Groupings of Tidal River Systems in Northern Australia Based on Mangrove Species

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Eighty two tidal systems encompassing the entire coastline of the Northern Territory and the major portion of the Kimberley region of Western Australia were sampled for the presence of mangrove species.

Four geomorphologically distinct tidal river systems were identified. Through classificatory analyses tidal systems were grouped on presence/absence of mangrove species. Climatic variations, particularly increasing seasonal aridity in many regions across Northern Australia appear to strongly influence mangrove species diversity and resultant tidal system groupings through the survey area.

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INTRODUCTION

The use of a classificatory approach has a long tradition in many areas of natural science. Methods of classification suitable for examining plant/environment relationships from local to regional scales range from the phytosociological, developed by Braun-Blanquet (1932) to an ever-expanding array of techniques including Association Analysis and other numerical clustering approaches of handling large data matrices (see Mueller-Dombois and Ellenberg 1974).

The results of classification using any of these techniques are evaluated in terms of the clarity of the groups produced and the ease with which rational hypotheses can be formulated concerning these groups and their environmental relationships. The applications of these approaches to ecology have been reviewed by Williams (1971), Clifford and Williams (1973), Frenkel and Harrison (1974), Clifford and Stephenson (1975) and Sandland and Young (1979).

In this paper numerical classificatory techniques are applied to mangrove plant communities through much of the Australian Monsoon region to explore floristic groupings of the tidal systems from an environmental viewpoint.

The potential of these approaches for an understanding of mangrove plant distribution is related to the fact that some species appear to be useful indicators of specific habitats. Schimper (1903) was among the earliest to emphasize that many mangrove species are useful biological indicators within intertidal areas reflecting changes in local microtopography, edaphic and climatic conditions. Other workers including Fosberg (1961, 1975), Macnae (1966, 1968), Chapman (1970, 1975, 1976), Zahran (1975) and Cintron *et al.* (1978) have stressed that increasing climatic aridity results in a reduction of floristic diversity of mangroves in both tropical and sub-tropical regions.

METHODS

Field work was conducted throughout the period 1975-1979 in 82 tidal systems comprising 110 tidal waterways across northern Australia. This included 527 km of waterways in the Kimberley and Joseph Bonaparte Gulf regions of Western Australia and a further

3998 km of waterways through the Northern Territory - from the Western Australian border to the Queensland border.

Fringing riverside mangrove communities were assessed on both banks for species composition and cover abundance at 2.5 km intervals. At each site associations were assayed for 20m deep quadrats stretching 100m along the river. Herbarium specimens were inspected at the Northern Territory Herbarium, Australian Institute of Marine Science, Townsville, James Cook University, Townsville, Department of Forestry Sarawak, Malaysia (Sarawak specimens deposited with Northern Territory Herbarium), Phuket Marine Biological Station, Thailand, University of Papua New Guinea, and Mangrove Research Centre, Forest Research Institute, Philippines for species verifications. Specimens have been deposited with the Northern Territory Herbarium and John Ray Herbarium, University of Sydney. Holotype specimens of new mangrove species resulting from these surveys of *Avicennia integra* N.C. Duke and *Sonneratia* spp. also described by Duke (1987, 1988, 1994) are located in the Herbarium of the Northern Territory, Darwin.

New combinations in the genus *Avicennia* have been reported by Everett (1994).

Groupings of tidal systems and mangrove species were obtained using the Multbet non-combinatorial information statistic program within the Taxon package (Dale *et al.*, 1980).

In this study 24 species recorded in the survey area (Table 1) are included in a matrix analysis of 24 species x 82 sites.

TABLE 1

Mangrove species from the survey area used in classificatory analyses.

ACANTHACEAE	*Acanthus ilicifolius* L.
AVICENNIACEAE	*Avicennia marina* subsp. *eucalyptifolia* (Valeton) J. Everett
	Avicennia integra N.C. Duke
BOMBACACEAE	*Camptostemon schultzii* Mas.
COMBRETACEAE	*Lumnitzera littorea* (Jack.) Voigt
	Lumnitzera racemosa Willd.
EUPHORBIACEAE	*Excoecaria agallocha* L.
MELIACEAE	*Xylocarpus australasicus* Ridl.
	Syn X. mekongensis Pierre
	Xylocarpus granatum King
MYRSINACEAE	*Aegiceras corniculatum* (L.) Blanco
MYRTACEAE	*Osbornia octodonta* F. Muell.
PLUMBAGINACEAE	*Aegialitis annulata* R. Br.
RHIZOPHORACEAE	*Bruguiera exaristata* Ding Hou
	Bruguiera gymnorhiza (L.) Lamk.
	Bruguiera parviflora (Roxb.) W & A ex Griff.
	Bruguiera sexangula (Lour.) Pior.
	Ceriops decandra (Griff.) Ding Hou
	Ceriops tagal (Perr.) C.B. Rob. var. *australis* C.T. White
	Ceriops tagal (Perr.) C.B. Rob.
	Rhizophora apiculata Blume
	Rhizophora stylosa Griff.
RUBIACEAE	*Scyphiphora hydrophyllacea* Gaertn.
SONNERATIACEAE	*Sonneratia alba* J.E. Sm.
	Sonneratia lanceolata Blume; Duke and Jackes

Study Setting

The survey area lies between 11°S and 16°S across the northern coastline of Australia. Climate is strongly conditioned by the seasonal shifting of prevailing winds and marked changes in air-mass properties. Two distinct seasons can be identified - the 'wet' season with dominant winds from the north-west to west, occurring from November-March and the 'dry' season with prevailing south-easterly winds from May-September. April and October are transitional months (Specht 1985; Southern 1966; Gentilli 1971).

Associated with these seasonal changes are significant variations in air temperatures, relative humidity, evaporation and precipitation (Bureau of Meteorology 1975). Variation in mean annual rainfall for the survey area and temperature- rainfall diagrams for selected sites are shown in Figures 1 and 2 respectively.

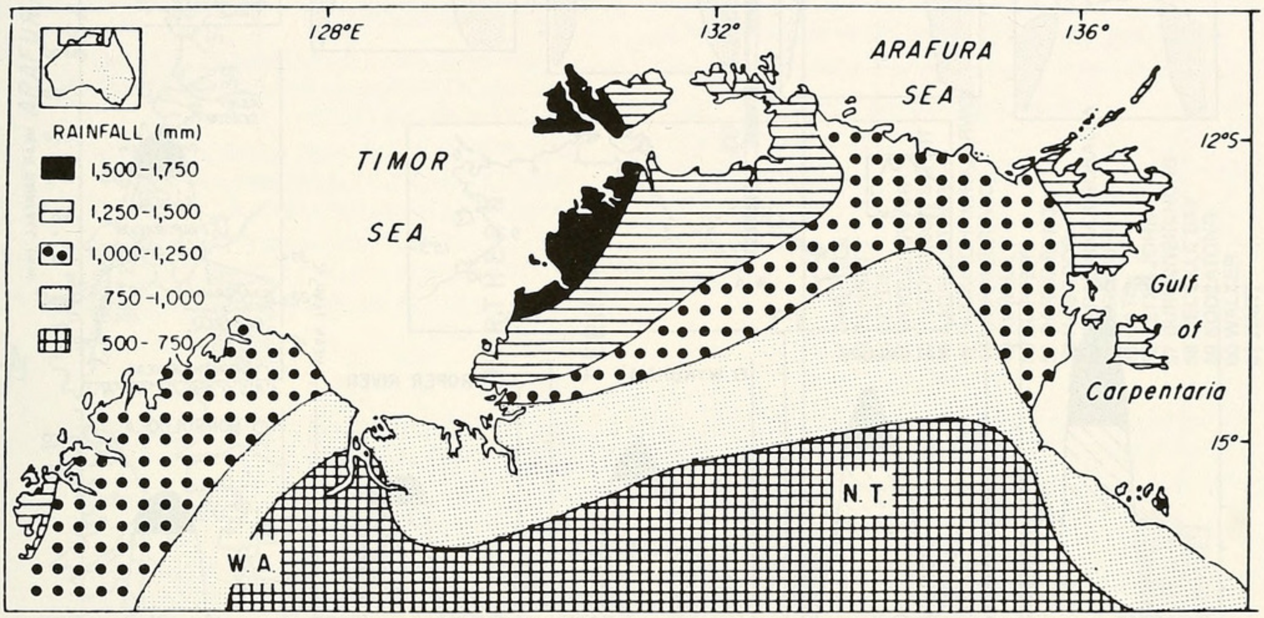

Fig. 1. Variation in mean annual rainfall for the study area (all years of record to 1975, Bureau of Meteorology.

Within the greater portion of the survey area, from the Kimberley region of Western Australia to Gove in the Northern Territory, semi-diurnal tidal patterns occur. Within the Gulf of Carpentaria diurnal tidal patterns are normal and lunar differences, particularly for spring and neap tides are not nearly so pronounced and may even be opposite in effect to those experienced in regions of the survey area experiencing semi-diurnal tides. Tidal bores occur on some river systems across the northern coastline during spring high tides. Spring tidal ranges vary from up to 11 metres in the Kimberleys, 8 metres in the Darwin region, 3 metres in the Gove region and 2.5 metres along the south-western portion of the Gulf of Carpentaria (Australian National Tide Tables).

Tidal Systems

Four geomorphically distinct estuarine systems were surveyed. These were: (1) those where drainage was structurally controlled, as in the northwest Kimberley region of Western Australia, where entire river courses follow geological jointing planes (e.g., Glenelg, Prince Regent, Roe, Hunter and Mitchell rivers); (2) those waterways of varying lengths which enter embayments after meandering across small or extensive alluvial floodplains; (3) those waterways entering into harbours or ports (e.g. Port Keats, Port Paterson, Bynoe and Darwin Harbours); or (4) short coastal inlets which do not drain any substantial upstream catchment areas (e.g. Mini Mini and Iwalg Creeks, Ilamaryi River).

The term tidal system used throughout this paper refers to groups of individual waterways possessing a common sea entrance. The distribution of the tidal systems examined in this study is shown in Figure 3. Individual waterways drain varying catchment areas although systems in the Alligator Rivers area may partially interconnect during some wet seasons (Williams 1979).

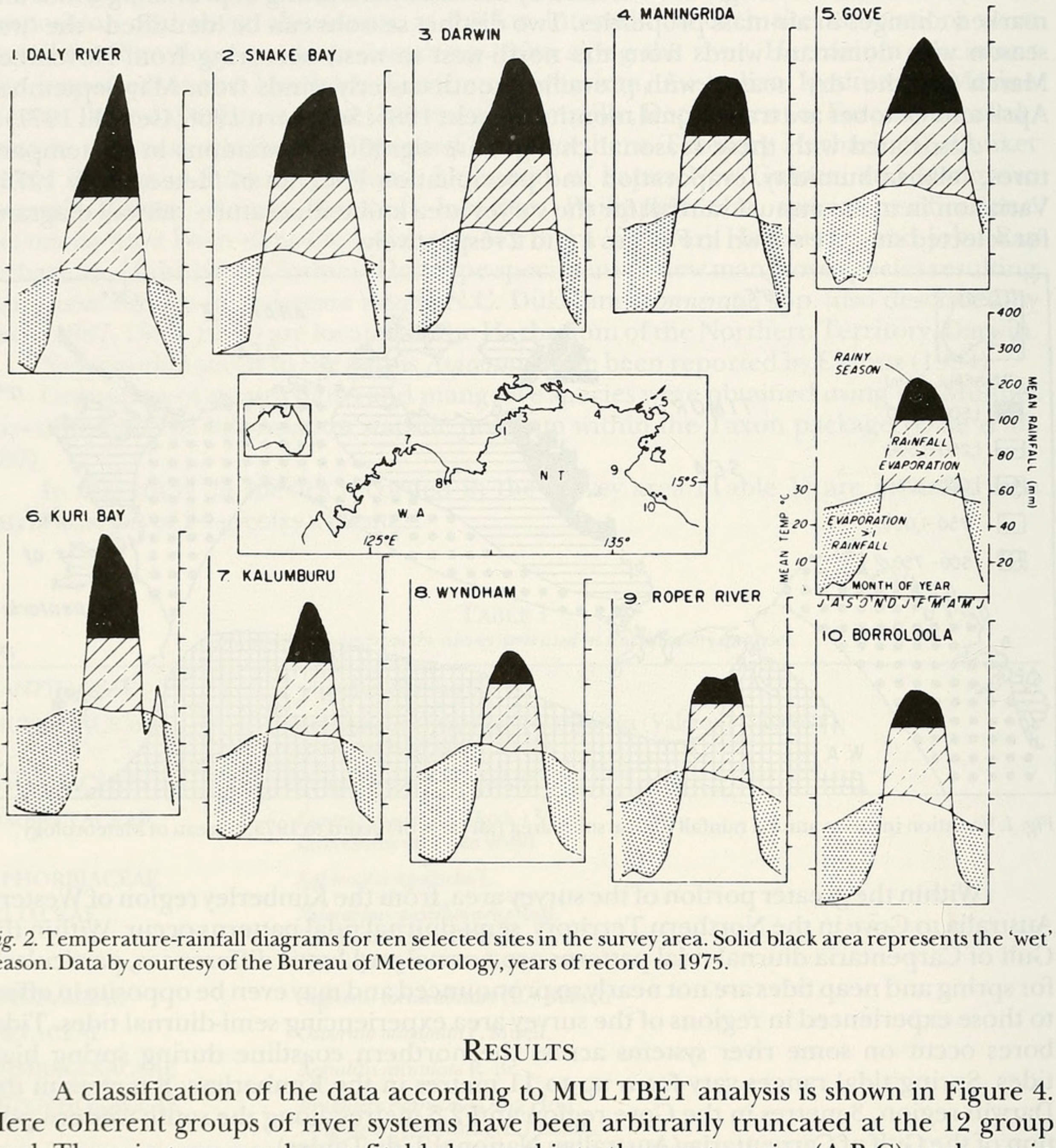

Fig. 2. Temperature-rainfall diagrams for ten selected sites in the survey area. Solid black area represents the 'wet' season. Data by courtesy of the Bureau of Meteorology, years of record to 1975.

Results

A classification of the data according to MULTBET analysis is shown in Figure 4. Here coherent groups of river systems have been arbitrarily truncated at the 12 group level. These in turn may be profitably lumped into three categories (A,B,C) as shown in Figure 4.

Grouping river systems rather than individual waterways as sites eliminates confusion due to between waterway variations in species composition found in any particular system. Category A systems represents floristically the least diverse sites (between 4-14 species). Such systems are seen in this analysis to occur only in the Gulf of Carpentaria and Joseph Bonaparte Gulf, in more seasonally arid portions of the survey area. Systems intermediate in their level of floristic diversity (Category B with between 11-16 species) represent systems throughout the Kimberley region of Western Australia and around Joseph Bonaparte Gulf and seawater systems across the northern coastline of the Northern Territory with only the Limmen Bight system from within the Gulf of Carpentaria. Category C systems with between 14-21 species are seen to occur only in the least seasonally arid areas across the northern coastline of the Northern Territory (11–12°S lat.)

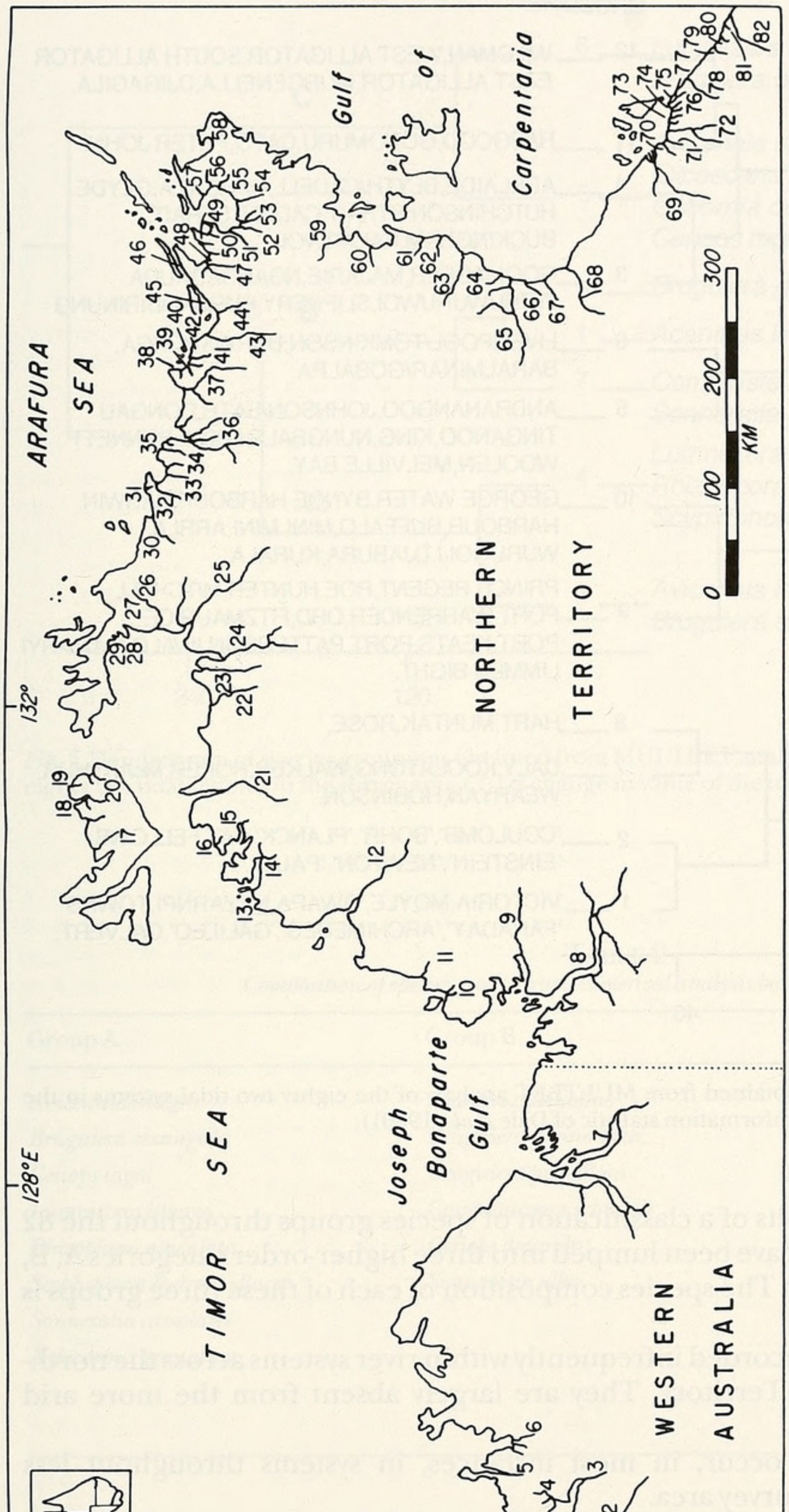

Fig. 3. Tidal systems of the survey area.

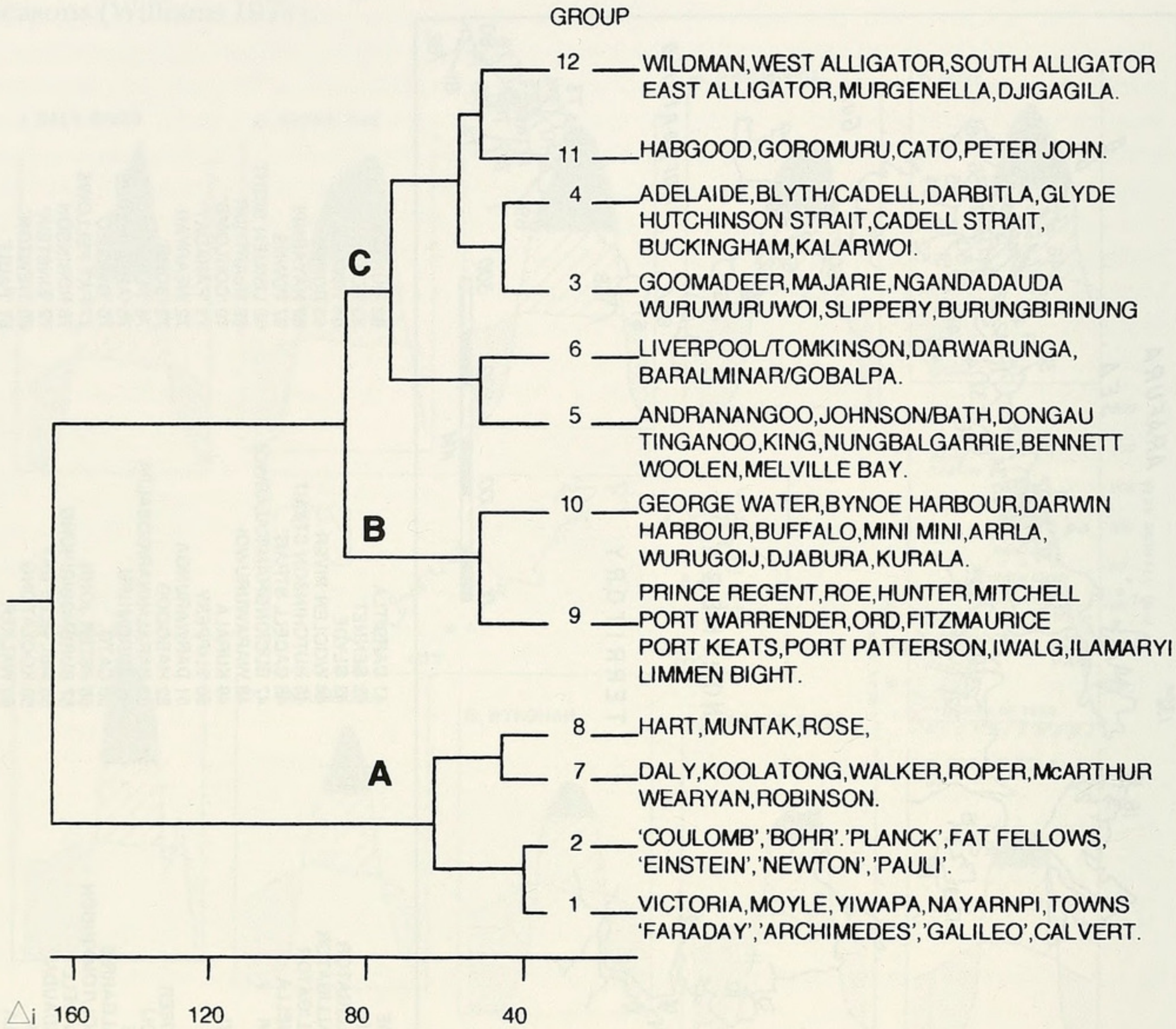

Fig. 4. Dendrogram of site groupings obtained from MULTBET analysis of the eighty two tidal systems in the survey area. △i is change in value of the information statistic of Dale *et al.* (1980)).

Figure 5 presents the results of a classification of species groups throughout the 82 sites surveyed. 7 species groups have been lumped into three higher-order categories A, B, C, as shown on the dendrogram. The species composition of each of these three groups is shown in Table 2.

Category A species were recorded infrequently within river systems across the northern coastline of the Northern Territory. They are largely absent from the more arid portions of the survey area.

Category B species also occur, in most instances, in systems throughout less seasonally arid portions of the survey area.

These species are considerably more common in occurrence than species represented in Category A (Wells 1984). Category C mangrove species are ubiquitous at least in some portion of most tidal systems in the survey area.

A two-way table of groupings of tidal systems based on presence/absence of mangrove species is shown in Figure 6. Here it is seen that a group of ubiquitous species (Species-Group 5), comprising *Avicennia marina* subsp. *eucalyptifolia, Excoecaria agallocha, Aegiceras corniculatum, Aegialitis annulata, Osbornia octodonta, Ceriops tagal* var. *australis* and

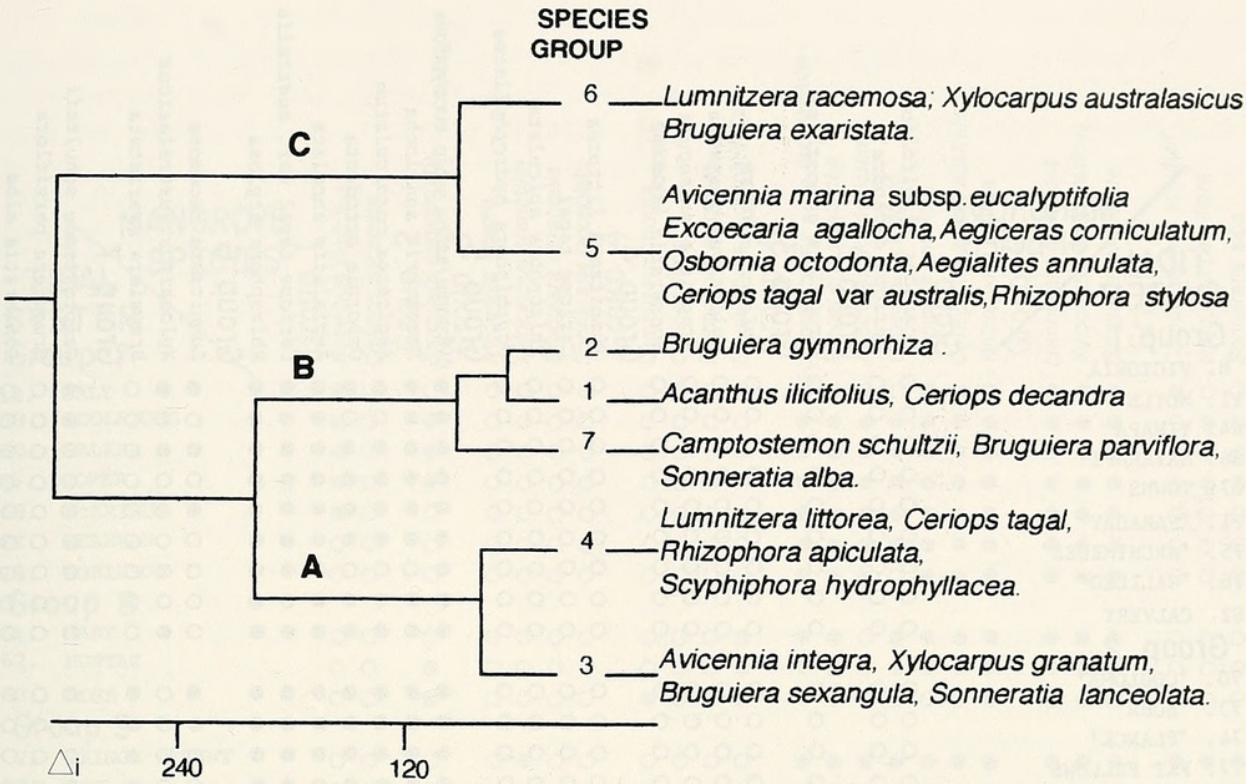

Fig. 5. Dendrogram of species groupings obtained from MULTBET analysis of mangrove species recorded for the eighty two tidal systems in the survey area (△i is change in value of the information statistic of Dale *et al.* (1980)).

TABLE 2

Composition of species groups from numerical analysis based on site distributions.

Group A	Group B	Group C
Avicennia integra	*Acanthus ilicifolius*	*Aegiceras corniculatum*
Bruguiera sexangula	*Bruguiera gymnorhiza*	*Aegialitis annulata*
Ceriops tagal	*Bruguiera parviflora*	*Avicennia marina* subsp *eucalyptifolia*
Lumnitzera littorea	*Camptostemon schultzii*	*Bruguiera exaristata*
Rhizophora apiculata	*Ceriops decandra*	*Ceriops tagal* var. *australis*
Scyphiphora hydrophyllacea	*Sonneratia alba*	*Excoecaria agallocha*
Sonneratia caseolaris		*Lumnitzera racemosa*
Xylocarpus granatum		*Osbornia octodonta*
		Rhizophora stylosa
		Xylocarpus australasicus

Rhizophora stylosa occurs at most sites. The grouping of tidal waterways on the basis of presence/absence of particular species or groups of species presents problems, not least of which is the increased importance of the 'rarer' species. Many species often emphasize specific habitats, assuming disproportionate importance and are ultimately responsible for many of the groupings formed in the analyses. The ubiquitous species, however, often contribute little to most groupings. Considerable care is thus required in interpreting some groupings.

TIDAL SYSTEM \ MANGROVE SPECIES	Group 1 *Acanthus ilicifolius*	*Ceriops decandra*	Group 2 *Bruguiera gymnorhiza*	Group 3 *Avicennia integra*	*Xylocarpus granatum*	*Bruguiera sexangula*	*Sonneratia lanceolata*	Group 4 *Lumnitzera littorea*	*Ceriops tagal*	*Rhizophora apiculata*	*Scyphiphora hydrophyllacea*	Group 5 *Avicennia marina* subsp. *eucalyptifolia*	*Excoecaria agallocha*	*Aegiceras corniculatum*	*Osbornia octodonta*	*Aegialitis annulata*	*Ceriops tagal* var. *australis*	*Rhizophora stylosa*	Group 6 *Lumnitzera racemosa*	*Xylocarpus australasicus*	*Bruguiera exaristata*	Group 7 *Camptostemon schultzii*	*Bruguiera parviflora*	*Sonneratia alba*
Group 1																								
8. VICTORIA	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	○	●	○	○
11. MOYLE	○	○	○	○	○	○	○	○	○	○	○	●	●	○	○	●	●	●	○	○	○	●	○	○
64. YIWAPA	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	○	○	○	○
66. NAYARNPI	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	○	○	○	○	○	○
67. TOWNS	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	○	○	○	○	○
71. 'FARADAY'	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	○	○	○	○	○	○
75. 'ARCHIMEDES'	○	○	○	○	○	○	○	○	○	○	○	●	○	○	○	●	●	●	○	○	○	○	○	○
76. 'GALILEO'	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	○	○	○	○	○	○
82. CALVERT	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	○	●	○	○	○	○
Group 2																								
70. 'COULOMB'	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	○	●	○	○	○
73. 'BOHR'	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	○	●	○	○	○
74. 'PLANCK'	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	○	○	●	○	○	○
77. FAT FELLOWS	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	○	○	●	○	○	○
79. 'EINSTEIN'	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	○	○	●	○	○	○
80. 'NEWTON'	○	○	○	○	○	○	○	○	○	○	○	●	●	●	○	●	●	●	○	○	●	○	○	○
81. 'PAULI'	○	○	○	○	○	○	○	○	○	○	○	●	●	○	●	●	●	●	●	○	●	○	○	○
Group 3																								
32 GOOMADEER	●	●	●	○	○	○	○	○	●	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
34. MAJARIE	●	●	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	○	●	●	●	●	●
38. NGANDADAUDA	●	●	○	○	○	○	○	○	●	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
48. WARAWURUWOI	●	●	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
50. SLIPPERY	●	●	○	○	○	○	○	○	●	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
57. BURUNGBIRINUNG	●	●	○	○	○	○	○	○	○	○	●	●	●	●	○	●	●	●	●	●	●	●	●	●
Group 4																								
21. ADELAIDE	●	●	●	●	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
37. BLYTH/CADELL	●	●	●	●	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
41. DARBITLA	●	●	●	●	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
43. GLYDE	●	●	●	●	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
45. HUTCHINSON STRAIT	●	●	●	○	○	○	○	●	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
46. CADELL STRAIT	●	●	●	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
47. BUCKINGHAM/KALARWOI	●	●	●	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
Group 5																								
17. ANDRANANGOO	●	●	●	○	●	○	●	○	○	●	●	●	●	●	●	●	●	●	●	●	●	○	●	●
18. JOHNSTON/BATH	●	●	●	○	○	○	○	●	○	●	●	●	●	●	●	●	●	●	●	●	●	○	●	●
19. DONGAU	○	●	●	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	○	●	●
20. TINANGOO	○	●	●	○	○	○	○	○	●	●	○	●	●	●	●	●	●	●	●	●	●	○	●	●
30. KING	●	●	●	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
35. NUNGBALGARRIE	●	●	●	○	○	○	○	○	○	●	○	●	●	●	●	●	●	●	●	●	●	●	●	●
42. BENNET	○	●	●	○	○	○	○	○	○	●	○	●	●	●	●	●	●	●	●	●	●	●	●	●
44. WOOLEN RIVER	●	●	●	○	○	○	○	●	○	●	●	●	●	●	●	●	●	●	○	●	●	●	●	●
58. MELVILLE BAY	●	●	●	○	●	○	○	●	○	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Group 6																								
36. LIVERPOOL/TOMKINSON	●	●	●	●	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
51. DARWARUNGA	●	●	●	○	○	○	○	●	●	○	●	●	●	●	●	●	●	●	●	●	●	●	●	●
53. BARALMINAR/GOBALPA	●	●	●	○	○	○	○	●	●	○	●	●	●	●	●	●	●	●	●	●	●	●	●	●

Fig. 6. Continued on next page.

TIDAL SYSTEM \ MANGROVE SPECIES	Group 1		Group 2	Group 3				Group 4				Group 5							Group 6			Group 7		
	Acanthus ilicifolius	*Ceriops decandra*	*Bruguiera gymnorhiza*	*Avicennia integra*	*Xylocarpus granatum*	*Bruguiera sexangula*	*Sonneratia lanceolata*	*Lumnitzera littorea*	*Ceriops tagal*	*Rhizophora apiculata*	*Scyphiphora hydrophyllacea*	*Avicennia marina* subsp. *eucalyptifolia*	*Excoecaria agallocha*	*Aegiceras corniculatum*	*Osbornia octodonta*	*Aegialitis annulata*	*Ceriops tagal* var. *australis*	*Rhizophora stylosa*	*Lumnitzera racemosa*	*Xylocarpus australasicus*	*Bruguiera exaristata*	*Camptostemon schultzii*	*Bruguiera parviflora*	*Sonneratia alba*
Group 7																								
12. DALY	●	○	○	○	○	○	○	○	○	○	○	●	●	●	○	●	○	●	●	●	●	●	○	○
59. KOOLATONG	●	○	●	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	○	●	○
60. WALKER	●	○	●	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	○	●	○
65. ROPER	●	○	●	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	○	●	○
69. McARTHUR	●	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	○	○	○
72. WEARYAN	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	○	○	○
78. ROBINSON	○	○	○	○	○	○	○	○	○	○	○	●	●	●	○	●	●	●	●	●	●	○	○	○
Group 8																								
61. HART	○	○	○	○	○	○	○	○	○	○	●	●	●	○	●	●	●	●	●	●	●	○	○	○
62. MUNTAK	○	○	●	○	○	○	○	○	○	○	●	●	●	○	●	●	●	●	●	●	●	○	○	○
63. ROSE	○	○	●	○	○	○	○	●	○	○	●	●	●	○	●	○	○	●	○	●	○	○	○	○
Group 9																								
2. PRINCE REGENT	○	○	○	○	●	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
3. ROE	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
4. HUNTER	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
5. MITCHELL	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
6. PORT WARRENDER	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
7. ORD	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	○	●
9. FITZMAURICE	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	○	○
10. PORT KEATS	○	○	○	○	○	○	○	○	○	○	○	●	○	●	●	●	●	●	●	●	○	●	●	●
13. PORT PATERSON	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
28. IWALG	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	○	●	●
29. ILAMARYI	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	○	●	●
68. LIMMEN BIGHT	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	○
Group 10																								
1. GEORGE WATER	○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	○	●	●	●	●	●
14. BYNOE HARBOUR	○	●	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●	●
15. DARWIN HARBOUR	○	●	●	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●	●
16. BUFFALO	○	○	●	●	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
27. MINI MINI	○	●	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
31. ARRLA	○	●	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
33. WURUGOIJ	○	●	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	○	●	●	●	●	●
39. DJABURA	○	●	○	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
49. KURALA	○	●	●	○	○	○	○	○	○	○	○	●	●	●	●	●	●	●	○	●	●	●	●	●
Group 11																								
52. HABGOOD	●	●	●	○	○	○	●	○	●	●	○	●	●	●	○	●	●	●	●	●	●	●	●	●
54. GOROMURU	●	●	●	○	○	○	●	○	●	○	○	●	●	●	○	●	●	●	●	●	●	●	●	●
55. CATO	●	●	●	○	○	●	●	○	●	●	○	●	●	●	●	●	●	●	●	●	●	●	●	●
56. PETER JOHN	●	○	○	○	○	●	●	○	○	●	●	●	●	●	●	○	●	●	●	●	●	●	●	●
Group 12																								
22. WILDMAN	●	●	○	●	○	○	●	○	○	○	○	●	●	●	○	●	●	●	●	●	●	●	●	●
23. WEST ALLIGATOR	●	●	●	●	○	○	●	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	○	●
24. SOUTH ALLIGATOR	○	○	○	●	○	○	●	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	○	●
25. EAST ALLIGATOR	●	○	○	●	○	○	●	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
26. MURGENELLA	●	●	○	●	○	○	●	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●
40. DJIGAGILA	●	●	○	●	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●	●	●

Fig. 6. Two-way table of site/species groups for the eighty two tidal systems in the survey area. Group numbers refer to multbet analysis, given for tidal systems in Figure 4 and for species in Figure 5.

DISCUSSION

There is a gradual decline in mangrove species richness southwards on both the east and west coasts of Australia (Saenger *et a*l., 1977; Semeniuk *et al.*, 1978; Love, 1981; Bunt, Williams and Duke, 1982; Wells, 1983; Duke, 1992; Semeniuk, 1993; Adam, 1994). At sites across the northern coastline of the Northern Territory (latitudes 11-13°S), 27 mangrove species have been recorded (Wells 1983). However, between latitudes 13 – 16°S, only 10-14 mangrove species are recorded in the area described in this paper. Such a reduction in species richness within only a few degrees of latitude is unusual and is not considered to result from latitudinal sifting, as on the east Australian coastline within an identical latitudinal range there is no decline in species richness (*cf.* Dowling and McDonald 1982).

Smith and Duke (1987) have devoted considerable attention to physical determinants of inter-estuary variation in mangrove species richness for northern Australia and utilizing data from the surveys reported here and their own data for the east Australian coast have concluded that estuary length, size of the surrounding catchment, rainfall variation and frequency of tropical cyclones have significant effects on species richness down the east Australian coastline, but not for mangrove forests throughout the Gulf of Carpentaria, and the northern coastlines of the Northern Territory and Western Australia. Reasons for species diversity are undoubtedly complex; however, their claim that estuaries with larger tidal amplitudes have fewer species than estuaries with smaller tidal ranges is not borne out by a simple inspection of Fig. 6 which shows many groupings of tidal systems (cf Groups 1, 7, 9, 10) — with similar species diversity — to include estuaries with both large and small tidal amplitudes [Australian National Tide Tables 1976+, Messel *et al.* (1979-82)]. In other cases many of the most floristically diverse estuaries *cf* Andranangoo, Goromuru, Habgood, Peter John, and Cato occupy extremely small catchments.

Consideration of the Site - Groups derived from the 82 tidal systems presents a tighter picture of floristic similarity and variation between latitudes and different climatic environments throughout the survey area. In grouping together all tidal waterways entering into a particular trunk stream, floristic variation between waterways in a particular system are profitably eliminated.

Site-Group 1 (Fig. 4) includes the Victoria, Moyle, Towns and Calvert systems, as well as several short coastal systems along the south-western shores of the Gulf of Carpentaria. As discussed by Wells (1984), all of these systems lie within extremely seasonally arid regions of the survey area and this is evidenced by a marked reduction in species diversity.

Site-Group 2 includes several more coastal systems along the south-western shores of the Gulf of Carpentaria. From an inspection of Figure 6 it is seen that this group is floristically most similar to Site-Group 1. As these systems also lie in seasonally arid regions of the survey area (Fig. 1 and 2), there is considerable merit in fusing Site-Groups 1 and 2 as systems of low species diversity.

Site-Groups 3, 5 and 6 are themselves floristically most similar to each other (Fig. 4 and Fig. 6), and includes systems occurring across the northern coastline of the Northern Territory only (Fig. 3). Sites within these groupings possess between 15-21 species, although it is apparent that irregular occurrences of less commonly recorded species (in Species-Groups 2, 3 and 4 of Fig. 6) do not in any way distract from the overall pattern and groupings. Floristically, Site-Groups 3, 4 5 and 6 have on average at least twice the number of mangrove species as Site-Groups 1 and 2.

Site - Groups 7 and 8 (Fig. 4) are also closely related floristically to Site-Groups 1 and 2, and although considerably less diverse in species than Site-Groups 3, 4, 5 and 6 have separated principally on irregular occurrence of *Acanthus ilicifolius, Bruguiera gymnorhiza, Camptostemon schultzii, Bruguiera parviflora, Lumnitzera littorea* and *Scyphiphora hydrophyllacea.* Increasing levels of seasonal aridity in these regions of the survey area maybe largely responsible for irregular occurrences of the latter mentioned species.

Site-Groups 9 and 10, also quite similar, separate from each other principally on occurrences of *Ceriops decandra, Bruguiera gymnorhiza* and *Scyphiphora hydrophyllacea* — present only in Group 10. Increasing levels of seasonal aridity in these regions of the survey area are considered to be largely responsible for irregular occurrences of the latter mentioned species. These groupings include all systems from the Kimberley, in Western Australia, and some sites from Joseph Bonaparte Gulf and the northern coastline of the Northern Territory (Fig. 6.).

Site-Groups 11 and 12 represent systems, with the exception of Djigagila, which occur either within Arnhem Bay or Van Diemen Gulf on the northern coastline of the Northern Territory where the regionality of these two groups is dramatically shown. Floristically these systems are most similar to each other and have recorded between 14-20 mangrove species. The occurrence of *Sonneratia lanceolata* is considered a major distinguishing species for both these groups from other groupings in this analysis and the additional presence at all sites in Group 12 only of *Avicennia integra* has resulted in the splitting of Group 11 from Group 12. The groupings shown in Fig. 4 and Fig. 6 have been made principally on sporadic occurrences of many of the less frequently observed mangrove species in the survey area.

Wells (1984) has shown that many mangrove species are disadvantaged in their ability to colonize all regions in monsoonal north Australia due to the presence of unfavourable currents during the wet season, the period when most fruiting occurs. Nevertheless, during cyclonic storms surface current directions are often reversed for considerable periods (Aust. Pilot Vol. 5,). Therefore floating fruits and hypocotyls of those mangrove species with restricted discontinuous distributions across the northern coastline of the Northern Territory could eventually reach all waterways of the survey area. That all species recorded in this study do not occur somewhere within all tidal systems is of considerable interest.

The three major site categories (A, B, C) for the 82 tidal systems appear to reflect local climatic variations across northern Australia. Sites occurring in category A (Fig. 4) show the lowest level of floristic diversity. They occur only within the Gulf of Carpentaria and Joseph Bonaparte Gulf. However, although the degree of seasonal aridity has been shown by Wells (1984) to be greater in these areas than elsewhere, such aridity is not the only factor responsible for much of the low diversity of mangrove species(Smith and Duke, 1987). The Daly River drains a large catchment area (51,800 km^2) and remains fresh above 40 km throughout most years (Messel *et al.* 1979-82). The resultant lack of extensive periods of brackish water inundation on this system has resulted in only 10 species being recorded. In fact, the Daly River System, although occurring in what has been shown in Fig. 1 as the wettest region, has amongst the lowest diversity of mangrove species for any site in the survey area. *Rhizophora stylosa*, a species which is fairly ubiquitous at most other sites, is only represented here by an occasional shrub, while absence of *Ceriops tagal* var. *australis* is most likely related to the nearly perennial freshwater inundation of sites. Macnae (1966), in particular, has pointed out that *Ceriops tagal* var. *australis* is often absent or infrequently observed on what are considered 'continually wet' portions of coastlines, although in the Daly River region there are distinct 'wet' and 'dry' seasons.

Tidal systems occurring in Category B (Fig. 4) are distributed almost entirely along the coasts of the Arafura and Timor Seas and are intermediate in floristic diversity between Categories A and C. Low species richness for systems within the Kimberley region of Western Australia (up to 14 species) and from Joseph Bonaparte Gulf (up to 12 species) appears to be largely a response to dry season aridity experienced in these regions. However, lack of suitable sites for colonisation by mangrove species due to rapidly rising land gradients, macro-tidal fluctuations (up to 11 metres) in many tidal waterways of the Kimberleys and unfavourable surface sea currents during fruiting periods may also contribute to low species richness (Wells, 1984).

Other river systems in Category B, such as Port Paterson, Bynoe and Darwin Harbours, Buffalo, Mini Mini, Iwalg, Arrla, Wurugoij and Djabura Creeks; Ilamaryi and Kurala Rivers, although occurring across the northern coastline of the Northern Territory — a less seasonally arid area — are also quite poor in mangrove species. All these tidal systems experience seawater salinities for most of the year and in some cases even become quite hypersaline by the end of the dry season (Messel *et al.* 1979 – 82). Such saline conditions could limit establishment of some mangrove species. The Limmen Bight System is included within Category B because of the presence of occasional shrubs of *Camptostemon schultzii.* This species has not been recorded from any other system surveyed down the east coast of Arnhem Land in the Gulf of Carpentaria. Reasons for the absence of *Camptostemon schultzii* in other systems in the Gulf of Carpentaria are unknown although it is considered that its absence here and the extreme rarity of the species at systems around Joseph Bonaparte Gulf may be related to a slightly higher level of seasonal aridity and more frequent occurrences of desiccating south-east trade winds and lower night temperatures during the dry season. *Camptostemon schultzii* is extremely abundant in mangrove swamps throughout the Kimberley region of Western Australia, which although experiencing considerable seasonal aridity, is largely protected from the south-east trade winds (blowing across from the interior of the Australian continent) by the high cliffs (300 metres) abutting mangrove swamps (Wells, 1981). Such rock outcrops may also act as microclimatic heat sinks raising dry season night temperatures and might be partially responsible for some restricted distributions of mangrove species in the Kimberley (*cf Xylocarpus granatum*).

Category C systems are floristically most diverse with 14-21 species. Such systems occur only across the northern coastline of the Northern Territory (11-12°S latitude) and are in regions receiving high annual precipitation with most also receiving at least a minimal amount of precipitation throughout 'dry' season months. For Category C sites, mean annual relative humidities are generally higher and mean annual evaporation losses much lower (Bureau of Meteorology, 1975) than for sites occurring throughout the Gulf of Carpentaria, Joseph Bonaparte Gulf and Kimberley regions. It is considered that the species/site groupings given in Fig. 6, in particular, are greatly influenced by climatic variation within the survey area. Many other factors have been noted as influencing floristic diversity of mangrove species within tidal waterways across northern Australia (Wells, 1984; Smith and Duke, 1987; Semeniuk, 1993). However, only when biogeographic, microclimatic and edaphic data for individual sites within these mangrove communities are available will a better understanding of known variations in species distributions in this survey area be attainable.

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