1b | SM2a | SM2b | SM3 | SP | Cas | Pc | Ps | Sw |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avicennia marina H+(Seedling) | 35 | 64 | 15 | 48 | 0 | 0 | 3 | 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avicennia marina H+(Mature) | 0 | 1 | 33 | 36 | 4 | 20 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avicennia marina H*(Seedling) | 0 | 6 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avicennia marina H*(Mature) | 0 | 0 | 21 | 28 | 2 | 45 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avicennia marina H1 | 0 | 13 | 19 | 22 | 0 | 15 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avicennia marina H2 | 35 | 20 | 18 | 34 | 2 | 20 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avicennia marina H5 | 25 | 30 | 14 | 10 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avicennia marina HX | 0 | 9 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avicennia marina D+ | 10 | 7 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avicennia marina D* | 10 | 19 | 1 | 6 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avicennia marina D1 | 15 | 16 | 10 | 6 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avicennia marina D2 | 0 | 13 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avicennia marina D5 | 5 | 6 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avicennia marina C+ | 10 | 19 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avicennia marina C1 | 15 | 17 | 11 | 8 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avicennia marina C2 | 10 | 17 | 19 | 4 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avicennia marina C5 | 5 | 7 | 8 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Briza maxima | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 |
| Briza minor | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 15 | 0 |
| Bromus unioloides | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 7 | 0 | 5 | 9 | 30 | 1 |
| Carex inversa | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 |
| Casuarina glauca H+ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35 | 0 | 0 | 0 |
| Casuarina glauca H* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 |
| Casuarina glauca H1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 |
| Casuarina glauca H2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 0 |
| Casuarina glauca H5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 0 |
| Casuarina glauca HX | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 0 | 0 | 0 |
| Centaurium spicatum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 | 0 | 0 | 0 | 0 |
| Chrysanthemoides monilifera | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 15 | 0 | 10 | 0 |

| | M1a | M1b | M2a | M2b | SM1a | SM1b | SM2a | SM2b | SM3 | SP | Cas | Pc | Ps | Sw |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cirsium vulgare | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 10 | 20 | 23 | 20 | 0 | 0 |
| Cortaderiea selloana | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| Cotula coronopifolia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 7 | 28 | 0 | 3 | 0 | 50 |
| Crassula sieberana | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 |
| Cynodon dactylon | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 20 | 33 | 59 | 80 | 0 |
| Dichelachne micrantha | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 |
| Dichondra repens | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 5 | 0 |
| Ehrharta erecta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35 | 0 |
| Eleocharis acuta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| Erigeron bonariensis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 8 | 4 | 0 | 0 |
| Erigeron floribunda | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 10 | 26 | 3 | 0 |
| Galenia secunda | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 |
| Gladiolus undulatus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 | 0 |
| Gnaphalium luteo-album | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 3 | 0 |
| Hydrocotyle bonariensis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 0 |
| Hypochoeris radicata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 10 | 8 | 0 |
| Juncus acutus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Juncus cognatus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 18 | 0 |
| Juncus subgen. genuini | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 9 | 15 | 0 |
| Juncus kraussii | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 80 | 0 | 0 | 3 | 0 | 1 |
| Lantana camara | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 |
| Lepidium hyssopifolium | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 28 | 1 | 0 | 0 |
| Lolium loliaceum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 13 | 0 | 6 | 0 | 0 |
| Lythrum hyssopifolia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 0 | 4 | 10 | 0 |
| Medicago truncatula | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 3 | 0 |
| Melaleuca sp. | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Melilotus indica | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 |
| Mimulus repens | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 36 |
| Modiola caroliniana | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 |

| | M1a | M1b | M2a | M2b | SM1a | SM1b | SM2a | SM2b | SM3 | SP | Cas | Pc | Ps | Sw |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monerma cylindrica | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 6 | 0 | 30 | 0 | 0 | 0 | 0 |
| Nothoscordum inodorum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Oenothera sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 18 | 0 |
| Opuntia stricta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 3 | 0 |
| Oxalis corniculata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 8 | 0 |
| Panicum capillare | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| Parapholis incurva | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 0 | 0 | 0 | 0 | 3 | 0 |
| Paronychia brasiliana | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 |
| Paspalum dilatatum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 59 | 0 | 0 |
| Paspalum distichum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24 |
| Pennisetum clandestinum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 11 | 0 | 0 |
| Petrorhagia nanteuilii | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 |
| Phragmites australis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 |
| Plantago lanceolatus | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 7 | 3 | 40 | 30 | 0 |
| Plantago myosuros | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 0 |
| Pneumatophore | 80 | 80 | 76 | 78 | 10 | 75 | 3 | 14 | 0 | 0 | 0 | 0 | 0 | 0 |
| Poa poiformis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| Polycarpon tetraphyllum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 | 0 |
| Polygonum arenastrum | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 14 | 3 | 37 | 3 | 6 | 3 | 3 |
| Polygonum decipiens | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| Polypogon monspeliensis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 3 | 20 | 0 | 4 | 10 | 13 |
| Potamogeton pectinatus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Romulea rosea | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 |
| Rubus vulgaris | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 | 0 |
| Rumex sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 4 | 15 | 0 |
| Ruppia megacarpa | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24 |
| Samolus repens | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 |
| Sarcocornia quinqueflora | 0 | 0 | 4 | 4 | 78 | 75 | 42 | 68 | 10 | 48 | 0 | 3 | 8 | 0 |

| | M1a | M1b | M2a | M2b | SM1a | SM1b | SM2a | SM2b | SM3 | SP | Cas | Pc | Ps | Sw |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scirpus cernuus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 |
| Scirpus fluviatilis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 5 | 0 | 3 | 0 | 40 |
| Scirpus litoralis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 44 |
| Scirpus nodosus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| Senecio lautus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 30 | 20 | 47 | 33 | 0 |
| Senecio linearifolia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| Sida rhombifolia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 5 | 0 |
| Solanun nigrum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 1 | 3 | 0 |
| Solanum nodiflorum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 |
| Soliva sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Sonchus sp. | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 6 | 3 | 43 | 38 | 16 | 13 | 0 |
| Spergularia rubra | 0 | 0 | 0 | 0 | 4 | 0 | 3 | 30 | 0 | 23 | 0 | 0 | 8 | 1 |
| Sporobolus africanus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24 | 10 | 0 |
| Sporobolus virginicus | 0 | 0 | 0 | 12 | 2 | 0 | 78 | 62 | 50 | 78 | 35 | 0 | 8 | 3 |
| Stenotaphrum secundatum | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 4 | 0 | 13 | 0 | 39 | 35 | 0 |
| Stump D+ | 0 | 0 | 35 | 12 | 0 | 10 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 0 |
| Stump D* | 0 | 0 | 6 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Stump D1 | 0 | 0 | 8 | 2 | 8 | 15 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Stump D2 | 0 | 0 | 14 | 2 | 10 | 15 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Suaeda australis | 0 | 1 | 3 | 4 | 4 | 65 | 30 | 8 | 0 | 2 | 38 | 1 | 5 | 0 |
| Tetragonia tetragonioides | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 |
| Tradescantia albiflora | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 8 | 0 |
| Trifolium repens | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 5 | 17 | 3 | 0 |
| Triglochin striata | 0 | 0 | 0 | 22 | 0 | 0 | 5 | 56 | 3 | 13 | 0 | 3 | 3 | 11 |
| Typha orientalis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 11 |
| Verbena bonariensis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 |
| Vicia sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 38 | 0 |

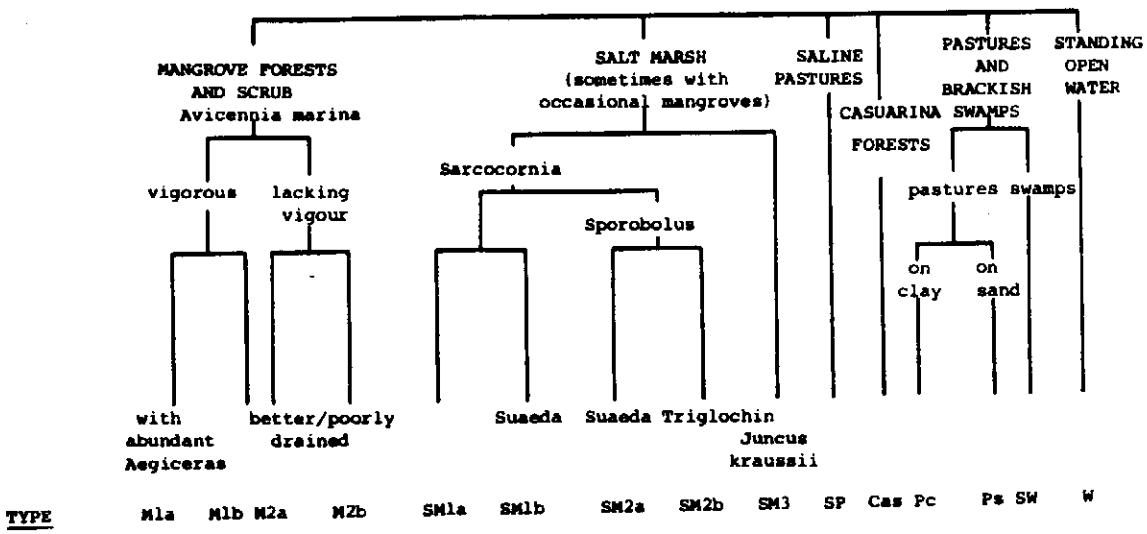
| | M1a | M1b | M2a | M2b | SM1a | SM1b | SM2a | SM2b | SM3 | SP | Cas | Pc | Ps | SW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Viola hederacea** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| **Vulpia bromoides** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 27 | 35 | 0 |
| **Wahlenbergia gracilis** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| **Xanthium occidentale** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |

TABLE 2

ADDITIONAL SPECIES RECORDED FROM KOORAGANG ISLAND

*Carex pumila*
*Cupaniopsis anacardioides*
*Euphorbia peplus*
*Ficus* sp.
*Juncus bufonius*
*Juncus microcephalus*
*Juncus polyanthemus*
*Juncus usitatus*
*Livistona australis*
*Podocarpus elatus*
*Rhynchelytrum repens*

FIGURE 3: THE HABITAT TYPES OF THE STUDY AREA



## DISCUSSION

### a) The Habitat Types

It should be noted that the habitat types are not totally distinct as they intergrade; nor are they totally homogeneous as they could be further subdivided. Nevertheless, they constitute a relevant and sufficiently detailed set of categories for the purpose of the study.

#### i) Vigorous mangroves with *Aegiceras* (Type M1a)

A vigorous mangrove community with fairly open tree layer 5 to 10 m tall containing *Avicennia marina* and a shrub layer of *Aegiceras corniculatum*. Pneumatophores are numerous and support thick growths of a very distinct red algal association of *Caloglossa, Catenella* and *Bostrychia*.

This vegetation type occurs along the margins of tidal channels that are subject to regular tidal inundation.

#### ii) Healthy mangrove forests without abundant *Aegiceras* (Type M1b)

A vigorous growing *Avicennia marina* forest with the tree layer 5 to 12 m high. Seedlings and saplings of *Avicennia* are also present and *Aegiceras corniculatum* may occur infrequently. Pneumatophores are numerous and support dense tufts of a red algal association of *Caloglossa, Catenella* and *Bostrychia* attached to the pneumatophores.

This type of vegetation is both widespread and common. It occurs in areas where frequent tidal inundation restricts the salinity to levels readily tolerated by *Avicennia* (viz. near that of sea water).

#### iii) Tall mangrove forest lacking vigour (Type M2a)

These mangrove communities contain large trees of *Avicennia marina* (canopy height 6 to 12 m). *Avicennia* seedlings are not very frequent, but stunted more mature plants occur. Live *Avicennia* exhibit stress symptoms such as defoliation, canopy dieback and epicormic growth. Occasional specimens of saltmarsh plants, *Sarcocornia quinqueflora* and *Suaeda australis*, may be present. Colonies of algae are rarely prominent on pneumatophores many of which appear dead. The substratum may be covered with a thin algal film, the dominant organism being a filamentous green alga, *Rhizoclonium*.

At the time of the survey, this type of vegetation was common and widespread. It occurs at sites that are less frequently inundated than those occupied by vigorous mangrove communities of Type M1a and M1b. The salinity at the time of the survey was often higher than that of sea water.

#### iv) Stunted mangroves lacking vigour (Type M2b)

Like the type of habitat described above (Type M2a) these are mangrove communities lacking in vigour. However, the plants are more stunted and shrub-like and the canopy is usually less than 5 m tall. *Avicennia* seedlings are more prevalent than in Type M2a and stunted mature specimens are frequent. Stumps of small *Avicennia* may be present and the live plants suffer from defoliation, canopy dieback and exhibit epicormic growth. Thick algal mats, consisting almost entirely of the filamentous green alga *Rhizoclonium*, cover the pneumatophores and the substratum.

Occasional specimens of the saltmarsh plants *Triglochin striata, Sarcocornia quinqueflora* and *Sporobolus virginicus* occur. This type of vegetation is common and widespread; like Type M2a it occurs at sites that are not inundated by every tide. However, the sites are less well drained and may remain waterlogged for prolonged periods.

#### v) *Sarcocornia* saltmarsh (Type SM1a)

These saltmarsh communities are dominated by *Sarcocornia quinqueflora*. Other species of saltmarsh plants are very infrequent. The *Sarcocornia* is interspersed with salt scald areas devoid of all plants except algae. The algae form characteristic thick mats, which, in the case of scalds, cover the surface of the substratum. The mats contain green filamentous algae *Rhizoclonium*, the blue green *Oscillatoria* and diatoms.

This habitat is common and widespread. It occurs at sites which are not inundated at every tide and where salinity is very high.

#### vi) *Sarcocornia/Suaeda* saltmarsh (Type SM1b)

A saltmarsh community with *Sarcocornia quinqueflora* and *Suaeda australis* is often interspersed with stunted *Avicennia* and thus could also be described as open scrubland.

This habitat is not thought to be very abundant in the areas studied. Its main occurrence is in the clearings within mangrove forests and scrubs. The salinity at sites occupied by Type SM1b is lower than those where Type SM1a occurs, being around that of sea water at the time of the present survey.

#### vii) *Sporobolus/Suaeda/Sarcocornia* saltmarsh (Type SM2a)

These saltmarsh communities are dominated by *Sporobolus virginicus, Suaeda australis* and *Sarcocornia quinqueflora*. Other salt tolerant plants such as *Atriplex hastata* and *Polygonum arenastrum* also occur. Algae are generally absent due to lack of surface water.

This habitat occupies well drained sites of moderate salinity. It frequently occurs as slightly elevated sites with Type SM2b saltmarsh in adjacent lower lying areas. Tidal inundation probably occurs less than a dozen times per annum.

viii) *Sporobolus/Triglochin/Sarcocornia* saltmarsh (Type SM2b)

Saltmarsh communities with a dense cover of *Sporobolus virginicus*, *Triglochin striata* and *Sarcocornia quinqueflora*. Other plants which may be present include *Cotula coronopifolia*, *Parapholis incurva*, *Polygonum arenastrum*, *Spergularia rubra* and *Aster subulatus*. There may be occasional stunted shrubs of *Avicennia marina*. Some ephemeral shallow pools of surface water are likely to occur. No algal cover is reported.

This habitat is common, especially in that area just north of the railway line (Fig. 1) and around Fullerton Cove. It occurs in areas of moderate salinity which are subject to periodic waterlogging.

ix) *Juncus* saltmarsh (Type SM3)

A saltmarsh community dominated by *Juncus kraussii*; *Sporobolus virginicus* is also likely to be present. An algal film of *Vaucheria* covers the substratum.

This habitat is not common in the areas studied. The only significant patches occur at the western part of Kooragang Island.

x) Saline pastures (Type SP)

This type of habitat is intermediate between a saltmarsh and pasture. The saltmarsh plants *Sporobolus virginicus* and *Sarcocornia quinqueflora* are still quite common, but the salinity is low enough for pasture grasses such as *Agrostis avenacea*, *Cynodon dactylon* (couch) and *Stenotaphrum secundatum* (buffalo grass) to occur, together with a variety of other herbs such as the daisies *Aster subulatus* and *Senecio lautus*. The environment is too dry to support algal growth.

This habitat is common in recently drained saltmarsh areas behind Fullerton Cove. Presumably a transition is found in the western parts of Kooragang Island where saltmarsh grades into pasture.

xi) *Casuarina* forest (Type Cas)

Forest communities with a canopy of *Casuarina glauca* 5-12 m tall. Beneath the trees there is open herbaceous understorey which may contain saltmarsh plants such as *Suaeda australis* and *Sporobolus virginicus* as well as *Opuntia stricta* (prickly pear) and a variety of pasture weeds.

This habitat occurs on well drained sandy banks just above the highest tides. It is widespread but not common.

xii) Pasture on clay soil (Type PC)

This habitat is characterised by an assortment of grasses, *Cynodon dactylon* (couch), *Paspalum dilatatum* (paspalum) and *Stenotaphrum secundatum* (buffalo grass) being the most abundant. There are also pasture weeds such as *Cirsium vulgare* (thistle), *Erigeron* sp. (fleabane), *Senecio lautus* and *Plantago lanceolata* (plantain). No algal cover is evident, presumably due to dryness.

These sites have supported eucalypt, casuarina or palm forest in the distant past.

This habitat occupies sites of low salinity. Tidal inundation is very infrequent or absent. This type is common in the western end of Kooragang Island and in the drained area behind Fullerton Cove.

xiii) Pasture on sand (Type PS)

As with Type PC, the grasses *Cynodon dactylon* (couch) and *Stenotaphrum secundatum* (buffalo grass) are abundant, along with a variety of other grasses. The daisy *Ambrosia tenuifolia* is very common and a number of other plants occur, such as *Rubus vulgaris* (blackberry), *Oenothera* sp. (evening primrose). Large colonies of *Chrysanthemoides monilifera* (boneseed), a troublesome weed of disturbed sand dunes, can be found. Occasional specimens of the rainforest tree *Cupaniopsis anacardioides* also occur.

Type PS occurs on well drained sandy sites which may, in the past, have supported *Melaleuca* forest, palm forest or littoral rainforest. The principal occurrence is at the eastern end of Kooragang Island.

xiv) Brackish swamps (Type SW)

The brackish swamps are dominated by *Scirpus fluviatilis* and *Scirpus litoralis* (sedges). *Cotula coronopifolia* (water button) is frequent and the aquatic plants *Ruppia megacarpa* and *Potamogeton pectinatus* occur in the wettest parts. Algae films occur in open pools of water and around plants in water: *Anabena*, a nitrogen fixing blue green alga, was found.

This habitat occurs in the low lying sites protected from tidal inundations where the water table is above ground level for much of the year. The most notable example is at the eastern end of the Island, just north of the railway line. Other, less extensive, and more ephemeral swamps occur further west on Kooragang Island. No occurrences were found in the Fullerton Cove area.

b) Occurrences of Weeds

Weed species were virtually absent from the mangrove habitats. The saltmarshes and brackish swamps were likewise fairly free of exotic species but the remaining habits: *Casuarina*, saline pasture and pasture were heavily infested. The high salinity protects the mangroves and saltmarsh areas from invasion by most weed species.

c) Temporal Variations

Temporal changes in the vegetation were investigated in the laboratory by inspecting aerial photographs dating back to 1954 and in the field by noting evidence of previous occurrences of mangroves (stumps) and pathological symptoms on live mangroves (defoliation, epicormic shoots etc.). Measurements of soil salinity and redox potential were analysed in an effort to understand the current distribution of the habitat types and the reasons some are exhibiting symptoms of stress. The results were as follows:

i) Mangrove areas are more extensive now than in 1954, mainly through transitions from saltmarsh. The newly established mangroves are away from the main drainage channels.
ii) Many of the mangroves established since 1954 are now exhibiting stress symptoms.
iii) The soil salinity in the areas occupied by these stressed mangroves is currently very high, considerably greater than that of sea water.
iv) Large stumps in some saltmarsh areas indicate that mangrove-to-saltmarsh transitions have occurred in the more distant past.

One hypothesis that would explain these results is that the mangrove/saltmarsh transitions are climatically controlled. During a succession of wetter years, the soil salinity would fall, allowing mangroves to establish. In sustained dry periods the salinity would rise sufficiently to stress or even kill the mangroves.

However, the following factors may also have contributed:

i) Sediment deposition in mangrove areas would eventually cause a transition to saltmarsh.
ii) Erosion would favour a transition from saltmarsh to mangroves.
iii) Construction of tidal channels for drainage and/or mosquito alleviation would favour the establishment of mangroves.
iv) Flood mitigation schemes on the Hunter Valley might affect the saltmarsh/mangrove equilibrium.

ACKNOWLEDGEMENTS

Algae were identified by Dr D.M.H. Cheng, School of Life Sciences, New South Wales Institute of Technology; his assistance is greatly appreciated. We are grateful to Miss Lynne Albertson who drew the figures. We are especially thankful for the support of the Department of Environment and Planning; Ms Jo Moss was particularly helpful.

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APPENDIX

## INDICATOR SPECIES KEY TO THE VEGETATION OF KOORAGANG ISLAND

To use the key:

1. Inspect the site, noting species present and assigning them scores according to the following scale: If there is estimated to be a better than 50% chance of encountering the species in a randomly-placed quadrat of area $\frac{1}{9}$ m², assign a score of 8, else if this criterion would be met for a $\frac{1}{3}$ m² quadrat, score 7 etc:

| Minimum size of quadrat estimated to give ≥ 50% frequency (m²) | Score |
|---|---|
| $\frac{1}{9}$ | 8 |
| $\frac{1}{3}$ | 7 |
| 1 | 6 |
| 3 | 5 |
| 9 | 4 |
| 27 | 3 |
| 81 | 2 |
| 243 | 1 |

2. At each division in the key, add the scores of all species present at the site that are listed as positive indicators, then subtract the scores of all negative indicators present.

3. Compare the result with the listed threshold values and hence determine which branch to follow.

Names in the key (genus and species) are abbreviated to the first four letters. In some cases the specific epithet is replaced by a size-class code. See Table 1 for explanation of size-class codes and expanded species names.

| | Negative Indicators | | Positive Indicators | | Habitat Type |
|---|---|---|---|---|---|
| 1. | Aste subu<br>Cotu coro<br>Cyno dact | Sene laut<br>Sonc sp.<br>Spor dact | Avic H+/S<br>Avic H+/M | Avic H2<br>Pneumato. | < = -1 ..... 2<br>> = 0 ..... 3 |
| 2. | Ambr tenu<br>Cyno dact<br>Sene laut | Spor virg<br>Sten secu | Cotu coro<br>Mimu repe<br>Pasp vagi | Scir fluv<br>Scir lito | < = -1 ..... 4<br>> = 0 ..... Sw |
| 3. | Avic C1<br>Avic C2<br>Avic D2<br>Avic H+/S | Avic H2<br>Avic H5<br>Penumato | Sarc quin<br>Suae aust<br>Spor virg | | < = -3 ..... 9<br>> = -2 ..... 12 |
| 4. | Aste subu<br>Sarc quin<br>Spor virg | | Ambr tenu<br>Cyno dact<br>Pasp dila<br>Plan lanc | Sene laut<br>Sten secu<br>Vulp brom | < = 5 ..... 6<br>> = 6 ..... 5 |
| 5. | Ambr tenu<br>Cyno dact<br>Ehrh erec<br>Hydr bona | Oeno drum<br>Poly tetr<br>Rubu vulg | Erig flor<br>Pasp dila | | < = -6 ..... Ps<br>> = -5 ..... Pc |
| 6. | Sarc quin<br>Sper rubr<br>Spor virg | Trig stri | Casu H+<br>Casu HX<br>Cyno dact | Lepi hyss<br>Suae aust<br>Sonc sp. | < = 0 ..... 7<br>> = 1 ..... Cas |
| 7. | Agro aven<br>Aste subu<br>Mone cyli<br>Poly avic | Sarc quin<br>Sper rubr<br>Trig stri | Ambr tenu<br>Junc krau<br>Phra aust | | < = -3 ..... 8<br>> = -2 ..... Sm3 |
| 8. | Agro aven<br>Aste subu<br>Cent spic<br>Cirs vulg<br>Cotu coro | Cyno dact<br>Lyth hyss<br>Mone cyli<br>Poly avic<br>Sene laut | | | < = -7 ..... SP<br>> = -6 ..... 9 |

9. Saltmarsh with *Sarcocornia*, sometimes with occasional mangroves

| | | | | |
|---|---|---|---|---|
| Aste subu | Sper rubr | Sarc quin | | < = -4 ..... 10 |
| Astri hast | Spor virg | | | |
| Cotu coro | Sten secu | | | > = -3 ..... 11 |
| Para incu | Trig stri | | | |
| Poly avic | | | | |

10. *Sporobolus/Sarcocornia* saltmarsh

| | | | |
|---|---|---|---|
| Atri hast | Agro aven | Sarc quin | < = 1 ..... SM2a |
| Suae aust | Cotu coro | Spor rubr | |
| Spor virg | Para incu | Trig stri | > = 2 ..... SM2b |
| | Poly mons | | |

11. *Sarcocornia* saltmarsh

| | | |
|---|---|---|
| Suae aust | | < = 3 ..... SM1a |
| | | > = 2 ..... SM1b |

12. Mangrove forest and scrub

| | | | | |
|---|---|---|---|---|
| Avic H+/M | Stump D+ | Aegi H+/S | Avic H+/S | < = 3 ..... 13 |
| Avic H*/M | | Aegi H1 | Avic H5 | |
| Avic H1 | | Aegi H2 | Avic D* | > = 4 ..... 14 |

13. Mangrove forest and scrub, lacking vigour

| | | | | |
|---|---|---|---|---|
| Avic C1 | Avic HX | Avic H+/S | Trig stri | < = -1 ..... M2a |
| Avic C2 | Stump D+ | Avic H2 | | |
| Avic D3 | Stump D2 | Spor virg | | > = 0 ..... M2b |

| | | | | |
|---|---|---|---|---|
| 14. Avic D2 | Avic H1 | Aegi H+/S | Aegi H1 | < = 0 ..... M1b |
| Avic H+/S | Avic HX | Aegi H*/M | Aegi HZ | |
| | | Aegi H*/S | | otherwise .... M1a |