INLAND WATERS OF THE PILBARA WESTERN AUSTRALIA (PART 1)

Environmental Protection Authority
Perth, Western Australia
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"A contribution to the State Conservation Strategy"

INLAND WATERS OF THE PILBARA, WESTERN AUSTRALIA

PART 1

A REPORT OF A FIELD STUDY CARRIED OUT

IN MARCH-APRIL, 1983

by

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Perth, Western Australia

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Cover Photograph: Crossing Pool, Millstream-Chichester National Park.

Back-Cover Photograph: Eera Baranna Spring, Chichester Ranges.

(Photographs by R J Masini)

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Participants :

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Note: Since preparation of this Report, The Forests Department, the Wildlife Division of the Department of Fisheries and Wildlife and the National Parks Authority have been amalgamated as the Department of Conservation and Land Management. The Public Works Department is now the Water Authority of Western Australia, and the Department of Conservation and Environment is now the Environmental Protection Authority.

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1. INTRODUCTION

1.1 BACKGROUND TO THE STUDY

In 1976 the Environmental Protection Authority identified the need to conserve wetland resources. Steps are being taken to do this in the south-west of Western Australia. The inland surface water resources of the semi-arid and arid areas of the State, notably the Pilbara, are less well known, and the pressures on them are less well understood.

In the south-west of the State, lakes, swamps and rivers are affected by clearing and drainage for rural and urban developments, by changes in salinity and by nutrient enrichment from agricultural fertilisers and waste disposal. In the Pilbara, the factors which could place inland surface waters in jeopardy are rather different. They include changing patterns of water use and increased demands for water, increased human access for recreation, and other developmental pressures. Because of the importance of water in the arid Pilbara environment, to wildlife, stock, residents and visitors, there was a clear need to better understand the resource.

A study of inland surface waters of the Pilbara was begun in 1983 with the following long-term objectives:

1. To produce an inventory of permanent and ephemeral inland surface waters which identifies and documents:

    (i) significant physical and biological characteristics;

    (ii) land tenure;

    (iii) amenity, conservation and recreational values; and

    (iv) pressures arising from existing and potential land uses, human access and population centres.

2. To classify the waters, using significant physical and biological characteristics.

3. To establish priorities for management and/or reservation.

4. To develop guidelines for appropriate conservation and management.

This report is concerned with a first phase of the Study and has three main objectives:

(i) To identify and document, as far as possible, inland surface waters in the Fortescue and De Grey river catchments in terms of their important physical and biological characteristics;

(ii) To develop a preliminary classification system based on observations made in the field; and

(iii) To make recommendations for future phases of the study.

1.2 DEFINITIONS

Definitions of <u>inland surface waters</u>, or <u>wetlands</u>, are broad and in general are formulated with particular regions and study aims in mind. For example Paijmans (1978) in his feasibility report on an Australian National Wetland Survey concluded that main river channels did not constitute wetlands and should be excluded from the survey. This approach may be useful in terms of a broad survey in largely temperate environments. However, in the Pilbara, where river flow is spasmodic and river pools are a significant part of the inland surface water resource, a survey using this definition as a working base would be inappropriate.

The definition of a wetland as accepted by the Wetlands Advisory Committee of the Western Australian Department of Conservation and Environment includes river channels as wetlands and has been adopted in this study:

"Wetlands are areas of seasonally, intermittently or permanently waterlogged soils or inundated land whether natural or otherwise, fresh or saline, eg waterlogged soils, ponds, billabongs, lakes, swamps, tidal flats, estuaries, rivers and their tributaries" (Wetlands Advisory Committee, 1977).

The Pilbara region lies north of the tropic of Capricorn and for the purposes of this study is defined as the area encompassed by the watersheds of the Ashburton, Fortescue and De Grey river systems (see Pilbara Study Group Report, June 1974, Map 1). The terms 'inland surface water' and 'wetland' are used interchangeably.

1.3 CLIMATE

The Pilbara has an arid climate: the result of the presence over the region of two air masses - Indian Tropical Maritime air moving in from the west or north-west; and Tropical Continental air from the inland. During the warmer half of the year, there is a hot low-pressure system over the region almost continually, caused by the transport of warm air from the south-east. This heat inflow and associated clear skies result in very high temperatures from November to February with average maxima often exceeding 40°C.

The Pilbara lies south of the area normally penetrated by the 'north-west monsoon' in the summer months, and is only occasionally influenced by weather systems of the westerly circulation in the winter months; an influence which is normally restricted to the south-west of the Pilbara. Rainfall is therefore low and variable. Average rainfall over the area ranges from about 200 mm to 350 mm, though may vary widely from the average in individual years. Most of this rain falls between December and June, with a pronounced dry period between August and November (Figure 1). Average yearly evaporation (about 2,500 $mm.yr^{-1}$) exceeds average yearly rainfall throughout the year (Davidson, 1975).

The area is subject to occasional tropical cyclones, usually between January and April, with a frequency of about seven in every decade. Tropical cyclones contribute 40 to 60% of the north coast rainfall, while in the south and west, 20 to 30% is derived from this source. The cyclonic influence results in 24-hour 10-year recurrence storm rainfall recordings of 100 mm to 250 mm.

1.4 PILBARA RIVER GEOMORPHOLOGY

The ephemeral Pilbara rivers have developed through stream rejuvenation since the Tertiary (Kriewaldt and Ryan, 1967). The river systems are shown in Figure 2. A major catchment divide is provided by the Chichester Range, a greatly undulating plateau developed on lower Proterozoic Fortescue Group lavas and volcanogenic sediments. The ranges form a watershed between north-flowing river systems (including the Harding, Maitland, Yule, Turner and De Grey) and the westerly flowing Fortescue River.

The headwaters of the north-flowing rivers have dendritic drainage patterns and are developed on large flat plains underlain by Archaean granite. These plains are occasionally interrupted by low hills of granite, dolerite or quartz. These rivers lead downstream into well-developed coastal drainage systems with braided stream channels and discontinuous anabranches. In the north of the area, streams are locally controlled by the steep ranges and high level gently undulating plains of the George Ranges.

On the southern flank of the Chichester Range, the drainage pattern changes from dendritic to parallel. The streams are short and end on the alluvial plain of the Fortescue River Valley in a series of coalescing outwash fans.

The Fortescue River Valley contains two major catchment systems. The upper catchment is referred to as the Fortescue River Floodout Catchment (Main Roads Department, 1984) and is separated from the Lower Fortescue Catchment by the Goodiadarrie Hills. The area east of the divide in the valley banks up water into extensive 'floodout' lowlands during flow periods. This water has been known to bank up past Roy Hill Station some 100 km east.

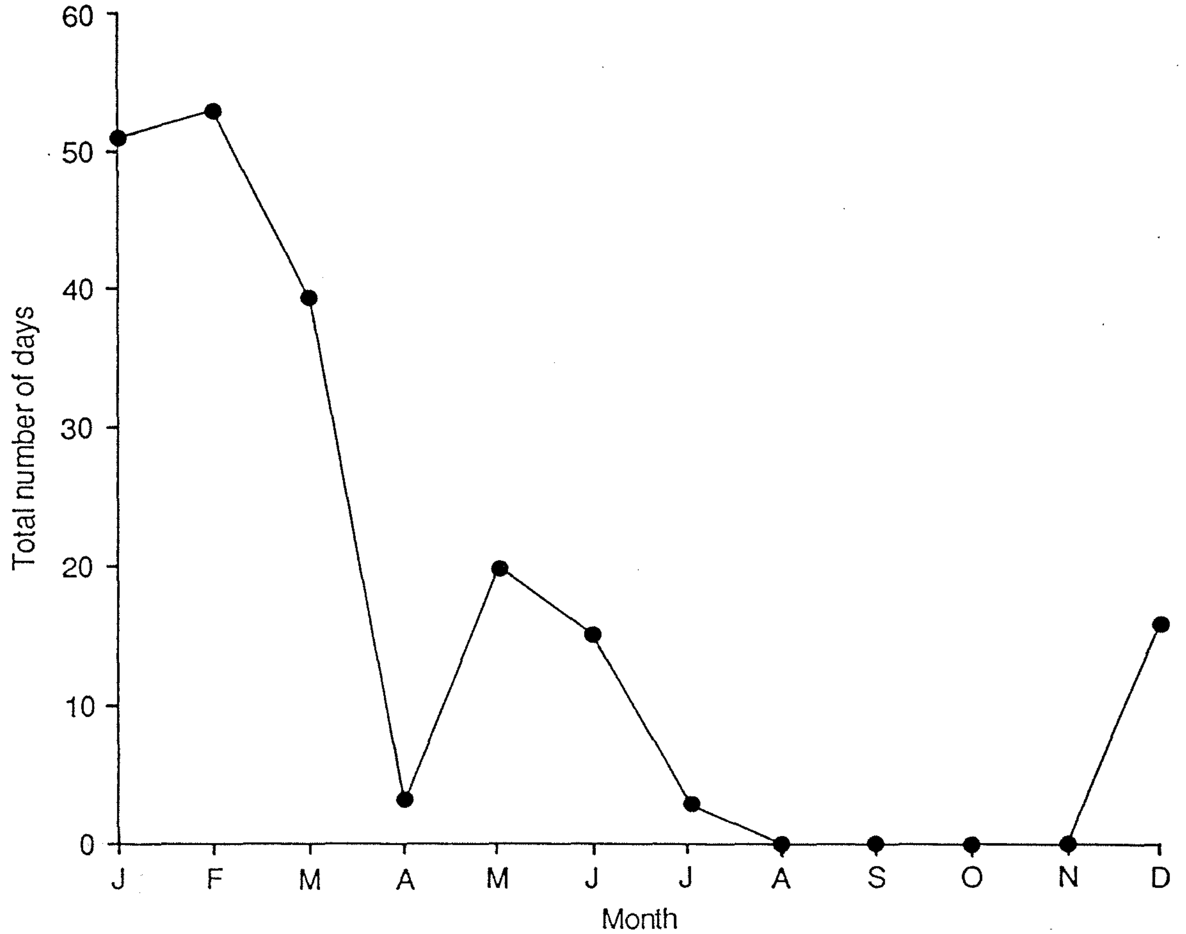


Figure 1. Total number of days per month of significant rainfall (> 1 mm) for 20 recording stations in the Pilbara from 1970-1980.

Source: Calculations based on Bureau of Meteorology data.

The actual Fortescue River is narrow immediately west of the divide, but due to very low surface gradients, the flows spread out and form ephemeral, narrow, elongated claypans.

The drainage lines on the northern flanks of the Hamersley Plateau (developed on lower Proterozoic volcanogenic sediments and volcanics) are parallel, short, have steep gradients and terminate in large coalescing outwash fans. Further south on the plateau, the patterns are dendritic with frequently interrupted drainage lines. The plains on the plateau often act as internal drainage basins, holding large volumes of water after cyclonic rains.

Cyclones cause major flows in a number of rivers almost every year. These flows commence between December and April and may persist into May or June. Winter rains in May, June or July can also produce significant flows. However, winter flows are more likely to occur in the rivers of the western Pilbara than in those further east because of a gradient of declining precipitation from west to east. The rivers are generally dry, experiencing only occasional short-lived flows between August and November.

Localised river flows may be sustained by small but continuous spring discharges from aquifers intersected by river channels.

2. METHODS

2.1 FIELD WORK

Field work was carried out from 10 March to 22 April, 1983. During that time 4,000 km was travelled within an area of 60,000 km^2. Accessibility was an important factor in site selection, particularly in the latter half of the Study because Cyclone Lena caused flooding which prevented travel to sites on the Oakover River.

Because of the remoteness of the Pilbara, use was made of a 4-wheel drive vehicle equipped with long-range fuel tanks, spare parts and a HF radio so that repairs could be carried out and contact made with Port Hedland Royal Flying Doctor Base if emergencies arose. Sufficient provisions and fuel were carried for several weeks work away from sources of supplies. As only a small amount of space was available for collecting gear and specimens, sampling of the fauna was limited. Appropriate licences to collect plants and animals were obtained from the Department of Fisheries and Wildlife

During the course of the study 76 sites were surveyed. Observations were made on a number of physical and biological characteristics at each site visited. Land tenure was ascertained from cadastral maps. Field observations were recorded on an amended version of Paijmans' (1978) proforma. This proforma was subsequently revised on the basis of field experience and from reference to a report on a field study of African wetlands (Morgan and Boy, 1982). The revised proforma (see Appendix 1) is recommended for recording field data on subsequent field studies of Pilbara inland waters.

The system of springs and pools at Millstream is the best known body of inland water in the Pilbara. Because it has been studied in some detail (Dames and Moore, 1975), and because the importance of Millstream is recognized by its National Park status, it was not intensively sampled in the course of this study.

The methods used for measuring and observing parameters are briefly outlined below.

2.2 PHYSICAL CHARACTERISTICS

Water temperature, conductivity, dissolved oxygen, pH and turbidity of surface waters (0-10 cm depth unless stated otherwise) were recorded with a thermometer and a Horiba U.7 Water Checker, Horiba Ltd Japan. Surface water permanency, water source and the relationship to groundwater were assessed where possible by direct observation and by reference to anecdotal data from local people familiar with the site. Observations of substrate types and bed gradients were also made.

The area and depth of each water body were estimated and recorded for the time of sampling. Estimates were made of prior maximum flood levels from flood debris along levee banks and caught in trees.

2.3 BIOLOGICAL CHARACTERISTICS

The dominant floral and characteristic faunal associations of different wetland types were examined to obtain base-line data useful in the formulation of a suitable classification system for the surface waters of the Pilbara region.

(i) Fringing vegetation - The fringing vegetation was sampled along a transect from the land/water interface to a point designated as the limit of wetland influence (eg top of a levee bank) and recording apparent zonation patterns. Plant specimens were collected, pressed and dried in the field, and mounted on herbarium sheets (often more than one specimen per sheet due to space limitations) for later identification.

Preliminary identifications were made in the field and at Karratha with the assistance of W Edgecombe and P Ryan from the Forests Department. Identifications were verified by M E Trudgen using the facilities of the W A Herbarium. Specimens will be mounted and used as aids for plant identification during future studies in the region.

(ii) Aquatic vegetation - The emergent and submerged aquatic macrophytes were sampled and zonations recorded. Specimens were collected and treated similarly to those of fringing vegetation. The more delicate submerged plants were preserved in 10% formalin.

(iii) Phytoplankton - Phytoplankton was sampled to determine concentration and major genera present. A known quantity of sample water, up to 1 L, was filtered through a Whatman 2.5 cm D GF/C filter. The filter was airdried and stored in the dark for subsequent determination of the major chlorophyll concentrations by the trichromatic method (Strickland and Parsons, 1972). A 5 ml water sample was also passed through a Metrical

GN-6 filter, 13 mm D with a 0.45 μ pore size, airdried in the shade and mounted in immersion oil on a microscope slide. After a coverslip was placed over the mounted filter, the slides were carefully wrapped in tissue paper and stored in the dark for later identification of major algal genera. Specimens of the larger filamentous and macroscopic algae were collected and preserved in 10% formalin solution.

(iv) Fauna - A limited faunal survey was performed by observations of non-passerine birds and fish populations. Zooplankton was sampled by passing 20 L of water through a 64 μ cloth and resuspending the sample in 12% formalin solution for later identification. The samples were sorted and identified by P Davies of the Department of Zoology, University of Western Australia.

2.4 LAND TENURE

Land tenure was determined from cadastral maps, and land use by general observation.

2.5 CLASSIFICATION OF WETLANDS

2.5.1 PHYSICAL CLASSIFICATION

From observations of the sites visited, five physical characteristics were selected as being useful in describing them and in identifying the similarities and differences between them. The five criteria used and comments on them are presented below:

(i) Water source : from either direct runoff or groundwater sources (or a combination of both).

(ii) Relationship to groundwater : This important relationship needs to be defined further by a hydrologist as detailed examination was not possible during this study.

(iii) Persistence : length of time in which water is available to the dependent biota. This was often difficult to assess accurately, but information from local informants was helpful. The persistence of available water during an average rainfall year ranges through:

Permanent - water available, near or at the land surface for dependent biota for all of the time;

Semi-permanent - as above, but biota may be subject to significant water stress during the dry season;

Ephemeral - water available for a few months of the year, dependent upon significant rainfall within catchment; and

Intermittent - water available for only short periods after rain.

(iv) Gradient of bed : as seen in the field for the water bodies surveyed (ie low, medium or steep) but requires further hydrogeological study.

(v) Substrate : a) type - predominant size fractions of bed material assessed by observation; and

b) permeability - relates to infiltration rate of the pool floor and flow through the substrate.

These characters were used to subjectively classify the wetlands into groups with similar physical characteristics.

2.5.2 NUMERICAL CLASSIFICATION

The vegetation data collected during this Study was analysed objectively, using the computer package TWINSPAN (Two Way Indicator Species Analysis) housed at the University of Western Australia. This computer package is designed for use on species presence/absence data and involves a comparison of species found at one site, to those found at other sites (Hill, 1979).

The output of TWINSPAN is in the form of a table which identifies groups of both species and sites. This enables a dendrogram to be drawn, which suggests a hierarchical relationship between groups of samples (species) and sites, so that sites with similar species are grouped (clustered) together.

Of the plant species collected, over 50% were restricted to one site: so to facilitate interpretation, only the 100 most common species were used in the analysis.

3. **RESULTS AND DISCUSSION**

3.1 GENERAL

Unlike much of the southwest of Western Australia, surface water in the Pilbara region is generally associated with rivers or other smaller drainage lines. Table 1 presents a list of sites visited, their location, tenure and usage. Location is also shown on Figure 2.

3.2 AREA AND DEPTH

The area and depth of an inland water body at any given time depends on the nature of the substrate, the profile, and in the case of rivers, gradient of the bed and time elapsed since the last major rainfall event in the catchment.

In general, peak flood levels, interpreted from debris zones on the banks and caught in trees, are between 1.5 and 2.5 m above normal dry season levels. The water depth is limited by the height of the levee bank. Overflow results in a vast increase in area with no significant depth increase. This generalization holds true for most water bodies, apart from the primary channels of the large rivers during peak flood conditions. Water would normally remain at maximum depths for short periods.

3.3 PHYSICAL CLASSIFICATION OF SURFACE WATERS

Nine subjective types of inland water were recognised using the significant physical characteristics. These nine types form the basis of a preliminary classification system (Table 2). The general relationship between the nine types and the landscape is schematically represented in Figure 3.

This report will use the nine groups identified by their physical characteristics as the frame of reference (see also section 3.5.5).

A description of the nine types of inland waters is presented below. Schematic diagrams of selected sites representative of each type are shown in Figures 4-11.

1. Spring

Springs vary with season and site characteristics. In the Hamersley and Chichester Ranges, both sets of springs examined consisted of a series of interconnected pools (up to 4.5 m deep in Eera Baranna), with water flowing from one to the next down a medium to steep gradient. Fed by associated aquifers, springs provide permanent sources of water for their associated biota in all but extended drought conditions (see Eera Baranna Spring, Figure 4).

2. Primary River Pool

Deep permanent and semi-permanent river pools (see Kunagunarrina Pool, Figure 5) tend to occur on the outer edge of meanders, or where the river is confined in a narrow section. In both cases active erosion during flood flows results in river bed scouring. The pools are initially filled by river flows but are sustained after flow ceases by water inputs either from

Table 1. Name, location and status of wetland sites studied in the survey, March-April 1983.

Site Number	Name	Map Number & Name 1 : 100 000 Series		Map Coordinates E	N	Land Use	Station Name	Lease Number	Reserves
1	Fortescue River Mouth	2155 : Fortescue		05	76	Pastoral Recreation	Mardie	3114 1027	380 (Public Purposes 259 ha)
2	Fortescue River 2.5 km	2155 : Fortescue		055	750	Pastoral	Mardie	3114 1027	380 (Public Purposes 259 ha)
3-5	Post Office Pool	2155 : Fortescue		065	730	Pastoral	Mardie	3114 1027	381 (Public Purposes 38 ha)
6	Bilanoo Pool	2155 : Fortescue		10	44	Pastoral			
7	Millstream-Palm Spring	2345 : Millstream		04	14	National Park			A24392 (Millstream-Chichester National Park 435 ha)
8-9	Millstream-Crossing Pool	2354 : Millstream		088	138	National Park			A24392 (Millstream-Chichester National Park 435 ha)
10	Millstream-Woodley Spring	2354 : Millstream		053	123				
11-12	Millstream-Crystal Pool	2345 : Millstream		070	123	National Park			A24392 (Millstream-Chichester National Park 435 ha)
13	Roy Hill 1	2852 : Roy Hill	QA	94	02	Pastoral	Roy Hill	3114 983	
14	Roy Hill 2	2852 : Roy Hill	RV	01	99	Pastoral	Roy Hill	3114 983	
15	Roy Hill 3	2852 : Roy Hill	RV	03	95	Pastoral	Roy Hill	3114 983	
16,17	Port Hedland-Newman Crossing	2852 : Roy Hill	RV	048	927	Pastoral	Roy Hill	3114 983	
18,19	Minnorinna Pool	2355 : Cooya Pooya		075	424	National Park			A30071 (Millstream-Chichester National Park 150 609 ha)

Table 1. Name, location and status of wetland sites studied in the survey, March-April 1983. (contd)

Site Number	Name	Map Number & Name 1 : 100 000 Series	Map Coordinates E	N	Land Use	Station Name	Lease Number	Reserves
20,21	Hooley Creek Nos 1 and 2	2454 : Mount Billroth	030	795	Pastoral	Mt Florance	3114 465	5515 (Water 259 ha)
22	Gnalka Gnoona	2553 : Wittenoom	52	49	Pastoral	Mulga Downs	3114 1047	1328 (Water and Stopping Place 259 ha)
23	Weeli Wolli Creek at Marabee	2752 : Weeli Wolli QA	318	018	Pastoral	Marillana	3114 984	
24,25	Junction : Marillana and Yandicoogina	2752 : Weeli Wolli QV	29	78	Pastoral	Marillana	3114 984	
26-32	Weeli Wolli Springs	2752 : Weeli Wolli	25 to 26	63 63	Pastoral	Marillana	3114 984	
33-34	Coondiner Pool	2852 : Roy Hill QV	729	842	Pastoral	Marillana	3114 984	
35	De Grey Q line Pool	2757 : De Grey	315	555		De Grey	3114 1142	
36	De Grey False I line Pool	2757 : De Grey	399	504		De Grey	3114 1142	
37	De Grey I line Pool	2757 : De Grey	440	478		De Grey	3114 1142	
38	De Grey Borefield Claypans	2757 : De Grey	45	51		De Grey	3114 1142	
39	Mulyie Pool	2856 : Coongan QC	68	29		De Grey	3114 1142	
40	Shay Gap, semi-permanent	2956 : Muccan	98	26		Muccan	3114 713	
41	Muccan Crossing	2956 : Muccan	94	16		Muccan	3114 713	
42,43	Red Rock Creek	2756 : Carlindie	165	220		Carlindie	3114 638	

Table 1. Name, location and status of wetland sites studied in the survey, March-April 1983. (contd)

Site Number	Name	Map Number & Name 1 : 100 000 Series		Map Coordinates E	N	Land Use	Station Name	Lease Number	Reserves
44	West Strelley River	2756 : Carlindie		20	19		Carlindie	3114 638	
45	Shaw River	2756 : Carlindie		42	07		Carlindie	3114 638	
46	Marble Bar Claypan	2855 : Marble Bar		96	74	Pastoral	Eginbah	3114 1120	
47	Marble Bar Dredge Pool	2855 : Marble Bar		999	567	Pastoral	Eginbah	3114 1120	
48	Garden Pool	2954 : Nullagine	SR	995	736	Cammon			2804 (Common 19 655 ha)
49,50	Five Mile Creek	2954 : Nullagine	TR	128	678	Pastoral	Bonney Downs	3114 1185	
51	Yule River North West Coastal Highway Bridge	2556 : Yule		350	103	Pastoral	Munda-bullangana	3114 517	
52,53	Chinnamon Pool	2655 : Wodgina		788	749	Pastoral	Tabba Tabba	3114 1102	
54-64	Eera Baranna Springs	2654 : White Springs		635	700	Pastoral	Hooley	3114 1074	
65,66	Turner River East Branch-Boodarie	2557 : Thouin		51	40	Pastoral	Boodarie	3114 618	
67,68	Turner River North West Coastal Highway	2556 : Yule		53	29	Pastoral	Munda-bullangana	3114 517	
69	Kunagunarrina Pool	2655 : Wodgina		90	48	Pastoral	Tabba Tabba	3114 1102	
70	Roebourne Pool 3#	2356 : Roebourne		173	066				

Table 1. Name, location and status of wetland sites studied in the survey, March-April 1983. (contd)

Site Number	Name	Map Number & Name 1 : 100 000 Series	Map Coordinates E	Map Coordinates N	Land Use	Station Name	Lease Number	Reserves
71	Roebourne Pool 1#	2356 : Roebourne	152	027				
72	Bamba Pool	2356 : Roebourne	12	85	Pastoral	Mount Welcome	3114 716	
73	Lockyer's Gorge	2355 : Cooya Pooya	125	776		Mount Welcome	3114 716	
74	Poverty Creek Claypan	2456 : Sherlock	02	92	Pastoral	MacRoy	3114 1029	3089 (Timber Protection 259 ha)
75	Doolena Gap	2856 : Coongan	90	83	Pastoral	Eginbah	3114 1120	4975 (Water 1036 ha)
76	Cowra	2753 : Mount Marsh QA	70	27		Mulga Downs	3114 1047	

Footnote:

numbers refer to Harding Report (Dames and Moore, 1982)

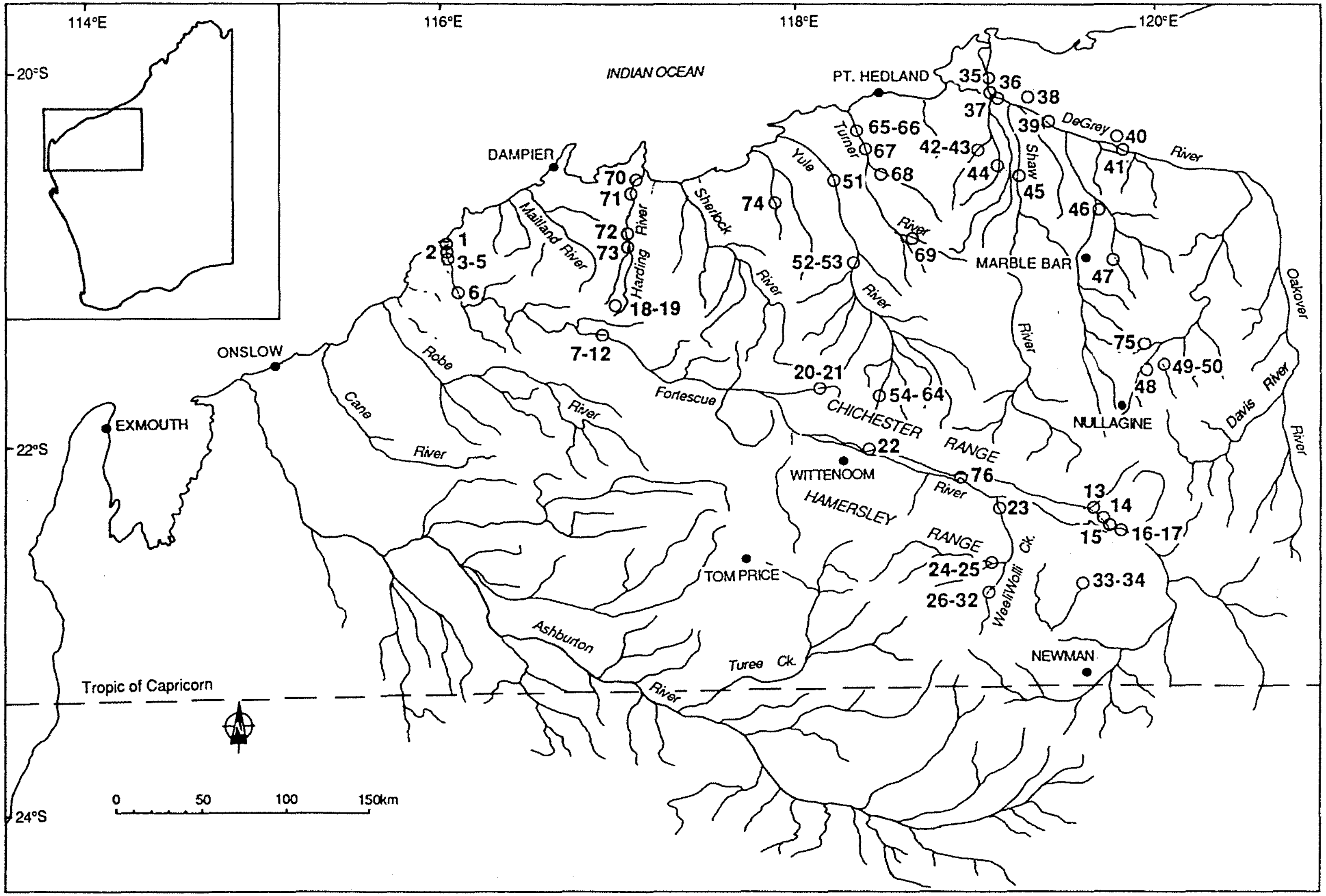


Figure 2. The Pilbara region showing major river systems and landforms, together with locations of sites visited in March-April, 1983. Numbers assigned to sites are used for identification throughout the report.

Table 2. Wetland sites classified according to characteristic water source, relationship to groundwater, persistence, gradient of bed and predominant substrate.

Wetland Type and Number	Water Source *	Relationship to Groundwater	Persistence	Gradient of Bed	Predominant Substrate Type	Predominant Substrate Permeability	Site Name and Number
1. SPRING	Aquifer	Watertable at surface	Permanent	Steep-medium	Shallow bedrock. unsorted .... alluvium	Very low High	Weeli Wolli Springs (26-32); Eera Barana Springs (54-64); Millstream (7-12)
2. PRIMARY RIVER POOL	Residue from river flow, bank storage and occasionally maintained by ground-water	Watertable often shallow - ie less than 2 m for most of year	Permanent - semi-permanent	Low	Variable: upper catchment bedrock and fine to medium alluvium; lower catchment fine-grained alluviums	Mixed - low	Bilanoo Pool (6); Kunagunarrina Pool (69); Chinnaman Pool (52, 53); Garden Pool (48); Minnorinna Pool (18, 19); Lockyer's Gorge (73); Mulyie (39); Bamba Pool (72); Junction:Marillan and Yandicoogina Creeks (24,25); Turner River, NWC Hwy (67,68) Weeli Wolli Creek at Marabee (23); Roebourne Pool 3 (70); Roebourne Pool 1 (71)
3. HEADWATER STREAM OR DRAINAGE CHANNEL	Runoff from catchment after rain	Ill-defined perched watertable, shallow	Ephemeral intermittent	Steep - medium	Coarse, unsorted alluvium .... over bedrock	 High Very low	Five Mile Creek (49,50); Doolena Gap (75)
4. PRIMARY RIVER CHANNEL	Rainfall in catchment via stream flow	Watertable greater than 2 m depth	Ephemeral	Medium - low	Thin layer of fine colloidal material .... (cracks on drying) over-lying medium to coarse-grained alluviums	Low High	Turner River, East Branch-Boodarie (65,66); Muccan Crossing (41); De Grey Q line Pool (35); De Grey I line Pool (37); De Grey False I line Pool (36); Yule River;NWC Hwy Bridge (51) Roy Hill (13,14); Yarrie Spring (15); Port Hedland-Newman Road Crossing (16,17) West Strelley River (44); Shaw River (45)

Table 2. Wetland sites classified according to characteristic water source, relationship to groundwater, persistence, gradient of bed and predominant substrate (contd)

Wetland Type and Number	Water Source *	Relationship to Groundwater	Persistence	Gradient of Bed	Predominant Substrate Type	Predominant Substrate Permeability	Site Name and Number
5. ADJOINING POOL	Stream outflow (outside true drainage channel)	Unknown	Ephemeral - inter-mittent	Effectively nil	Fine-grained alluvium	Low	Red Rock Creek (42, 43) Shay Gap, semi-permanent (40)
6 EPHEMERAL CLAYPAN	Local runoff via sheet flow or seepage	Variable - unknown	Ephemeral - inter-mittent	Effectively nil	Fine-grained alluvium	Low	Marble Bar claypan (46); De Grey Borefield claypans (38); Poverty Creek claypan (74)
7 SEMI-PERMANENT CLAYPAN	On slight drainage line, local runoff and catchment	Unknown	Semi-permanent	Effectively nil	Medium to fine-grained alluvium	Low	Gnalka Gnoona (22);Cowra (76); Coondiner Pool (33,34); Hooley Creek 1 and 2 (20, 21)
8 TIDAL REACH	Ocean via tide	Often below watertable	Permanent	Effectively nil	Fine-grained alluvium	Low	Fortescue River System(1,2,3-5)
9 MAN-MADE WETLAND	Variable - often altered drainage line	Unknown	Variable	Effectively nil	Variable	Usually low	Ophthalmia Dam; Marble Bar dredge pool (47)

* Water source in addition to direct input from rainfall and local runoff.

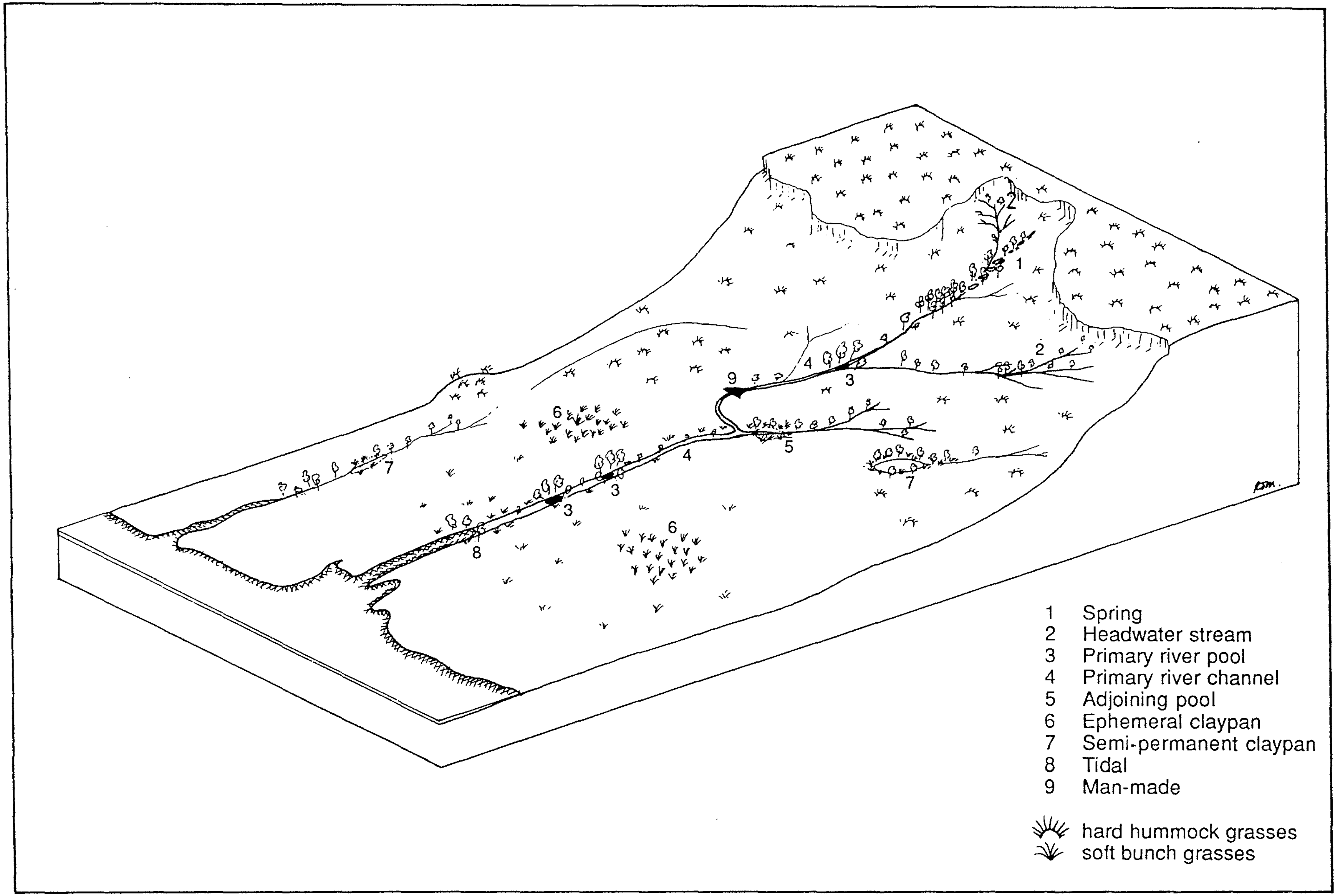


Figure 3. Schematic representation of Pilbara wetland types, in relation to topography.

localised bank storage or by a direct link with the water table. The permanence of the pools depends on the relationship between pool depth and the water table. During dry periods the water table may decline. Permanent pools occur where pool depth exceeds the limit of decline of the water table, or where pool volume exceeds annual evaporation losses.

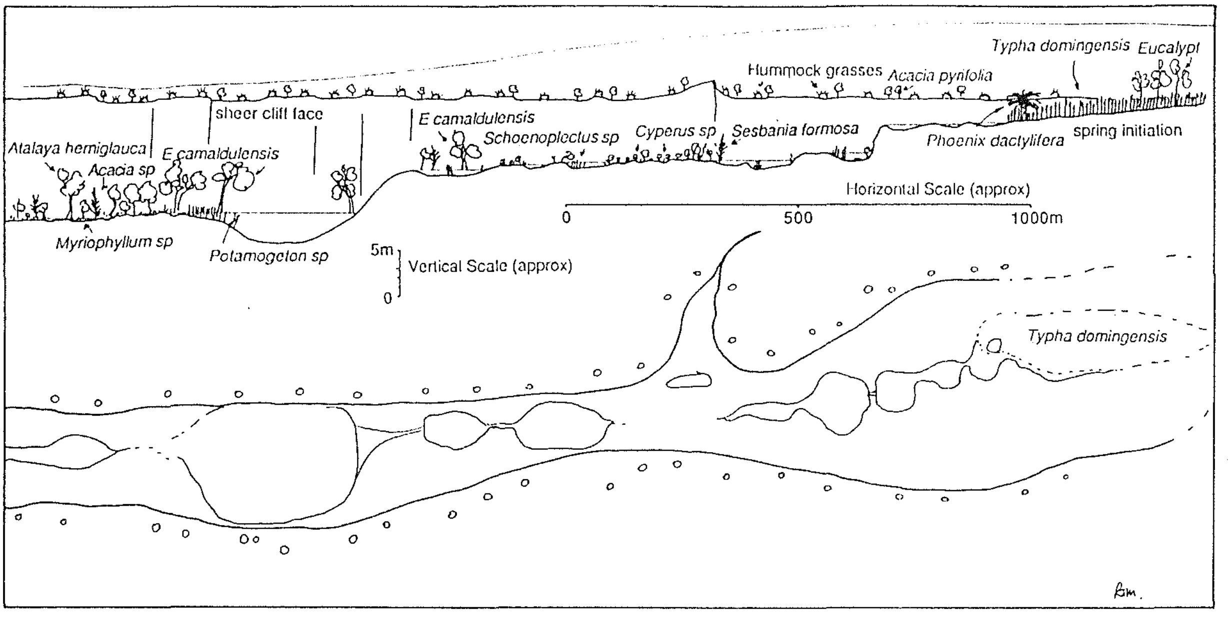


Figure 4. Spring, Eera Baranna (sites 54-64): diagrammatic section and surface view to show the relationship of characteristic plant species to wetland features.

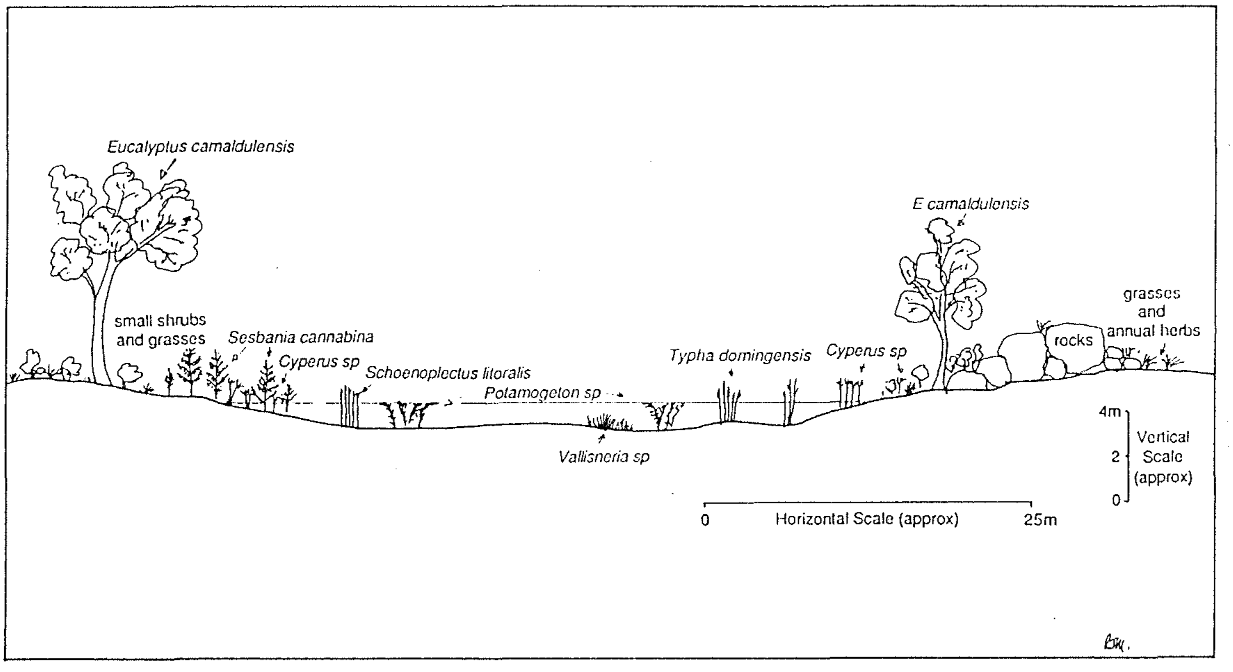


Figure 5. Primary River Pool, Kunagunarrina Pool site 69): diagrammatic section to show the relationship of plant species to wetland features.

3. Headwater Stream or Drainage Channel

As they drain a relatively small catchment, headwater streams and drainage channels (see Five Mile Creek, Nullagine, Figure 6) are generally quite narrow and shallow, have relatively steep bed gradients and are fast flowing. The streams usually drain relatively small catchments and cumulatively, supply water to primary river channels.

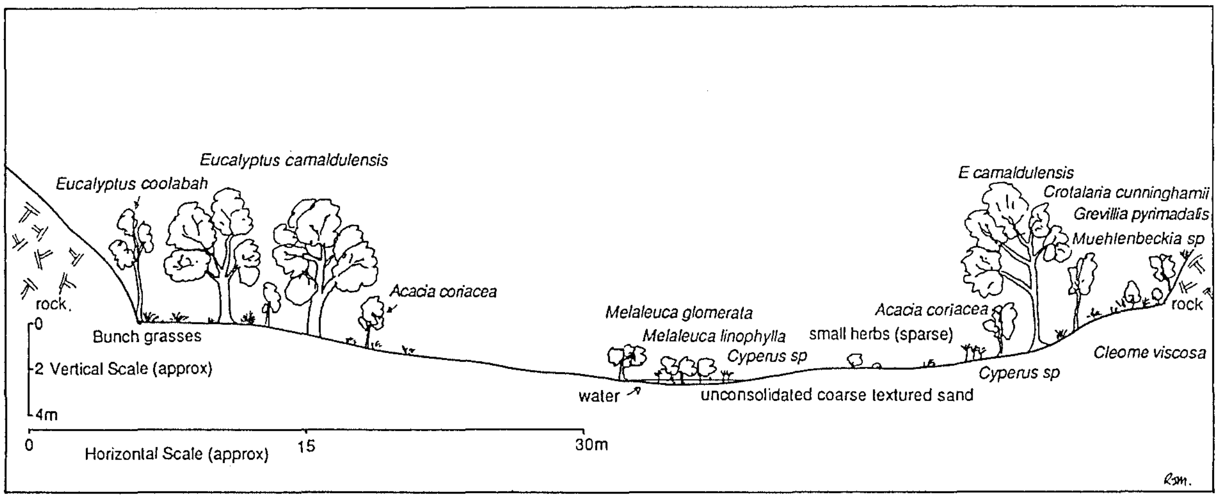


Figure 6. Headwater Stream, 5 Mile Creek, Nullagine (sites 49, 50): diagrammatic section to show the relationship of plant species to wetland features.

4. Primary River Channel

Primary river channels cope with spasmodic influxes of large volumes of water and hence are often quite wide (up to 1 km). For most of the year these channels are usually dry (see Fortescue River channel, dry section, Figure 7). Shallow ephemeral pools often occur in the river beds but these are subject to frequent changes in position and profile due to changes in location of river bed sediments during river flow.

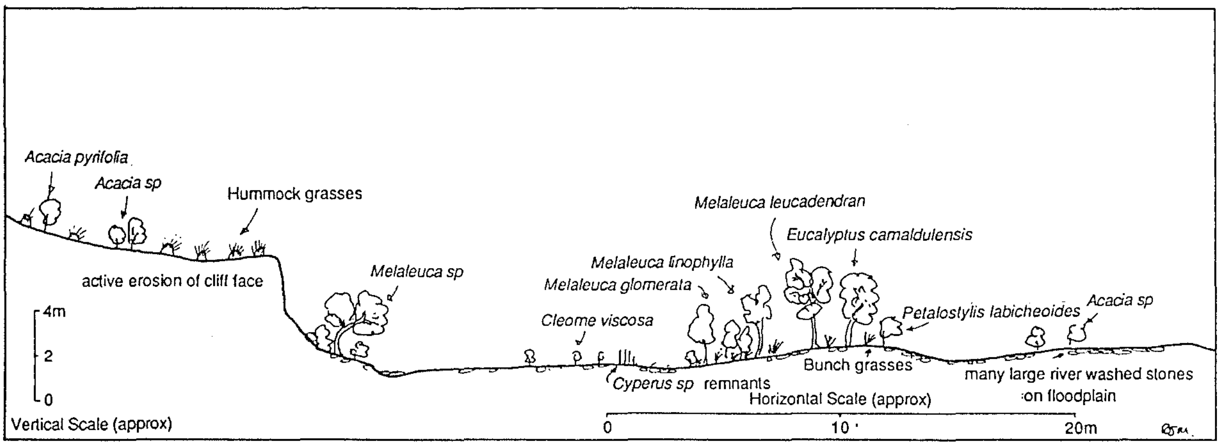


Figure 7. Primary River Channel, Fortescue River bed - dry section, upstream from Bilanoo Pool (site 6): diagrammatic section to show the relationship of plant species to topography.

5. Adjoining Pool

Adjoining pools are ephemeral to intermittent occupying depressions adjacent to rivers which are subject to flooding. These depressions include cut off meanders and wind deflation hollows between vegetation hummocks. Once saturated, the fine sediments of these areas may retain moisture for considerable periods after surface water has gone (see Red Rock Creek, Figure 8).

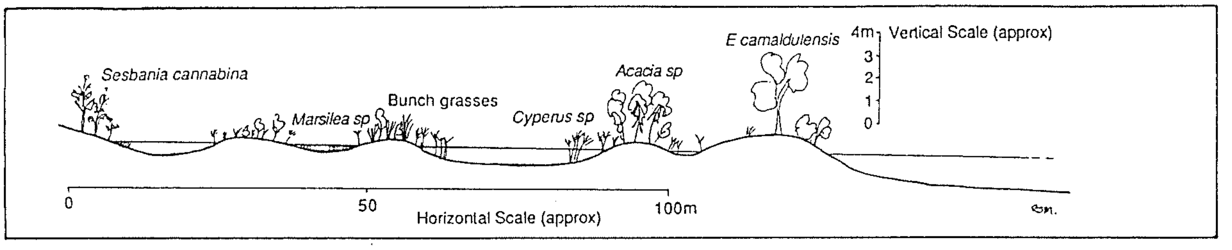


Figure 8. Adjoining Pool , Red Rock Creek (sites 42, 43): diagrammatic section to show the relationship of plant species to wetland features.

6. Ephemeral Claypan

In areas of fine-grained soils, clay pans have developed where sheet runoff may collect after rains (see Poverty Creek Flats, Figure 9). Although characterised by small, shallow depressions (<0.2 m deep), ephemeral claypans may occupy wide areas where large expanses of relatively flat land with no definite drainage patterns occur, as seen on the De Grey River borefield.

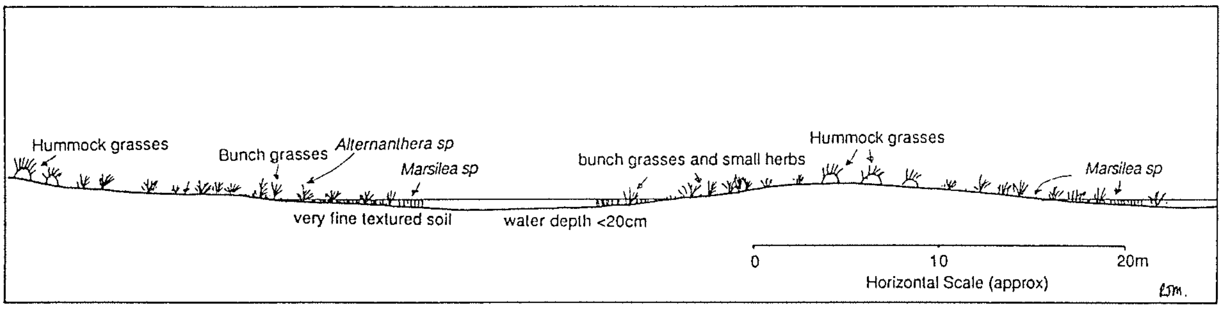


Figure 9. Ephemeral Claypan, Poverty Creek Flats (site 74): diagrammatic section to show the relationship of plant species to wetland features.

7. Semi-permanent Claypan

Semi-permanent claypan areas (see Coondiner Pool, Figure 10) are quite shallow, with low permeability and low through-flow. Located within better-defined drainage channels than the ephemeral soaks, they are usually deeper and more persistent, but occupy a smaller area.

8. Tidal Reach

The tidal reaches of the Pilbara rivers experience large diurnal fluctuations in water depth and area, particularly if the channels have gently sloping banks. Active erosion and deposition within many tidal creek systems leads to constantly changing stream channels (see Fortescue River, Post Office Pool System, Figure 11).

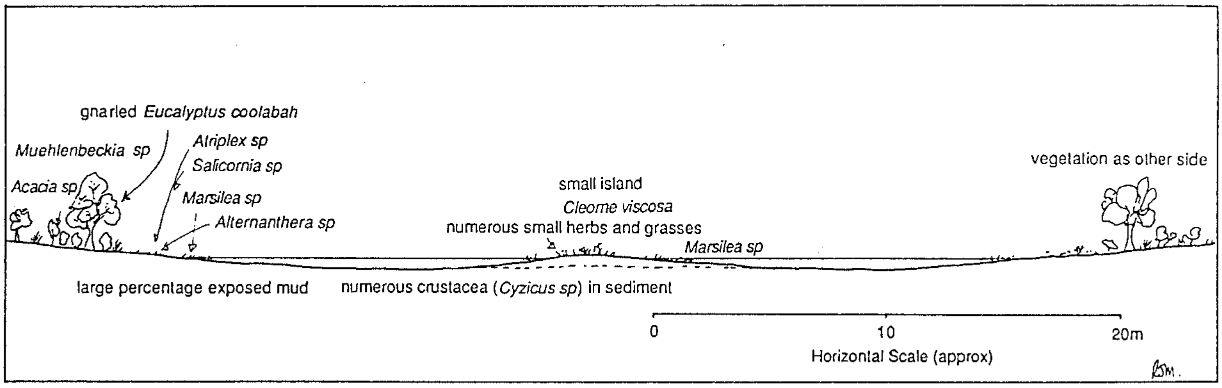


Figure 10. Semi-permanent Claypan, Coondiner Pool (sites 33, 34): diagrammatic section to show the relationship of plant species to wetland features.

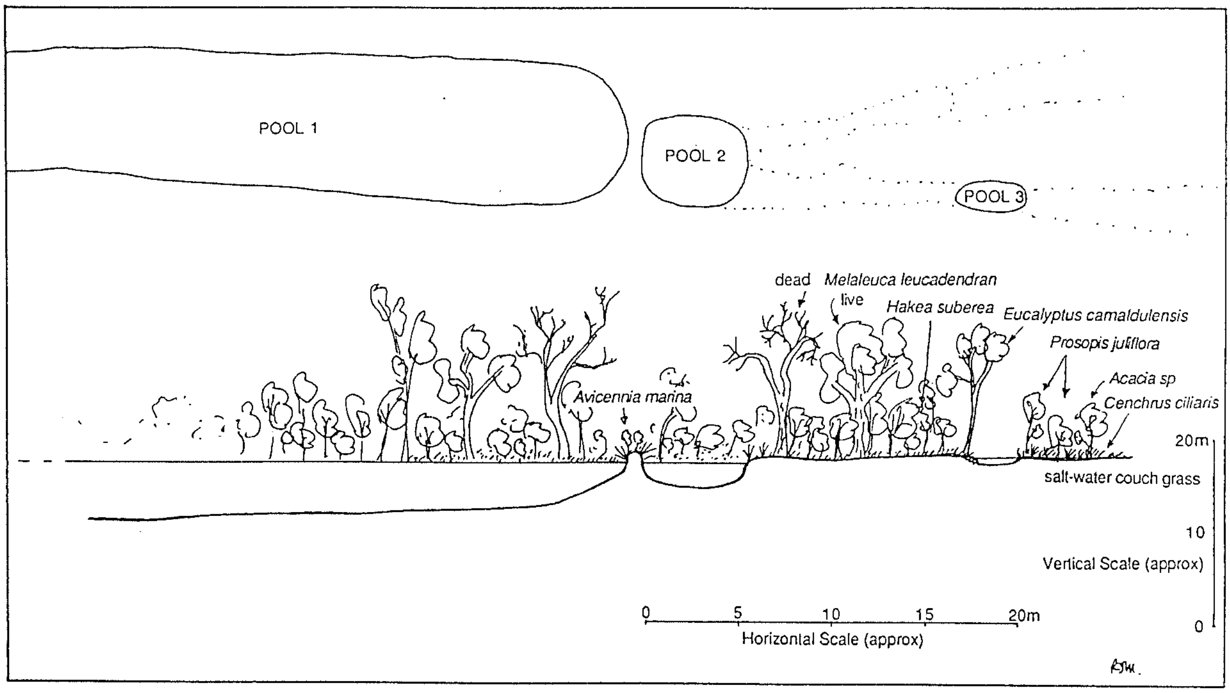


Figure 11. Tidal Reach, Fortescue River, Post Office Pool (sites 3, 4, 5): diagrammatic surface view and section to show the relationship of plant species to wetland features.

9. Man-Made Wetland

Man-made inland waters vary in area and depth according to their function eg dam, sewage pond.

Table 3. Physico-chemical properties (conductivity, pH, dissolved oxygen, temperature and turbidity) of inland waters of the Pilbara, March-April 1983)

	Site No	Conductivity ms.m^{-1} 25°C	pH	Dissolved Oxygen mg/l	Temperature °C	Turbidity ppm
Fortescue River System						
Fortescue River Mouth	1	779.0	7.4	10.6	27.0	12
Fortescue River 2.5 km	2	702.0	7.6	8.5	30.2	0
Post Office Pool a	3	871.0	7.8	4.6	33.5	60
b	4	874.0	7.4	9.3	34.0	37
c	5	5.7	8.0	8.1	33.0	-
Bilanoo Pool	6	5.0	7.7	6.1	31.4	3
Millstream						
- Palm Pool	7	6.0	7.8	8.7	32.0	25
- Crossing Pool 1	8	5.5	7.4	4.4	31.3	34
2	9	1.0	7.6	6.9	29.0	18
- Woodley Spring	10	5.5	7.4	4.4	31.1	94
- Crystal Pool Aquifer	11	6.0	6.7	7.2	29.0	31
- Crystal Pool True Spring	12	2.0	7.0	10.3	30.9	25
Roy Hill Site 1	13	1.1	6.7		25.5	89
Roy Hill Site 2	14	0.9	5.6		26.0	77
Yarrie Spring	15	0.8	7.4		26.0	686
Port Hedland-Newman Road Crossing	16	1.2	7.6	4.2	26.5	729
Port Hedland-Newman Road Crossing post T.C. Lina	17	5.5	8.7	3.4	22.8	535
Harding River System						
Minnoria Pool- feed creek	18	9.5	8.2	8.7	37.7	83
- main pool	19	12.5	7.7	8.1	37.1	78
Fortescue Catchments						
Hooley Creek 1	20	1.0	8.7	11.3	31.0	20
2	21	7.0	8.7	9.5	32.0	20
Gnalka Gnoona	22	12.0	8.4	9.0	30.5	105
Weeli Wolli creek at Marabee	23	8.0	9.4	8.3	33.2	153
Junction : Marillana and Yandicoogina creeks 1	24	11.1	8.4	4.3	32.6	15
2	25	16.0	8.4		33.1	12
Weeli Wolli Springs 1	26	9.5	6.7	4.3	29.0	9
" 2	27	10.0	7.0	10.3	29.2	17
" 3	28	11.5	7.0	4.3	29.5	3
" 4	29	11.5	6.95	4.4	29.5	9
" 5	30	12.0	7.7	5.0	31.6	16
" 6	31	12.0	7.9	11.6	30.0	15
" 7	32	13.5	7.9	4.9	29.2	7
Coondiner Pool 1	33	14.5	7.8	4.2	23.7	235
Coondiner Pool: post T.C. Lina 2	34	7.0	8.8	0.8	28.9	510

Table 3. Physico-chemical properties (conductivity, pH, dissolved oxygen, temperature and turbidity) of inland waters of the Pilbara, March-April 1983) (contd)

	Site No	Conductivity ms.m^{-1} 25°C	pH	Dissolved Oxygen mg/l	Temperature °C	Turbidity ppm
De Grey River System						
De Grey Q line pool	35	1.1	9.3	5.7	29.8	164
De Grey False I line pool	36	0.95	8.1	1.7	28.9	84
De Grey I line pool	37	1.0	8.2	1.7	30.6	110
De Grey Borefield claypans	38	0.85	5.7	2.2	31.2	765
Mulyie Pool	39	0.70	8.7	3.0	30.5	55
Shay Gap, semi-permanent	40	0.60	8.2	2.7	28.3	5
Muccan Crossing	41	0.3	9.3	6.0	29.2	6
De Grey River Catchments						
Red Rock Creek a	42	5.5	8.8	4.4	24.6	16
" b	43	10.0	8.9	4.0	28.2	7
West Strelley River	44	6.0	8.9	1.2	28.9	10
Shaw River	45	10.5	8.7	6.8	26.2	7
Marble Bar Claypan	46	10.5	9.8	1.6	29.9	15
Marble Bar dredge pool	47	10.0	9.2	6.7	25.0	37
Garden Pool	48	11.5	8.3	4.0	22.8	95
Five Mile Creek - flowing	49	9.0	9.0	4.0	26.8	17
- eddy	50	9.5	9.0	3.6	27.0	10
Yule River System						
Yule River North West						
Coastal Highway Bridge	51	12.0	9.1	7.2	28.3	8
Chinnamon Pool - surface	52	6.0	9.3	4.8	28.2	0
- bottom	53	4.0	9.3	3.4	27.9	0
Eera Baranna Springs						
1 Surface	54	7.0	7.9	7.1	31.8	0
50 cm	55	6.0	7.2	5.0	30.0	0
2	56	8.0	7.8	11.1	30.0	0
3 Surface	57	11.0	6.8	7.8	28.0	15
50 cm	58	11.0	6.8	8.9	28.0	0
6	59	13.0	8.5	4.4	27.5	21
5 Surface	60	15.5	7.9	4.3	27.0	19
2 m	61	15.5	7.7	4.4	27.0	21
3	62	15.5	7.7	8.0	27.0	22
2	63	15.5	8.2	4.4	27.0	21
1	64	15.5	8.0	4.4	23.5	14
Turner River System						
Turner River East						
Branch-Boodarie - a	65	37.5	8.9	4.7	26.3	2
- b	66	0.5	8.8	4.5	26.8	47
Turner River North West	67	6.5	8.9	7.2	28.9	10
Coastal Hwy - East Turner	68	12.0	8.5	6.0	30.8	8
Kunagunarrina Pool	69	2.0	9.2	3.6	25.2	10

Table 3. Physico-chemical properties (conductivity, pH, dissolved oxygen, temperature and turbidity) of inland waters of the Pilbara, March-April 1983) (contd)

		Site No	Conductivity $ms.m^{-1}$ 25°C	pH	Dissolved Oxygen mg/l	Temperature °C	Turbidity ppm
<u>Harding River System</u>							
Roebourne Pool	3	70	63	7.4	7.8	25.0	23
"	1	71	59.0	7.8	9.1	28.0	78
Bamba Pool		72	70.0	8.3	4.5	37.5	24
Lockyer's Gorge		73	5.0	7.6	6.4	33.0	24
Poverty Creek Claypan		74	6.5	8.7	3.5	25.8	280
<u>No Water</u>							
Doolena Gap		75	-	-	-	-	-
Cowra		76	-	-	-	-	-

3.4 WATER QUALITY

The results of the water quality sampling are presented in Table 3. Sampling sites are arranged in order of increasing distance upstream, either along the major river systems or within the associated catchments.

3.4.1 CONDUCTIVITY*

Conductivities were highest in areas subject to tidal influences, (up to 874 $mS.m^{-1}$), while most waters were fresh, with conductivities between 5 and 15 $mS.m^{-1}$. A progressive increase in conductivity was measured downstream from the water source of the two spring systems surveyed (sites 26-32 and 54-64; Table 3). Evaporation and transpiration concentrate the spring water's ambient salt load as it flows downstream over shallow or exposed bedrock.

Conductivities are known to increase in ephemeral river pools as they diminish in size through evapotranspiration (Dames and Moore, 1975).

Groundwater conductivities are generally higher in fine grained sediments with lower permeabilities and also in association with thick vegetation cover, compared to coarse permeable alluvium (Davidson, 1975). Thus river pools, even if linked to the aquifer, may become saline as the dry season progresses. For example, Bamba Pool (site 70) on the Harding River was a small, 10 cm deep depression in the river bed with a conductivity of 70 $mS.m^{-1}$; this was significantly higher than the 18 $mS.m^{-1}$ reported by Dames and Moore in 1982, when the pool was 1.5 m deep.

If required, conductivity in $mS.m^{-1}$ may be approximated to Total Dissolved Salts (TDS) by a multiplication factor of 6.25 and Total Soluble Salts (TSS) by a multiplication factor of 7.25 (Snowy Mountains Engineering Corporation, 1982).

3.4.2 pH

pH ranged from 5.8 to 9.8, with most surface waters having a pH between 7.5 and 9.0.

Annual and longer term variation in the pH of surface waters is evident when data collected by Dames and Moore between 1973 and 1982 are compared with pH values recorded for the same sites during this Study (Table 4).

Table 4. A comparison of surface water pH data from 1973 to 1982 with data collected during this Study in 1983.

Site(s) # This Study	Name	1973**	1975*	1976**	1982**	1983 This Study
26-32	Weeli Wolli Spring		7.8			7.3
73	Lockyers Gorge				8.0	7.6
71	Roebourne Pool 1				8.3	7.8
70	Roebourne Pool 3				7.5	7.4
37	"I" Line Pool	9.4		8.6		8.2

* Dames and Moore (1975)
** Dames and Moore (1982)

The pH of Coondiner Pool changed from 7.8 before tropical cyclone Lena to 8.8 one week later. The pH variation over the week was probably influenced by rainfall and/or runoff from the cyclone.

The spatial variation in pH within systems was also apparent and prominent, eg within the Weeli Wolli and Eera Baranna Spring systems, sites 26-32 and sites 54-64 respectively.

Due to the low ionic buffering capacity of fresh water in general, pH will tend to fluctuate according to factors such as catchment soil types and seasonal/diurnal fluctuations in carbon fixation and utilization rates of the primary producers and the benthos.

3.4.3 DISSOLVED OXYGEN

Dissolved oxygen concentrations were quite variable and ranged from 0.8 to 11.6 $mg.L^{-1}$. High dissolved oxygen concentrations were found in rapidly flowing shallow waters eg sites 27 and 31, Table 3.

Although the accuracy of the Horiba water tester used to measure this parameter is in some doubt, most water bodies apparently had high dissolved oxygen concentrations over the range of water temperatures recorded.

3.4.4 WATER TEMPERATURE

Water temperatures of 22.8°C to 37.5°C were recorded and generally reflected ambient air temperatures. Relatively low temperatures were found in gorge systems and other sites well shaded for appreciable amounts of time during the day. In contrast, the highest temperatures were recorded in the middle of the day for shallow, unshaded pools. Vertical water temperature stratification was evident wherever complete water mixing was inhibited to some degree by depth or shelter from wind (ie sites 54 and 55, Table 3).

Although controversy exists over the importance of temperature stratification in water bodies (see Bayly and Williams, 1973), the maintenance of stable thermoclines probably increases habitat diversity (often closely related to biological species diversity), and is likely to be of significance to benthic organisms, which are often at the lower end of the food chain.

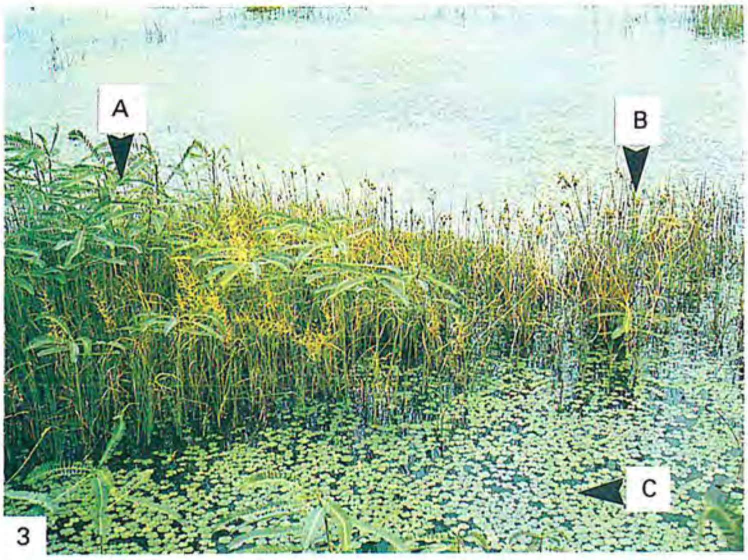
3.4.5 TURBIDITY

The optical density or turbidity of the water bodies varied markedly over the range of wetlands surveyed. Relatively clear water with turbidities approaching zero were common in spring systems and upper catchment streams consisting of typically coarse-grained, highly permeable substrates. In low-lying areas such as the Fortescue marshes, fine colloidal material brought into suspension after rain or by water flow, resulted in turbidities in excess of 500 ppm (corresponding to a secchi depth of <1 cm).

Turbidity can be related to the salt concentration of a water body due to salting out of non-electrolytes (Kolthoff et al 1969, p 337). At Boodarie on the Turner River, a small pool (site 63) had a turbidity of 45 ppm and conductivity of 0.5 $mS.m^{-1}$. A similar pool (site 64) on the ocean side of the previous site had a conductivity of 37.5 $mS.m^{-1}$, but was relatively clear with a measured turbidity of 7 ppm. The suspended colloidal material had apparently flocculated out of suspension quicker at site 64 due to the higher salt load.

3.5 <u>FLORA</u>

More than 250 plant species were collected from 38 wetland areas in the Pilbara (Appendix 2). The species that were collected are representative of the wetland areas surveyed. However, more comprehensive collections at the areas surveyed at different times of the year should add many species to the list; many plants were not in flower at the time of collection, making identification even to the generic level difficult.



1. View of the arid Pilbara landscape.

2. Gnalka Gnoona Pool (site 22) in the Fortescue marshes. The halophilic Chenopodiaceae (samphire) in the foreground are good biological indicators of salt affected land.

3. The semi-permanent water persistence of this pool (site 40) near Shay Gap is reflected by its vegetation. A= *Sesbania cannabina*, B= *Cyperus sp* and C= *Marsilea sp.*

4. The cajeput (*Melaleuca leucadendran*) signifies permanent water persistence. The height of flood-water levels can be gauged by debris caught in trees.

5. Looking downstream from the limit of tidal influence in the Fortescue River (sites 2-3). This is classified as a Tidal Reach (type 8 wetland).

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6. The start of a Spring (type 1 wetland), Eera Baranna Spring (sites 54-61) showing the steep bed gradient, rock pools and surrounding spinifex (*Triodia sp*) covered plateau of the Chichester Ranges.
7. The Fortescue River, (type 4 wetland, Primary River Channel) approximately 2 weeks after the passage of Tropical Cyclone Lena. When sampled prior to T.C.Lena, the only visible surface water was present in Bilanoo Pool (site 6, Primary River Pool, type 2 wetland), underneath the river gums in the centre of the photograph.
8. Hooley Creek (site 20) is a Primary River Pool (type 2 wetland) and has reservation status as a stopping and resting place for travellers and for watering stock.
9. Hooley Creek (site 20) in the late dry season. Most surface water bodies in the Pilbara dry up during the dry winter months. When no rainfall occurs during the wet season, the more permanent water supplies come under increasing pressure from wildlife and stock.
10. Headwater streams (type 3 wetlands) such as 5 Mile Creek (sites 49-50), and the smaller drainage channels hold water for very short periods after rain. This photograph was taken approximately 1 week after the passage of T.C.Lena.
11. Stream overflow, in this case from Red Rock Creek (site 42) provides water for Adjoining Pools (type 5 wetlands). After significant rainfall these wetlands have diverse floral assemblages of both 'dryland' and 'wetland' plants.
12. Site 42 at Red Rock Creek in the dry season. During periods of dry weather (sometimes lasting years) adjoining pools have low floral diversity and look anything but wetlands.
13. Ephemeral claypans (type 6 wetlands) such as site 46 near Marble Bar are characterised by soft bunch grasses (foreground) compared with the hard spinifex grasses found in the dryland areas.
14. Coondiner Pool (sites 33-34) is classified as a Semi-Permanent Claypan (type 7 wetland).
15. Man-made wetlands (type 8 wetlands) can take a variety of forms, but like this tin dredging area near Marble Bar, often provide a useful habitat for water-birds such as the jabiru (*Xenorhynchus asiaticus*) and white necked heron (*Ardea pacifica*), in otherwise inhospitable areas.
16. The Fortescue Marshes, a very flat, low-lying area situated between the Chichester and Hamersley Ranges (in the background). After a heavy cyclonic downpour such as that caused by T.C. Joan in 1975, the surface water body can be 100 km long and 30 km wide. Under these conditions the area becomes avery important breeding area for thousands of pelicans, spoonbills, swans and other large water-birds.
17. Unlike many water-birds which can migrate to more favourable areas during extended dry periods, the majority of the biota rely to some degree on the sparce permanent water resources provided by Springs and some Primary River Pools. The olive python (*Morelia olivacea*) is relatively uncommon, but favours areas with permanent water. This specimen from Weeli Wolli Springs (sites 26-32) was over 3 m in length.

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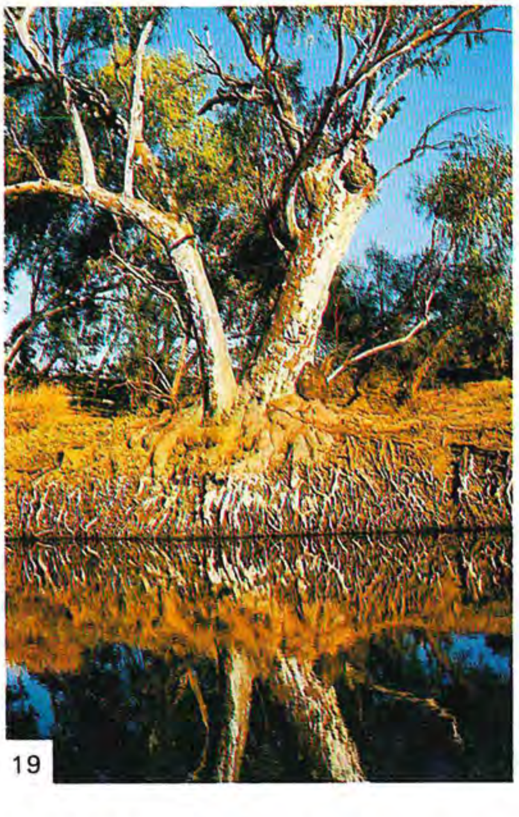

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18. *Sesbania formosa*, the brown-barked tree seen in the left of the photograph, is a perennial legume that can reach a height of 7-8 m, and is only found near permanent water. Notice also the cajeputs and well developed submerged aquatic vegetation, also characteristic of permanent water bodies.
19. The river gum (*Eucalyptus camaldulensis*) is an indicator of semi-permanent water persistence. This species can cope with short periods of flooding, but not prolonged waterlogged conditions.
20. The coolabah (*Eucalyptus coolabah*) is quite drought resistant when established but cannot survive in waterlogged soils and is usually found well up the levee bank in the more permanent wetlands, or in those that are semi-permanent to ephemeral.
21. The rooted submerged aquatic macrophytes such as *Myriophyllum sp.* are only found in permanent and semi-permanent wetlands.
22. Another unusual submerged aquatic plant that is restricted to permanent and semi-permanent wetlands, *Vallisneria sp.* has floating white flowers on coiled peduncles.

(Photographs: R J Masini)

3.5.1 SPECIES RICHNESS

Species richness is a measure of the number of different species found within a defined area, and is useful for comparative purposes. The use of this parameter depends largely upon the researcher being consistent (a) when defining the limits of the influence of the water body; and (b) when collecting the representative species. Hence for this analysis, only data collected during the March-April 1983 field trip will be compared as the scope of collection at each site was known to be relatively standard.

Analysis of species richness data (Figure 12) reinforces the classification system described earlier. The high species richness characteristic of spring systems (average 36 species), headwater streams (average 33 species) and adjoining pools (average 39 species) largely reflects a high habitat diversity. More plant species are able to survive because of the relative stability afforded by the permanent/semi-permanent water availability and diverse habitat of these systems.

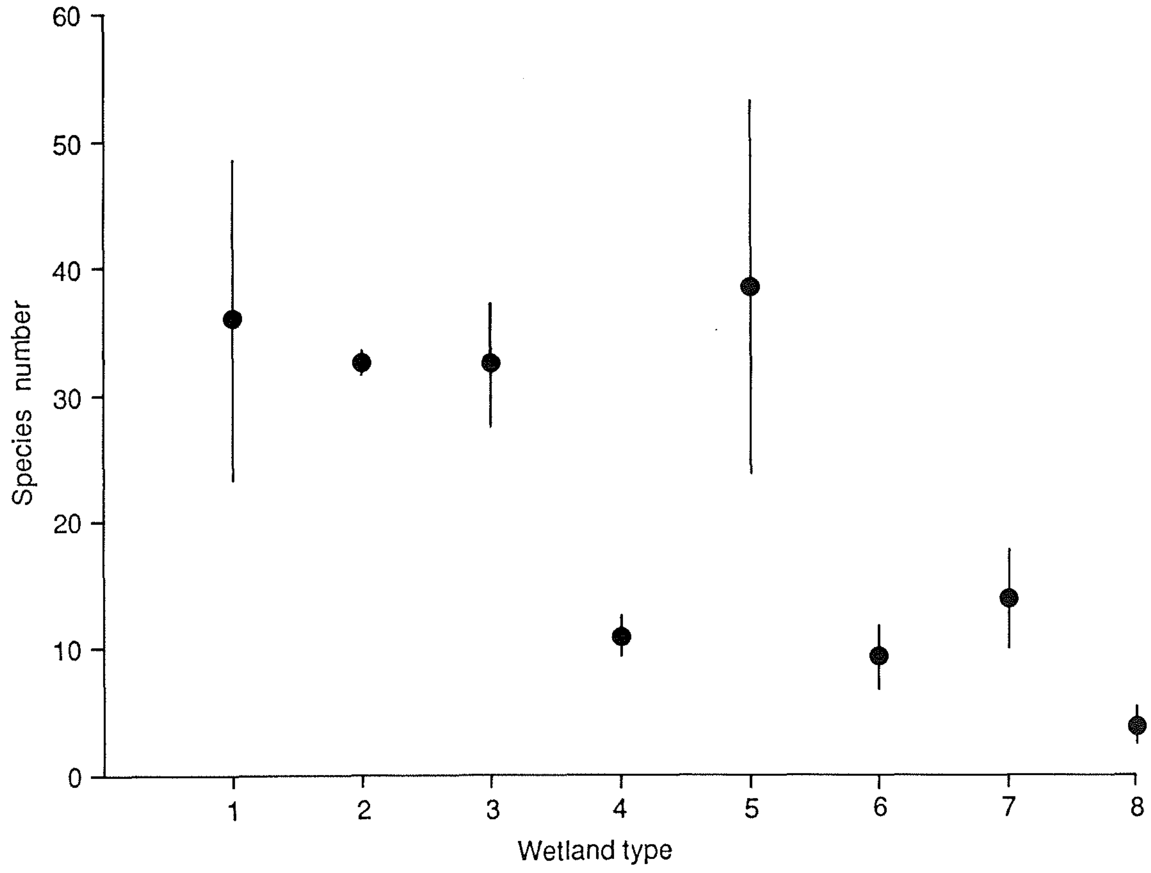


Figure 12. Mean number of plant species (+/- 1 standard error) observed at sites representing wetland types 1-8.

In contrast, ephemeral soaks (average 9 species) with relatively flat topography and little habitat diversity, have only a potential for annual wetland plants, and so species richness is low. The lowest number of species was recorded for tidal areas (average 4 species).

The areas with highest species richness were also the most variable in species number. A larger number of sample sites within each wetland class would be required if all species were to be included in the analysis.

3.5.2 VEGETATION PATTERNS

The physiology and physiognomy of a species are of course related to the habitat in which it occurs. The presence or absence of species which are known to be confined to specific habitats allow them to be used as indicators of certain environmental variables, and can be useful in differentiating between types of inland waters.

Analysis of the flora, and a knowledge of the physiology of certain plant species, allowed recognition of patterns related to the water table, persistence and periodicity of inundation characteristic of particular inland water types (Table 5).

3.5.2.1 Melaleucas

Melaleuca leucadendran (the cajeput) has a shallow platform root system occupying a large area, well developed aerenchyma and the ability to cope with waterlogged conditions for extended periods of time. It is apparently dependent on water table levels between 1 and 2 m from the surface (Dames and Moore, 1975). According to bush-lore, large, thick-trunked cajeputs are indicative of permanent water. Consistent with their ecophysiology, *M leucadendran*, *M glomerata* and *M linophylla* were restricted to wetland types 1, 2, 3, 4 and one site under tidal influence (Table 5).

3.5.2.2 Eucalypts

Eucalyptus camaldulensis (the river gum) and *E coolabah* (the coolabah) withstand drought conditions for considerable lengths of time, but apparently obtain an advantage by being near water during their early growth and establishment. These eucalyptus appear fairly susceptible to long periods of static flooding. Moving flood waters, and water tables below 2 m, appear to favour the growth and survival of these eucalypts. They were found in the same locations as the melaleucas, with the addition of the semi-permanent claypans and adjoining pools: wetland types 5 and 7. River gums and coolabahs usually occupy distinct but overlapping zones in relation to the water body, with coolabahs predominantly in the drier areas.

3.5.2.3 Sesbanias

The development of cork-like aerenchymous tissue in the root, stem and nodules of the legumes *Sesbania formosa* and *S cannabina* allow the establishment of seedlings along high water zones and enable the mature plants to survive waterlogging in a similar manner to that described for *Viminaria juncea*, a native wetland legume found in the southwest of the state (Walker, Pate and Kuo, 1983). Due to their fast growth and adaptability, these legumes have the potential to colonise disturbed areas. *S cannabina* is often found on steep banks cut by river or stream flow (eg Mulye Pool, site 39) and also road verges (eg Shay Gap, site 40). *S formosa* may reach 7 or 8 m in height, and large plants are only found near permanent water (eg Eera Baranna, site 54).

3.5.2.4 Aquatic Macrophytes

The emergent and submerged aquatic macrophytes are also useful indicator species. *Vallisneria* sp., *Myriophyllum* sp., and *Potamogeton* sp. are submerged/semi-emergent, rooted angiosperms and can be seen to occupy only the spring-fed and river pool systems (see Table 5). The emergents *Schoenoplectus litoralis* (=Scirpus litoralis) and *Typha domingensis* show similar distributions, while Cyperus species are generally more opportunistic and may be found away from permanent or semi-permanent water.

3.5.2.5 Pteridophytes and Chenopods

Marsilea sp (nardoo), an aquatic fern with floating leaves, capable of withstanding seasonal desiccation by resistant sporocarp formation, is a useful indicator of claypan conditions (see Table 6). Members of the halophylic Chenopodiaceae indicate salt affected areas, often difficult to distinguish from physical properties alone.

Table 5. Relationship of wetland indicator plant species to wetland types.

Species	(Wetland Type) and Site Numbers																																
	(1)		(2)							(3)		(4)								(5)		(6)			(7)						(8)		
	26	54	6	24	39	48	51	52	69	49	76	13	14	15	16	35	36	37	67	40	42	38	46	74	0	20	21	22	23	33	1	2	3
Melaleuca leucadendran (L.)L.	*		*	*	*		*	*	*							*	*	*	*														*
M glomerata F. Muell.	*		*	*			*	*		*		*	*					*	*														*
M linophylla F. Muell.		*								*			*																				
Eucalyptus camaldulensis Dehnh.	*	*	*	*	*	*	*	*	*	*		*		*	*	*			*		*					*		*	*	*			*
E coolabah Blakely & Jacobs		*	*	*			*			*				*	*	*		*	*							*		*	*	*			
Sesbania formosa (F. Muell.) N.T. Burbidge		*	*		*	*																											
S cannabina (Retz.) Poir.		•						*	*									*		*		*					*		*				
Phoenix dactylifera L.	*	*																															

Table 5. Relationship of wetland indicator plant species to wetland types (contd)

Species	(Wetland Type) and Site Numbers																																
	(1)		(2)							(3)		(4)								(5)		(6)			(7)						(8)		
	26	54	6	24	39	48	51	52	69	49	76	13	14	15	16	35	36	37	67	40	42	38	46	74	0	20	21	22	23	33	1	2	3
Cyperus spp	*	*	*	*			*	*	*	*										*	*		*	*	*		*			*			
Schoenoplectus littoralis (Schrader)	*	*		*	*	*	*	*	*																								
Typha Palla *domingensis* Pers.		*					*		*																								
Potamogeton sp		*					*		*																								
Myriophyllum sp		*	*				*																										
Vallisneria sp	*		*						*																								
Marsilia sp						*												*		*	*	*	*	*			*		*	*			
Chenopodiaceae											*	*	*												*			*			*	*	

3.5.3 VEGETATION AND STABILITY

In the broad river systems such as the De Grey, *Melaleuca glomerata* and *M linophylla* colonise and help stabilise small islets within the main river channel. Once established, the baffling effect of the vegetation protruding through the flowing water leads to deposition of finer-grained alluvium and sediments in the eddy behind the islet. These areas of finer alluvium provide a suitable substrate for colonisation by opportunistic species, such as *Cyperus* sp, which in turn stabilize the river bed.

The establishment of bank-stabilising vegetation along the river and pool systems depends on water availability. Changes in water table characteristics, by drawdown of an aquifer for example, may alter the species composition of the fringing vegetation, favouring the more drought-resistant species such as river gums and coolabahs. This would, in turn, significantly alter the distribution of the understorey and ground cover vegetation. Significant aquifer drawdown (>2 m) for long periods would kill dependent cajeputs in two to three years. During the lag until they were replaced with a river gum-dominated community, a lowered bank stability could be expected in the vicinity of deep flow channels or pools. This would result in increased erosion which could fill pools and hinder the establishment of aquatic vegetation (Dames and Moore, 1978).

Although the position of main river channels (often delineated by levee banks and stabilized by vegetation) is relatively static over a period of years, erosion and deposition occur within them, altering the configuration and position of pools and islets after each major flow. There is evidence that the position of main river channels may alter over longer time periods. This is demonstrated by a section of the De Grey River which presently flows approximately 300 m away from an old drainage channel, marked by a line of river gums.

3.5.4 ZONATION AND DISTRIBUTION

Most of the plant species mentioned in section 3.5.2 are not difficult to identify and have typical though sometimes overlapping habitat requirements. Their presence or absence make them useful indicators of physical characteristics related to water availability and wetland geomorphology, which form the basis of the proposed classification system.

The well established perennial species are more likely to reflect long term characteristics of their environment compared with ephemeral species, which may reflect recent conditions which may be "atypical" of long-term conditions at the site of collection.

The typical zonation pattern of the indicator species in relation to each other in a stylized wetland unit is shown in Figure 13.

3.5.5 NUMERICAL CLASSIFICATION

Seven groups of sites and 11 species associations were identified after five divisive levels (see section 2.5.2). The species associations are shown in Table 6. The dendrogram (Figure 14) produced from Table 6 shows the site groups, 'indicator' species used for the divisions and the species richness for each group. Also shown in Figure 14 are the wetland class groups according to the subjective classification described earlier, the substrate type and water persistence for each site.

3.5.5.1 Site Groups and Indicator Species

The first division split the sites under tidal influence (group A) from the 'fresh' water sites using *Spinifex longifolius*, *Prosopsis juliflora* and *Triodia pungens* as indicators.

The second division produced group G, consisting of sites in the eastern Fortescue marsh area. This group was characterised by *Muehlenbeckia cunninghamii*, *Atriplex* sp and *Frankenia* sp. These species are salt tolerant and during the survey were found to be generally restricted to this area.

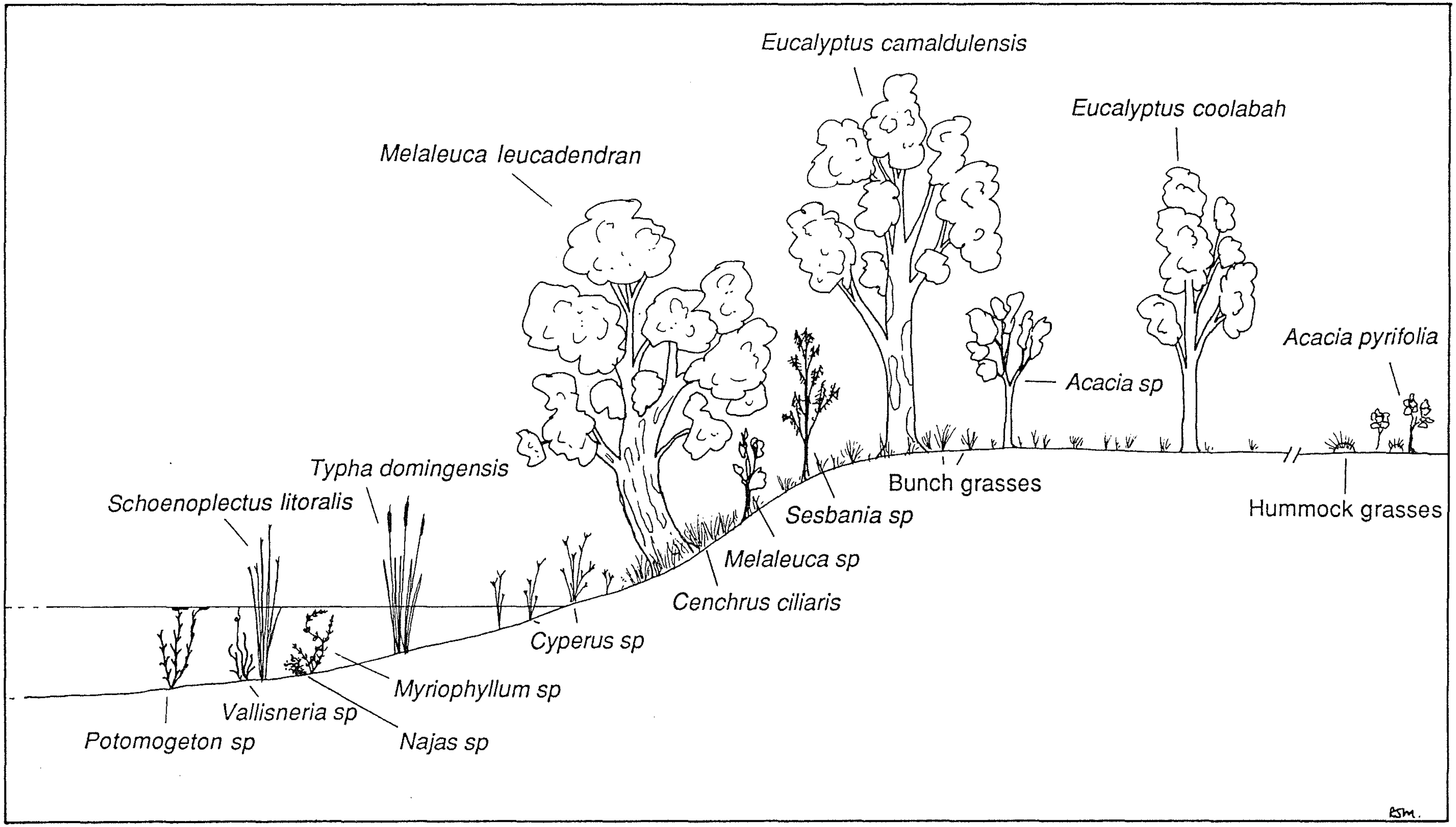
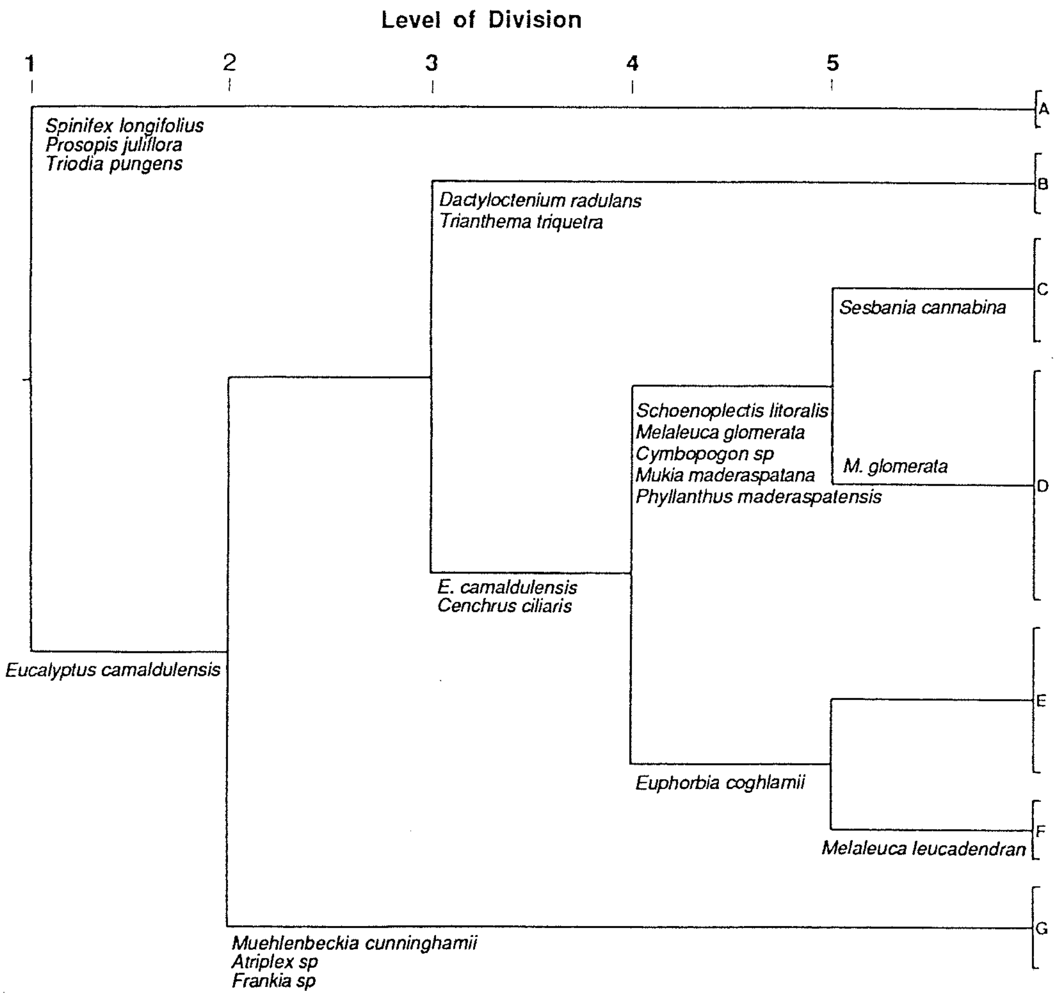


Figure 13. Typical location of indicator plant species in relation to the water body of a stylized wetland unit.

			111 111122 1122223333122223233	
			167867891259164534078901250234354623	
40	TRIO	PUN	---- --- ------- -11--------- ----- --- 11	011
220	STEM	SPE	-1-- --- ---11-- --1--------- ----- --- --	01011
209	MUEH	CUN	1111 --- -1-1--- -----------1 ----- --- --	01011
190	MELA	LIN	--1- --- ------- ------1--1-- ----- --- --	01011
162	ACAC	FAR	-11- --- ------- --1--1---1-- ----- --- --	01011
155	ACAC	AMP	-1-- --- ------- --------1--- ----- --- --	01011
127	FRAN	SPE	1-1- --- ------- ------------ ----- --- --	01011
117	BERG	SP2	-1-- --- ---1--- ------------ ----- --- --	01011
97	ATRI	SPE	1-1- --- ------- ------------ ----- --- --	01011
74	CENT	SPE	-1-- --- -----1- --11-------- ----- --- --	01011
64	ALTE	HOD	---1 -11 --111-- ------------ 1---- --- --	01011
63	AERU	JAV	---1 1-- --1---1 ------------ ----1 --- --	01011
59	TRIA	TRI	-1-- --- ---1-11 ------------ ----- 1-1 --	01011
57	TYPH	DOM	1--- --- ------1 -------1-1-- ----- --- --	01011
56	POTO	SPE	1--- --- ------- -------1-1-- ----- --- --	01011
45	GRAS	SPR	1--- --- -----1- ------------ ----- --- --	01011
38	SPOR	SP1	-11- --- ------- ------------ ----- --- --	01011
188	MELA	GLO	-11- --1 ------- -111--111-11 ----- --- --	01010
161	ACAC	COR	1--- --- --1---- 11-1-11-11-- ----- --- --	01010
189	MELA	LEU	-1-- 111 ------- 1-111--11-11 --111 --- --	0100
180	EUCA	CAM	-1-- --- 11111-- 11-1111-111- --111 --- --	0100
176	ACAC	SP3	---- --- -----1- ------------ -1--- --1 --	00111
168	ACAC	SPH	---- --- ------- ------------ -1--- --1 --	00111
165	ACAC	MON	---- --- ------- ---------1-- ----- --1 --	00111
133	CASY	SP1	---- --- ------- ------------ -1--- --1 --	00111
131	DACT	RAD	---- --- -----1- ------------ ----- 1-1 --	00111
126	SECU	MEL	---- --- ------- -----1------ ----- --1 --	00111
86	CASS	OLU	---- --- ------- ---------1-- ----- --1 --	00111
80	EHRE	SAL	---- --- ------- ---------1-- ----- --1 --	00111
72	PTIL	GON	---- --- ------- ------------ -1--- 1-- --	00111
39	THEM	AUS	---- --- ------- ------1----- ----- --1 --	00111
30	ERIA	SP1	---- --- ------- ------------ 1---- 1-- --	00111
2	MARS	SPE	---- --1 ---111- -----1------ 11--- 11- --	00111
212	PORT	SPE	---- --- --1--11 ------------ ----- --- --	00110
203	SESR	CAN	---- --1 -1-111- --------1--- 11111 --- --	00110
194	ROER	SP3	---- -11 1------ -----1------ ----- --- --	00110
181	EUCA	COO	---- 1-1 11-1--- -1----1--11- ----- --- --	00110
167	ACAC	PYR	---- --- -1--1-- -1-------1-- -1--- --- --	00110
157	ACAC	ANE	---- --- -1-1--- ------------ ----- --- --	00110
136	LORE	SP1	---- --- ---1--- -----------1 ----- --- --	00110
92	LYSI	CUN	---- 1-1 ------- ------------ ----- --- --	00110
85	CASS	RIV	---- --- --11--- ------------ ----- --- --	00110
81	HELI	CON	---- --- ---1--- ------------ -1--- --- --	00110
76	PLUC	SP1	---- --- -----11 ------------ ----- --- --	00110
67	AMAR	SPE	---- 1-- ------- ------------ 1---- --- --	00110
43	TRIO	SP3	---- --- -----1- ------1----- ----- --- --	00110
37	SPOR	AUS	---- --1 -----1- ------------ ----- --- --	00110
35	SPIN	SP1	---- 1-1 ------- ------1----- ----- --- --	00110
27	ERAG	SP4	---- 1-1 ------- ----1------- ----- --- --	00110
26	ERAG	SP2	---- --- ---1--- -------1---- ----- --- --	00110
25	ERAG	SP1	---- --- ---1-1- ------------ ----- --- --	00110
21	CHRY	FAL	---- --- 1----1- -----1------ 1---- --- --	00110
20	CENC	SPE	---- 1-1 ------- ------------ ----- --- --	00110
7	CYPE	IRI	---- --- ---1-1- ------------ 1---- --- --	00110
199	INDI	MON	---- --- ------- --1---1----- 1---- --1 --	00101
211	CALA	SP2	---- --- -----1- --------1--- ----1 --- --	00100
109	IPOM	MUE	---- 1-1 -----1- --11111----1 -111- --- --	00100
58	MOLL	MOL	---- --- -----1- --------1--- ----1 --- --	00100
46	GRAS	SPC	---- --- ----1-- ----1--1---- ----- --- --	00100
19	CENC	CIL	---- --1 1---111 11--1-1-11-1 11--- --- --	00100
202	RHYN	MIN	---- --- ------- ---1-------- 11--1 --1 --	00011
166	ACAC	MOR	---- --- ------- ---1-----11- 1---- --1 --	00011
23	CYMB	SPE	---- --- ------- ---1--1--1-- -111- --1 --	00011
219	STEM	GRO	---- --- -----1- --11----11-1 1---1 --- --	00010
171	ACAC	TRA	---- --- -----1- ----1--1--1- -1111 --- --	00010
141	ARUT	SP1	---- --- --1---- ---1----11-- -1--- --- --	00010
120	EUPH	COG	---- --- -----1- --1-11-----1 -1--- --- --	00010
119	EUPH	AUS	---- 1-- ------- -11--11----1 ----1 --- --	00010
95	CLEO	VIS	---- --- -----1- -11--11--1-1 ----- --- --	00010
9	CYPE	VAG	---- --- ---1--- -1-1-1--11-- 1---- --- --	00010
196	CROT	CUN	---- --- ------- ------1----- -11-1 --- --	00001
150	MALV	AME	---- --- ------- -----1------ -1--- --- --	00001
147	HYBI	PAN	---- --- ------- ------------ -1--1 --- --	00001
125	PHYL	MAD	---- --- ------- -1----1-1--- 11--1 --- --	00001
112	POLY	SP1	---- --- ------- ---------1-- -1--- --- --	00001
107	RONA	ROS	---- --- ------- ------1----- -1--- --- --	00001
93	PETA	LAB	---- --- ------- -1---------1 -1--- --- --	00001
88	CASS	NOT	---- --- ------- ------------ -1--1 --- --	00001
84	TRIC	ZEY	---- --- ------- ------1----- -1--1 --- --	00001
71	PTIL	GAU	---- --- ------- ------------ --1-1 --- --	00001
33	EULA	FUL	---- --- ------- ---1-------- 1---- --- --	00001
17	VALL	SPE	---- --- ------- -1-1-------- ----1 --- --	00001
8	CYPE	IXI	---- --- ------- --1--------- --1-1 --- --	00001
5	CYPE	CON	---- --- ------- --------1--- -1--- --- --	00001
216	ATAL	HEM	---- --- ------- --1--11--1-1 ----- --- --	00000
214	GREV	VIC	---- --- ------- -1---11----- 1---- --- --	00000
204	SESR	FOR	---- --- ------- -1--11---1-1 ----- --- --	00000
170	ACAC	TEN	---- --- ------- --1--------1 ----- --- --	00000
158	ACAC	ARI	---- --- ------- -1-1-------- ----- --- --	00000
154	TINO	SMI	---- --- ------- -----1---1-- ----- --- --	00000
145	GOSS	ROR	---- --- ------- --11--1----1 ----- --- --	00000
142	ARUT	SP2	---- --- ------- ------1--1-- ----- --- --	00000
132	MYRI	SPE	---- --- ------- -1-------1-- ----- --- --	00000
124	EUPH	SP4	---- --- ------- ------1-1--- ----- --- --	00000
122	EUPH	SP2	---- --- ------- ------1--1-- ----- --- --	00000
114	MUKI	MAD	---- --- ------- --1--111-11- ----- --- --	00000
94	CAPP	SP1	---- --- ------- ---1-1-----1 ----- --- --	00000
77	PLUC	SP2	---- --- ------- -------11--- ----- --- --	00000
16	SCHO	LIT	---- --- ------- --111--111-1 ----- --- --	00000
1	PHOE	DAC	---- --- ------- ---1-1---1-- ----- --- --	00000
			0000 000 0000000 000000000000 00000 000 11	
			0000 111 1111111 111111111111 11111 111	
			000 0000000 000000000000 00000 111	
			000 0000000 111111111111 11111	
			000 1111111 000000000000 11111	

Table 6. Output of the numerical analysis program TWINSPAN, showing site and species associations for the 100 most common plant species collected from 36 sites in the Pilbara during March-April 1983.



Group	SITE NUMBER AND NAME		CLASS NUMBER	PERSISTENCE	SUBSTRATE
A	2	Fortescue 2.5 km from mouth	8	Tidally inundated	mud flat
	1	Fortescue river mouth	8	" "	" "
B	75	Doolena Gap	2	Transient	coarse alluv/br
	74	Poverty ck marshes	6	Ephemeral	fine clay
	46	Marble Bar soak	6	"	" "
C	69	Kunagunarrina Pool	3	Semipermanent	" "
	45	Shaw river crossing	4	Ephemeral	river alluvium
	44	West Strelley River	4	"	" "
	42	Red Rock Creek	5	"	fine river alluv.
	21	Hooley Creek #2	7	Semipermanent	" " "
D	67	Turner R. NWC Hwy	3	"	river alluvium
	54	Eera Baranna	1	Permanent	coarse alluv/br
	52	Chinnamon Creek	3	Semipermanent	" "
	51	Yule River NWC Hwy	3	"	" "
	49	Five Mile Creek	2	Ephemeral	" "
	48	Garden Pool	3	Semipermanent	" "
	39	Mulye Pool	3	"	river alluvium
	26	Weeli Wolli Spring	1	Permanent	coarse alluv/br
	24	Jcn. Marillana&Yandicoojina Cks	3	Semipermanent	river alluvium
	6	Bilanoo Pool	3	"	" "
	3	Post Office Pool	8	"	" "
E	47	Marble Bar Dredged area	9	"	fine clay
	40	Semi-Perm. Shay Gap	5	"	" "
	38	DeGrey marshes	6	Ephemeral	" "
	33	Coondiner Pool	7	Semipermanent	" "
	23	Weeli-Wooli Creek at marshes	7	"	" "
	22	Gnalka Gnoona Pool	7	"	" "
	20	Hooley Creek #1	7	"	" "
F	37	True "I" line	4	Ephemeral	river alluvium
	36	False "I" line	4	"	" "
	35	"Q" line transect	4	"	" "
G	15	Yarrie Spring	4	"	fine river alluv.
	14	Roy Hill #2	4	"	" " "
	13	Roy Hill #1	4	"	" " "
	0	Cowra	7	"	" " "

Figure 14. Dendrogram produced from the numerical analysis program, TWINSPAN of the 100 most common plant species collected from 36 wetland sites in the Pilbara during March-April, 1983.

The next group of sites to emerge (group B) were characterised by soft grasses (*Dactyloctenium radulans* in particular) and an absence of large tree species. *Eucalyptus camaldulensis* and *Cenchrus ciliaris* characterised the remaining sites.

The fourth division produced two groups, based on the presence of *Schoenoplectus litoralis*, *Melaleuca glomerata*, *Cymbopogon* sp, *Mukia maderaspatana* and *Phyllanthus maderaspatensis* for the first; and by the presence of the small herbaceous annual *Euphorbia coghlanii* for the second.

The first group of the fourth division was in turn divisible into two groups of sites at the fifth divisive level. The presence of *Sesbania cannabina* characterised group C, while it's absence, and the presence of *Melaleuca glomerata* characterised group D.

The second group of the fourth division was split into group F by the presence of *Melaleuca leucadendran*, while the remaining sites became group E.

3.5.5.2 Site Groups and Physical Characteristics

Physical characteristics were generally consistent for sites within each group (Figure 14). Sites in group D had substrates consisting of coarse alluvium over bedrock with permanent to semi-permanent water persistence. This group is equivalent to the spring and river pool categories (types 1 and 3) described earlier.

Group E sites were semi-permanent (with the exception of site 38) and had substrates predominated by fine clays. This group consisted of all the semi-permanent claypans (type 7 wetlands) and one site from each of types 5, 6 and 9.

Group F (type 4 wetlands) were ephemeral river channels on the De Grey River, type 4 wetlands, as were group G, though these had finer alluvial substrates.

Group C consisted of a mixture of type 3, 4, 5 and 7 wetland units, determined by the presence of *Sesbania cannabina*, an opportunistic wetland species (see section 3.5.2). Water persistence was semi-permanent to ephemeral.

Group B consisted of 2 ephemeral claypans (type 6) and an intermittently inundated creek, site X.

Group A were tidally influenced, type 8 wetlands.

The highest species richness was found for group D, with a decrease in both directions away from this central group in the dendrogram. A similar trend is apparent for water persistence, with group D being the most permanent, with permanency decreasing away from the centre in both directions.

3.5.6 COMPARISON BETWEEN SUBJECTIVE AND OBJECTIVE CLASSIFICATION

The site groups described subjectively, based on physical characteristics show a high degree of similarity with the groups identified objectively using the numerical analysis program TWINSPAN.

Although the site groups produced by the two methods were similar, sites within the groups identified using the numerical classification method tended to be spatially close together (eg Groups A, F, G and to a lesser extent group C). This may be due to a number of factors, such as ephemeral species being common to those sites due to localised rainfall, soil type similarities favouring particular species, or similar management practices (eg stocking density, mining type) for sites within a particular pastoral lease or mining area.

It must be kept in mind that the area surveyed is large, and the wetland areas themselves are very small and relatively isolated, making the overall structure of the wetland (ie its geomorphology and associated flora and fauna) very site specific.

Table 7. Algal genera collected from Pilbara inland surface waters, March-April 1983

	Site Number																	
Algal Genera	20	24	25	26	33	41	42	46	49	51	52	54	56	57	60	67	68	69
CHLOROPHYTA																		
CHLOROCCALES																		
Scenedesmus sp										*						*	*	
DESMIDIACEAE																		
Cosmarium sp	*			*						*								
Desmidium sp		*		*														
Staurastrum sp				*					*	*								
EUGLENOPHYTA																		
Phacys sp									*									
OEDOGONIALES																		
Oedogonium sp		*									*							
ULOTRICHALES																		
Ulothrix sp				*														
ZYGNEMATALES																		
Spirogyra sp		*	*	*														
Zygnema sp				*														
CYANOPHYTA																		
Anabaena sp								*										
Chroococcus sp														*				
Lyngbya sp														*				
Oscillatoria sp				*	*													
Scytonema sp															*			
Unidentified sp							*											
Rhizoclavium						*												
DIATOMACEAE	*	*	*	*						*			*					
CHARALES	*	*		*										*				

It is evident that both classification systems, one based on species, the other on physical characteristics, have shortcomings, but both identify a common denominator, namely water persistence.

Water persistence in each wetland is a result of physical attributes (eg substrate type, bed gradient). The flora associated with a wetland is also influenced by these physical factors, and associated therefore with their relationship to water persistence and availability. Superimposed on this basic framework are the more site specific characters such as geographic location, soil type and rainfall consistency.

3.5.7 ALGAE

The algal populations of the wetlands studied were both diverse and variable. The greatest diversity occurred in the Weeli Wolli Spring System (Table 7). It is interesting to note that although Weeli Wolli Creek and Eera Baranna Spring are both classified as spring systems, their algal floras are quite different. Only one genera of blue green alga occurred in Weeli Wolli Spring (site 26). In contrast the Eera Baranna Spring System (sites 54 to 60) was dominated by blue greens. The Zygnematales were found only in samples from the Weeli Wolli Creek area.

Overall, chlorophyll concentrations were lowest in the spring systems despite their high algal species diversity eg Weeli Wolli Spring (0.5 $\mu g.L^{-1}$) compared to the stiller area such as adjoining pools e.g. Red Rock Creek (5.7 $\mu g.L^{-1}$, Table 8).

Table 8. Chlorophyll concentrations in water samples from 12 Pilbara wetland sites, March /April, 1983.

SITE	CHLOROPHYLL CONCENTRATION ($\mu g.L^{-1}$) chl a	chl b	chl c
20	3.0	2.4	2.6
24	3.4	2.7	2.9
26	0.6	0.7	0.6
32	0.5	0.6	0.6
41	1.3	0.9	0.7
42	5.7	5.7	6.4
49	2.0	1.0	0.9
54	0.9	1.0	0.4
62	1.8	1.3	1.0
64	1.3	1.4	1.7
68	1.3	1.4	1.7
69	5.0	2.5	2.6

These values are similar to or less than those reported for pools along the Harding River (Dames and Moore, 1982), and relatively low for freshwaters in general.

3.6 AQUATIC FAUNA

3.6.1 ZOOPLANKTON

Details of the zooplankton collected are presented in Table 9. The taxa obtained are representative of those reported by Dames and Moore (1975 and 1982) for the Fortescue and Harding River catchments. It should be noted that the aquatic invertebrate fauna of the Pilbara is poorly documented and the taxonomic status of many families is ill defined.

Table 9. Invertebrate animal groups represented in zooplankton samples from 10 Pilbara wetland sites, March-April 1983.

Animal Group	(Wetland Type) and Site Number									
	(1)		(2)			(3)	(4)	(5)	(7)	
	26	54	52	69	6	49	41	42	20	33
ARTHROPODA										
INSECTA										
Coleoptera										
Dytiscidae										
1 species								+		
Gyrinidae										
Dineutus australus										o+
Collembola										
1 species			+							
Diptera										
Chironomidae										
sp 1					+					
sp 2									+	
sp 3									+	
sp 4	o+									
Chironomidae, Tanypodinae										
Perametina sp			+							
Culicidae										
1 species	o+									
Simulidae										
1 species	o+									
Tipulidae										
1 species						+				
Ephemeroptera										
Baetidae										
sp 1									+	
sp 2	o+									
Hemiptera										
Notonectidae										
Anisops sp										+
Trichoptera										
Hydropsychidae										
1 species	+									

Table 9. Invertebrate animal groups represented in zooplankton samples from 10 Pilbara wetland sites, March-April 1983 (contd)

Animal Group	(Wetland Type) and Site Number									
	(1)		(2)			(3)	(4)	(5)	(7)	
	26	54	52	69	6	49	41	42	20	33
CRUSTACEA										
Calanoida										
sp 1										+
sp 2				+						
Conchostraca										
Cyzicus										o+
1 species										
Copepoda										
1 species			+							
Notostraca								+		
Triops australiensis australiensis										
MOLLUSCA										
BIVALVIA										
Corbiculina sp					o+					
Velesunio wilsoni		o+			o+					
GASTROPODA										
Thiara australia					o+					
Lymnaea sp (?)		o+								

+ species present
o species collected from sediment

Small crustaceans (*Cyzicus* sp) were quite abundant in the sediments of Coondiner Pool. It is recommended that future surveys sample the sediments as knowledge of mollusc and crustacean populations may be of assistance in classifying water body types (McMichael, 1967).

3.6.2 FISH

The best-developed fish assemblages were found in the relatively clear waters of wetland types 1 and 3 (Table 10) ie those which have permanent or semi-permanent water supplies. No fishes were recorded from the claypan areas, except for Hooley Creek #1 (site 20), but limited searching revealed some crustaceans (Table 10).

The freshwater herring (*Nematalosa erebi*) is susceptible to eutrophic conditions and will be the first species lost when water quality deteriorates (Allen, 1982). This makes it a useful indicator of water quality. During this study large numbers were found dead in Lockyers Gorge, bleeding from the gills; a possible symptom of O_2 starvation. Cohabitant grunter species (Teraponidae) and rainbow fish (Melanotaeniidae) were, however, showing no signs of stress. Dissolved oxygen levels measured at the time were close to saturation (6.4 $mg.L^{-1}$, site 73, Table 3) and significantly higher than recorded in May 1976 (3.5 $mg.L^{-1}$ at 0.1 m and 2.1 $mg.L^{-1}$ on the bottom). It is possible that the fish were stressed as a result of increased biological oxygen demand at night.

3.7 AVIFAUNA

Results of the avifaunal sightings are presented in Table 11. The most diverse site was Coondiner Pool, a shallow semi-permanent claypan, affording a good feeding ground for wading birds with abundant crustaceans (see above). Second most diverse were the spring systems, and the semi-permanent claypan at Hooley Creek. Insufficient time was available to make a detailed study and hence diversity may be underestimated and biased.

The majority of birds sighted were nomadic or migratory, reflecting the intermittency of suitable water bird habitats within the arid Pilbara. Waterfowl are opportunistic in their breeding strategies and may disperse over wide areas during good seasons. Large populations of water birds such as pelicans, spoonbills and swans are known to breed in the Fortescue marshes during a good wet season, but this did not occur in 1982/83.

During seasons of poor rainfall, the wetlands with permanent and semi-permanent surface water come under increased pressure from large concentrations of waterbirds.

3.8 LAND USE

Pastoral, mining and recreational activities are the dominant land uses affecting Pilbara wetlands. The wetland sites examined that were reserved under the Land Act were within the Millstream-Chichester National Park (Minnorinna Pool) and within reserves designated for the purposes of watering stock and as resting places for travellers (Hooley Creek Reserve 5515, Gnalka Gnoona Pool Reserve 1328). The majority of sites however are located within pastoral leases, and as such are managed by the lessee as a source of water and feed for stock.

The widespread system of bores and wells installed by the pastoralists has allowed them to carry more stock over a wider range than was previously possible. Naturally-occurring water sources are also utilized, as they supply not only water, but provide conditions favourable for the growth of forage grasses.

Cenchrus ciliaris (buffel grass) and *Aerva javanica* (kapok), both exotic species, have been introduced and actively spread by pastoralists to improve feed quality and availability. In many areas buffel grass has out-competed natural grasses, and, especially in the vicinity of water, has become widespread over much of the Pilbara. Hoof prints and trampled vegetation were common sights around the wetlands surveyed. This disturbance is undoubtedly associated with erosion by wind and rain, due to a lack of ground cover and substrate instability. At certain sites, such as Yarri Spring on Roy Hill station, ground cover was almost non-existent because of poor rains and over-grazing by cattle.

Table 10. Aquatic macrofauna collected at 14 Pilbara wetland sites, March-April 1983.

Species	Site Number														
	6	7	20	24	29	33	41	42	46	49	51	60	68	69	73
Western Rainbowfish *Melanotaenia splendida australis* (Castelnau)	x	x	x	x	x		x			x		x		x	x
Barred Grunter *Amniataba percoides* (Gunther)	x	x	x							x	x	x	x	x	x
Spangled Perth *Leiopotherapon unicolor* (Gunther)	x	x		x	x							x			
Fork-tail Catfish *Arius australis* (Gunther)		x	x												x
Eel-tail Catfish *Neosilurus hyrtlii* (Steindachner)		x			x										
Freshwater Herring *Nematalosa erebi* (Gunther)															x
Tadpoles								x							
Mollusca	x					x			x			x			
Crustacea								x	x						

Table 11. Bird species observed at 20 Pilbara wetland sites, March-April 1983*.

Bird Species		Site Number																			
Common Name	Scientific Name	1	3	6	13	16	20	21	22	24	26	33	35	41	46	47	48	49	51	54	69
Tern	*Sterna*	+																			
	Chlidonias sp					+															
Australian Pelican	*Pelecanus conspicullatus*												+								
Cormorant	*Phalocrocorax* sp														+	+				+	+
Black Bittern	*Dupetor flavicollis*						+														
Australian Bustard	*Eupodotis australis*		+																		
Emu	*Dromaius novaehollandiae*																			+	
Jabiru	*Xenorhynchus asiaticus*																		+		
Yellow-Billed Spoonbill	*Platalea flavipes*											+									+
White-Faced Heron (adult)	*Ardea novaehollandiae*	+		+							+	+			+	+		+			+
White-Faced Heron (immature)	*Ardea novaehollandiae*			+																+	
White-Necked Heron	*Ardea pacifica*											+									
White Egret	*Egretta alba*															+					
Black-Fronted Dotterel	*Charadrius melanops*				+		+					+			+		+		+	+	
Terek Sandpiper	*Xenus cinereus*											+									
Black-Winged Stilt	*Himantopus himantopus*											+			+						
Snipe	*Gallinago* sp											+									

Table 11. Bird species observed at 20 Pilbara wetland sites, March-April 1983* (contd)

Bird Species		Site Number																			
Common Name	Scientific Name	1	3	6	13	16	20	21	22	24	26	33	35	41	46	47	48	49	51	54	69
Black Duck	*Anas superciliosa*			+	+			+		+		+			+					+	+
Pink-Eared Duck	*Malacorhynchus membranaceus*				+																
Coot	*Fulica atra*					+															+
Australian Little Grebe	*Podiceps novaehollandiae*																			+	
Blue-Winged Kookaburra	*Dacelo leachii*			+																	
Sacred Kingfisher	*Halcyon sancta*						+			+			+					+			
Cuckoo	*Chrysococcyx* sp										+									+	
Welcome Swallow	*Hirundo neoxena*						+						+								
Galah	*Eolopus roseicapillus*		+						+		+	+							+	+	
Little Corella	*Cacatua sanguinea*			+			+		+	+		+		+							+
Port Lincoln Parrot	*Barnardius zonarius*								+		+	+									
Willie Wagtail	*Rhipidura leucophrys*			+			+														
Crow	*Corvus* sp						+				+	+								+	+
Magpie Lark	*Grallina cyanoleuca*				+	+					+	+	+			+					
Painted Finch	*Emblema picta*										+									+	
Red-Plumed Pigeon	*Lophophaps plumifera ferruginea*			+			+				+										

* Identifications were made using: Slater, P. (1970). A Field Guide to Australian Birds. Passerines; A Field Guide to Australia Birds. Non-passerines. Scottish Academic Press, Edinburgh.

The direct effect of mining was apparent in only one of the wetlands surveyed (site 47), where dredging for tin had occurred. Although not widespread throughout the Pilbara, this form of mining causes high localised disturbances to the environment. Mining companies in remote inland locations have developed new towns and stable communities such as Newman and Telfer. The increased accessibility afforded by 4-wheel drive vehicles and the amenity provided by wetlands, in particular spring systems and permanent river pools, results in them becoming focal points for recreational activities, especially during the drier months. General camping along with water sports such as wildfowl hunting, fishing and swimming are influential on the wetland systems and their associated biota. Increased pedestrian and vehicular traffic has resulted in gully erosion at popular places such as Mulye Pool (site 39) and the Turner River (site 67), while the human presence creates stress on the natural biota, especially those species dependant on the wetland areas for breeding.

The careless disposal of detergents and other wastes is known to tarnish aesthetic appeal and affect the environment, but the effects of more subtle perturbations such as disruption of the thermocline by swimming are unknown.

Wetlands and water courses are an intrinsic part of the Aboriginal culture and have been used to obtain food, water and shelter and as aids in travel and navigation. Grinding patches in river stone (eg Chinnamon Pool, site 52) and associated stone implements are indicators that aboriginal use of many of the Pilbara wetlands has been significant.

4. RECOMMENDATIONS FOR FURTHER STUDY

1. A survey of wetlands in the Oakover/De Grey River catchments, with particular emphasis on the Carawine Gorge System and Skull Springs on the Davis River, needs to be undertaken. Similarly wetlands along the Ashburton River and its catchment require incorporation into the data base for the Pilbara.

2. Once adequate data have been obtained, the classification system should be revised to encompass the entire Pilbara region.

3. Concurrent distribution of recommended proforma (Appendix 1) to interested individuals and groups such as Department of Conservation and Land Management officers, high schools and tertiary institutions, will be a possible way to generate more information on numbers and locations of wetland sites, notes on wildlife usage and their seasonality. A location for lodging completed proformas will be necessary (eg c/o Environmental Protection Authority, Karratha).

4. Once the data base is sufficiently expanded and a classification system for the wetlands resolved, representative wetland types should be chosen and monitored regularly to accurately document the seasonality of these systems.

5. Recommendations for wetland management and reservation should be made to protect particularly delicate and unique systems and ensure that adequate numbers of all wetland types are protected to maintain the genetic diversity and high productivity of these diverse and rare systems.

5. SUMMARY AND CONCLUSIONS

A classification system based primarily on five physical parameters is proposed, identifying nine wetland types. Water quality data and results of the preliminary biological survey are largely consistent with this classification system. Inconsistencies illustrate the need to incorporate floral and faunal indicator species which, due to their prominence and ease of indentification, are suggested as suitable indicators for particular wetland types.

Species richness was highest in wetlands with permanent water supplies and/or high integral habitat diversity. Springs and permanent/semi-permanent river pools fall into this category, and, as at Millstream, probably harbour endemic species of aquatic fauna and associated flora. Such endemics would be extremely rare and vulnerable.

Pastoral, mining and recreational activities combined with the unpredictable climate of the region impose considerable pressure on the fragile wetland systems. Due to the combined effect of human activities over time, few, if any pristine wetlands now exist in the Pilbara.

It is imperative that adequate measures be taken to determine the extent of these wetland resources; obtain a working knowledge of the inter-relationship between the various physical and biological components; and ultimately formulate a suitable management plan to conserve these unique systems where this is still possible.

6. **REFERENCES**

Allen, G R (1982), Inland Fishes of Western Australia, Western Australian Museum, Perth, Western Australia.

Bayly, I A E and Williams, W D (1973), Inland Waters and their Ecology, Longman, Melbourne.

Dames and Moore (1975), Environmental investigations, Gregory and Dogger Gorge dam sites, Fortescue River, Western Australia, Report for the Public Works Department, Western Australia.

Dames and Moore (1978), Environmental review and management programme, De Grey River borefield, Port Hedland, Western Australia, Report for the Public Works Department, Western Australia.

Dames and Moore (1982), Harding Dam Project, Draft Environmental Review and Management Programme, Report for Engineering Division, Public Works Department, Western Australia.

Davidson, W A (1975), Hydrogeological reconnaissance of the Northwest Pilbara region, Record Number 1975/12, Geological Survey of Western Australia.

Hill, M O (1979), TWINSPAN - A Fortran programme for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes ecology and systematics, Cornell University, Ithaca, New York 14850.

Kolthoff, I M, Sandell, E B, Meehan, E J and Bruckenstein, S (1969), Quantitative Chemical Analysis, 4th Ed, Collier-Macmillan, London, 337pp.

Kriewaldt, M and Ryan, A R (1967), Pyramid, Western Australia, GSWA 1:250,000 Geological Series Explanatory Notes, Sheet SF/50-7.

Main Road Department, Western Australia (1984), Perth to Darwin National Highway, Newman to White Springs, Draft Environmental Review and Management Programme and Environmental Impact Statement, Main Roads Department, Perth, Western Australia.

McMichael, D F (1967), in A H Weatherley, Australian Inland Waters and their Fauna: Eleven Studies, ANU Press, Canberra, 123-149.

Morgan, N C and Boy, V (1982), 'An ecological survey of standing waters in Northwest Africa. I. Rapid survey and classification', Biol Conserv **24**,5-44.

Paijmans, K (1978), Feasibility report on a National Wetland Survey. C S I R O Technical Memorandum 78/6. Division of Land Use Research.

Pilbara Study Group (1974) The Pilbara Study: Report on the Industrial Development of the Pilbara, AGPS, Canberra, Map 1.

Slater, P (1970). A Field Guide to Australian Birds, Vol 1, Non-passerines, 428pp. A Field Guide to Australian Birds, Vol 2, Passerines, 309pp. Scottish Academic Press, Edinburgh.

Snowy Mountains Engineering Corporation and Water Resources Branch, PWD (1982), Hydrologic Investigations for the Harding Dam, Vol 1, Public Works Department, Perth, Western Australia.

Strickland, J D H and Parsons, T R (1972), A Practical Handbook of Seawater Analysis, Bulletin 167 (2nd Ed), Fisheries Research Board of Canada, Ottawa.

Walker, B A, Pate, J S and Kuo, J (1983), 'Nitrogen fixation by nodulated roots of *Viminaria juncea* (Schrad & Wendl) Hoffmans (Fabaceae) when submerged in water', Aust J Plant Physiol **10**,409-421.

Wetlands Advisory Committee (1977). The Status of Wetland Reserves in System 6, Report of the Wetlands Advisory Committee to the Environmental Protection Authority, Perth, Western Australia.

APPENDICES

Key
* Site numbers (see Table 1)
** Wetland type (see Table 2)

APPENDIX 1

	PLANT SPECIES COLLECTED AT WETLAND *	1		2		3						4										5		6			7						8		9	
	SITES IN THE PILBARA, MARCH-APRIL 1983 **	26	54	75	49	6	39	48	51	52	69	76	13	14	15	35	36	37	44	45	67	40	42	38	46	74	20	21	22	23	24	33	1	2	3	47
	Arecaceae																																			
1	*Phoenix dactylifera* L.	●	●					●																												
	PTERIDOPHYTA																																			
	Marsileaceae																																			
2	*Marsilea* sp.							●										●				●	●	●	●	●		●				●				
	ANGIOSPERMAE																																			
	Monocotyledonae																																			
	Cyperaceae																																			
3	*Bulbostylis barbata* (Rottb.) C.B. Clarke.																					●														
4	*Cyperus bulbosus* Vahl											●																								
5	*Cyperus conicus* (R.Br.) Boeck.									●													●													
6	*Cyperus difformis* L.									●																										
7	*Cyperus iria* L.																					●						●				●				
8	*Cyperus ixiocarpus* F. Muell.										●								●												●					
9	*Cyperus squarrosus* L.																																			
10	*Cyperus vaginatus* R. Br.	●	●			●		●		●																		●				●				
11	*Cyperus* sp1																											●								
12	*Cyperus* sp2																															●				
13	*Cyperus* sp3																					●														
14	*Cyperus* sp4																					●														
15	*Cyperus* sp5																								●											
16	*Eleocharis geniculata* (L.) Roem. & Schult.		●																																	
17	*Schoenoplectus litoralis* (Shrader) Palla # (*Scirpus litoralis* Schrad. = *Schoenoplectus*)	●	●				●		●	●																					●					
	Hydrocharitaceae																																			
18	*Vallisneria* sp	●				●					●																									
	Najadaceae																																			
19	*Najas* sp								●																											
	Poacea																																			
20	*Cenchrus ciliaris* L.		●		●	●	●			●								●				●	●	●			●	●							●	●
21	*Cenchrus* sp															●		●																		
22	*Chrysopogon fallax* S.T. Blake							●														●					●	●								
23	*Chrysopogon* sp						●																													
24	*Cymbopogon* sp	●	●	●	●														●	●			●													
25	*Enneapogon* sp																																			
26	*Eragrostis basedowii* Jedw.	●																																		
27	*Eragrostis* sp1																					●										●				
28	*Eragrostis* sp2								●																							●				
29	*Eragrostis* sp3																																			
30	*Eragrostis* sp4						●									●		●																		
31	*Eragrostis* sp5																						●													
32	*Eragrostis* sp6																		●																	
33	*Eriachne* sp1																								●			●								
34	*Eriachne* sp2		●																																	
35	*Eriachne* sp3																								●											
36	*Eulalia fulva* (R.Br.) Kuntze	●																										●								
37	*Spinifex longifolius* R.Br.#																																●			
38	*Spinifex* sp1				●											●		●																		

		26	54	75	49	6	39	48	51	52	69	76	13	14	15	35	36	37	44	45	67	40	42	38	46	74	20	21	22	23	24	33	1	2	3	47
39	*Spinifex* sp2				●																															
40	*Sporobolus australasicus* Domin																	●				●														
41	*Sporobolus* sp1												●	●																						
42	*Themeda australis* (R.Br.) Stapf			●	●																															
43	*Triodia pungens* R.Br.					●																									●		●	●		
44	*Triodia* sp1			●																																
45	*Triodia* sp2			●																																
46	*Triodia* sp3				●																	●														
47	Unidentified grass spA																														●					
48	" " spB											●												●												
49	" " spC						●		●															●												
50	" " spD						●																													
51	" " spE																					●														
52	" " spF																					●														
53	" " spG																						●													
54	" " spH																						●													
55	" " spI																						●													
56	" " spJ																						●													
57	" " spK																																			●
58	" " spL				●																															
	Potamogetonaceae																																			
59	*Potamogeton* sp		●						●			●																								
	Typhaceae																																			
60	*Typha domingensis* Pers.		●						●			●																								●
	DICOTYLEDONAE																																			
	Aizoaceae																																			
61	*Mollugo molluginea* (F. Muell.) Druce									●	●											●														
62	*Trianthema triquetra* Willd.			●									●									●			●							●				●
63	*Trianthema* sp1																					●														
64	*Trianthema* sp2																																			●
	Amaranthaceae																																			
65	*Achyranthes aspera* L.							●																												
66	*Aerva javanica* (Burm f.) Juss. ex Schult.										●				●	●														●						●
67	*Alternanthera nodiflora* R.Br.														●		●	●						●				●		●		●				
68	*Alternanthera* sp1																							●												
69	*Alternanthera* sp2																							●												
70	*Amaranthus* sp															●												●								
71	*Gomphrena canescens* R.Br.																							●												
72	*Gomphrena cunninghamii* (Moq.) Druce		●																																	
73	*Ptilotus exaltatus* Nees					●																														
74	*Ptilotus gaudichaudii* (Steud.) J.M. Black										●								●																	
75	*Ptilotus gomphrenoides* F. Muell. ex Benth.#																						●		●											
76	*Ptilotus* sp																								●											
	Asteraceae																																			
77	*Centipeda* sp	●																						●							●					
78	*Pluchea rubelliflora* (F. Muell.) B.L. Robinson	●																																		
79	*Pluchea* sp1																					●														●
80	*Pluchea* sp2								●	●																										
81	*Pluchea* sp3									●																										
	Bignoniaceae																																			
82	*Dolichandrone heterophylla* (R.Br.) F. Muell.																						●													
	Boraginaceae																																			
83	*Ehretia saligna* R.Br.		●	●																																

No.	Taxon	26	54	75	49	6	39	48	51	52	69	76	13	14	15	35	36	37	44	45	67	40	42	38	46	74	20	21	22	23	24	33	1	2	3	47
84	*Heliotropium cunninghamii* Benth.#	●																					●													
85	*Heliotropium* sp1																	●																		
86	*Heliotropium* sp2				●																															
87	*Tricodesma zeylanicum* (Burm.f.) R.Br.				●						●												●													
	Caesalpiniaceae																																			
88	*Cassia* sp																													●		●				
89	*Cassia glutinosa* DC.		●	●																																
90	*Cassia helmsii* Symon																															●				
91	*Cassia notabilis* F. Muell.										●												●													
92	*Cassia oligophylla* F. Muell.			●																																
93	*Cassia venusta* F. Muell.																						●													
94	*Cassia* sp			●																																
95	*Lysiphyllum cunninghamii* (Benth.) De Wit#															●		●																		
96	*Petalostylis labicheoides* R.Br.					●																	●													
	Capparaceae																																			
97	*Capparis spinosa* L.	●						●																												
98	*Cleome viscosa* L.		●		●	●		●														●									●					
	Chenopodiaceae																																			
99	*Atriplex cinerea* subsp *rhagodioides* (F. Muell.) Aellen = *Altiplex rhagodioides* F.Muell													●																						
100	*Atriplex* sp											●		●																						
101	*Halosarcia auriculata* Paul G. Wilson #												●																							
102	*Halosarcia indica* subsp. *leiostachya* (Willd.) P.G. Wilson											●																								
103	*Halosarcia* sp1																												●							
104	*Halosarcia* sp2											●																								
105	*Halosarcia* sp3											●																								
106	*Salsola kali* L.			●																																
	Compositae																																			
107	*Olearia spinescens*											●																								
108	*Pterocaulon* sp																●																			
109	*Senecio* sp																	●																		
	Convolvulaceae																																			
110	*Bonamia rosea* (F. Muell.) Hall. f.				●																		●													
111	*Evolvulus alsinoides* L.																						●													
112	*Ipomea muelleri* Benth.				●		●	●								●		●	●	●		●	●							●	●					
113	*Ipomea* sp														●																					
114	*Operculina brownii* Oostrtr.#						●																													
115	*Polymeria* sp1		●																				●													
116	*Polymeria* sp2								●																											
	Cucurbitaceae																																			
117	*Mukia maderaspatana* (L.) M.J. Roem.		●		●			●	●												●										●					
	Elatinaceae																																			
118	*Bergia pedicellaris* (F.Muell.) F.Muell. ex Benth.																					●														
119	*Bergia* sp1																														●					
120	*Bergia* sp2												●																			●				
	Euphorbiaceae																																			
121	*Adriana* sp								●																											
122	*Euphorbia australis* Boiss.				●	●		●			●					●															●					
123	*Euphorbia coghlanii* F.M. Bail.						●	●														●	●								●					
124	*Euphorbia* sp1		●																																	
125	*Euphorbia* sp2		●		●																															
126	*Euphorbia* sp3		●																																	

No.	Taxon	26	54	75	49	6	39	48	51	52	69	76	13	14	15	35	36	37	44	45	67	40	42	38	46	74	20	21	22	23	24	33	1	2	3	47
127	*Euphorbia* sp4				●					●																										
128	*Phyllanthus maderaspatensis* L.				●	●				●	●												●					●								
129	*Securinega melanthesiodes* (F. Muell.) Airy Shaw = *Flueggea virosa* (Roxb.ex Willd.)			●				●																												
	Frankeniaceae																																			
130	*Frankenia* sp											●		●																						
	Goodeniaceae																																			
131	*Goodenia* sp1																											●								
132	*Goodenia* sp2											●																								
133	*Scaevola spinescens* R.Br.													●																						
	Gramineae																																			
134	*Dactyloctenium radulans* (R.Br.) Beauv.			●																		●			●											
	Haloragaceae																																			
135	*Myriophyllum* sp		●			●																														
	Lauraceae																																			
136	*Cassytha* sp1			●																			●													
137	*Cassytha* sp2				●																															
	Lobeliaceae																																			
138	*Lobelia quadrangularis* R.Br.#		●																																	
139	*Lobelia* sp1	●																																		
	Lythraceae																																			
140	*Ammannia* sp1		●																																	
141	*Ammannia* sp2																														●					
142	*Ammannia* sp3				●																															
143	*Rotala* sp		●																																	
	Malvaceae																																			
144	*Abutilon* sp1	●	●							●													●							●						
145	*Abutilon* sp2		●		●																															
146	*Abutilon* sp3																						●													
147	*Abutilon* sp4							●																												
148	*Gossypium australe* F. Muell.		●																																	
149	*Gossypium robinsonii* F. Muell. #	●			●																										●					
150	*Hibiscus panduriformis* Burm.f.										●												●													
151	*Hibiscus* sp1																						●													
152	*Hibiscus* sp2			●																																
153	*Malvastrum americanum* (L.) Torr.							●															●													
154	*Sida rholenae* Domin.			●																																
155	*Sida* sp1																													●						
	Meliaceae																																			
156	*Owenia* sp						●																													
	Menispermaceae																																			
157	*Tinospora smilacina* Benth.		●					●																												
	Mimosaceae																																			
158	*Acacia ampliceps* Maslin									●			●																							
159	*Acacia ancistrocarpa* Maiden & Blackely																													●						
160	*Acacia aneura* F. Muell. ex Benth.																												●			●				
161	*Acacia arida* Benth.#	●				●																														
162	*Acacia bivenosa* DC.#			●																																
163	*Acacia citrinoviridis* Tind. & Maslin#	●																																		
164	*Acacia coriacea* DC.	●	●		●	●		●		●		●																		●					●	
165	*Acacia farnesiana* (L.) Willd.		●					●					●	●																	●					
166	*Acacia holosericea* A. Cunn. ex G. Don							●																												
167	*Acacia maitlandii* F. Muell.		●																																	
168	*Acacia monticola* J.M. Black		●	●																																

		26	54	75	49	6	39	48	51	52	69	76	13	14	15	35	36	37	44	45	67	40	42	38	46	74	20	21	22	23	24	33	1	2	3	47
169	*Acacia morrisonii*	●	●	●																	●							●								
170	*Acacia pyrifolia* DC.		●			●																	●	●					●							
171	*Acacia sphaerostachya* E. Pritzel#			●																			●													
172	*Acacia stipuligera* F. Muell.		●																																	
173	*Acacia tenuissima* F. Muell.																														●					
174	*Acacia trachycarpa* E. Pritzel#						●		●		●								●	●	●	●	●													
175	*Acacia translucens* A. Cunn. ex Hook.								●																											
176	*Acacia xiphophylla* E. Pritzel#																												●							
177	*Acacia* sp1	●																																		
178	*Acacia* sp2	●																																		
179	*Acacia* sp3			●																		●	●													
180	*Acacia* sp4																						●													
181	*Neptunia dimorphantha* Domin														●										●											
182	*Prosopis juliflora* Sw. DC.																																	●	●	
	Myrtaceae																																			
183	*Eucalyptus camaldulensis* Dehnh.	●	●		●	●	●	●		●	●		●						●	●	●			●			●		●	●		●			●	
184	*Eucalyptus coolabah* Blakely & Jacobs#		●		●	●										●		●			●						●		●			●				
185	*Eucalyptus dichromophloia* F. Muell.			●																																
186	*Eucalyptus papuana* F. Muell.			●																																
187	*Eucalyptus setosa* Schauer																●																			
188	*Eucalyptus* sp1																●																			
189	*Eucalyptus* sp2																●																			
190	*Melaleuca bracteata* F. Muell.	●																																		
191	*Melaleuca glomerata* F. Muell.	●			●	●			●	●				●				●			●										●				●	
192	*Melaleuca leucadendran* (L.)L.#	●				●	●		●	●	●					●	●	●	●	●	●										●				●	
193	*Melaleuca linophylla* F. Muell.		●		●									●																						
194	*Melaleuca* sp1																						●													
	Nyctaginaceae																																			
195	*Boerhavia* sp1		●		●																															
196	*Boerhavia* sp2						●																									●				
197	*Boerhavia* sp3							●							●		●	●																		
	Oleaceae																																			
198	*Jasminium lineare* R.Br.		●																																	
	Papilionaceae																																			
199	*Crotalaria cunninghamii* R.Br.				●						●								●				●													
200	*Crotalaria trifoliastrum* Willd.#		●																																	
201	*Erythrina vespertilio* Benth.							●			●		●																							
202	*Indigofera monophylla* DC.			●	●																							●			●					
203	*Indigofera* sp																						●													
204	*Psoralea* sp										●	●			●																					
205	*Rhynchosia minima* (L.) DC.	●		●							●												●					●								
206	*Sesbania cannabina* (Retz.) Poir.									●	●							●	●	●		●		●				●				●				
207	*Sesbania formosa* (F. Muell.) N.T. Burbidge		●			●	●																●				●									
208	*Tephrosia rosea* (F. Muell.) ex Benth.			●																																
209	*Tephrosia* sp1.	●																																		
210	*Tephrosia* sp2																						●													
211	*Zornia nervata* Mohlenbrock						●																													
	Polygonaceae																																			
212	*Muehlenbeckia cunninghamii* (Meisn.) F. Muell.										●	●	●	●															●			●				
	Portulacaceae																																			
213	*Calandrinia* sp1																					●														
214	*Calandrinia* sp2								●	●												●														
215	*Portulacia* sp.																					●								●						●

	26	54	75	49	6	39	48	51	52	69	76	13	14	15	35	36	37	44	45	67	40	42	38	46	74	20	21	22	23	24	33	1	2	3	47
Primulaceae																																			
216 *Samolus junceus* R.Br.#												●	●																						
Proteaceae																																			
217 *Grevillea wickhamii* Meisn.				●	●		●																				●								
218 *Grevillea pyramidalis* A. Cunn.		●																																	
Sapindaceae																																			
219 *Atalaya hemiglauca* (F. Muell.) F. Muell. ex Benth.		●		●			●																							●					
Scrophulariaceae																																			
220 *Mimulus gracilis* R.Br.																															●				
221 *Peplidium* sp																															●				
222 *Stemodia grossa* Benth.#	●	●							●	●											●						●			●					
223 *Stemodia* sp												●											●							●	●				
Solanaceae																																			
224 *Datura leichhardtii* F. Muell. ex Benth.						●																													
225 *Solanum diversiflorum* F. Meull.		●																																	
226 *Solanum lasiophyllum* Dun.				●																															
227 *Solanum phlomoides* Cunn. ex Benth.#								●																					●						
228 *Solanum* sp1					●																														
229 *Solanum* sp2						●																													
230 *Solanum* sp3				●																															
Stylobasidiaceae																																			
231 *Stylobasium spathulatum* Deft.#	●																																		
Sterculiaceae																																			
232 *Melhania oblongifolia* F. Muell.							●																												
Tiliaceae																																			
233 *Corchrus parviflorus* Domin					●																														
234 *Corchrus* aff. *walcottii* F. Muell		●																				●													
235 *Corchrus* sp1																											●			●					
236 *Corchrus* sp2																															●				
237 *Corchrus* sp3																						●													
238 *Corchrus* sp4			●																																
239 *Triumfetta appendiculata* F. Muell.				●																		●													
240 *Triumfetta micracantha* F. Muell.																						●													
Verbenaceae																																			
241 *Clerodendrum lanceolatum* F. Muell.		●																																	
Violaceae																																			
242 *Hybanthus aurantiacus* (F. Muell. ex Benth.) F. Muell.										●												●													
Zygophyllaceae																																			
243 *Kallstroemia angustifolia* (R.Br.) Engler									●																						●				
244 *Tribulus* sp						●																													

All identifications were made using:—
Jessop, J. (editor-in-chief) (1985). FLORA OF CENTRAL AUSTRALIA, Australian Systematic Botany Society.
except
Green, J.W. (1985). CENSUS OF THE VASCULAR PLANTS OF WESTERN AUSTRALIA, W.A. Herbarium, Department of Agriculture, Perth. 2nd Edition.

APPENDIX 2

SUGGESTED PROFORMA FOR RECORDING INFORMATION ON PILBARA WETLANDS

1. Site name and number

2. Date of sampling

3. Time of day

4. Recorder's name

5. 1:100 000 map number

6. Map grid reference (6 figures)

7. Cadastral information

8. Depth of water body
   (a) Mean
   (b) Maximum at time of sampling
   (c) Potential maximum depth

9. Wetland type

10. Water supply

11. Relationship and depth to water table

12. Persistance of surface water

13. Conductivity

14. Temperature

15. pH

16. Dissolved Oxygen

17. Turbidity

FAUNA

18. Birds (species names and notes on wetland usuage ie feeding, breeding etc)

19. Fish

20. Molluscs and other benthic faunal

21. Zooplankton Mesh size — Water volume filtered
Sample reference number(s)

FLORA

22. Microalgae — Volume filtered — Microscope slide number(s)

23. Macro and filamentous algal sample reference number(s)
notes . . .

24. Submerged aquatics . . . . . (species and % cover)

25. Emergent aquatics . . . (species and % cover)

26. Fringing vegetation

Trees

Shrubs

Herbs and ground covers

Chenopodiacea (Salt-bush and Samphire)

27. Crosssectional and areal diagram of wetland showing zonation patterns of vegetation

28. Wetland uses : . notes on main types (ie recreation, duck shooting pastoral activities, mining, Aboriginal usage); Intensity and visible effects of that uses.

29. Names of local informants with first hand knowledge about seasonal cycles and other relevant information.

30. General comments about the wetland . . . . . points of interest or aspects warranting special consideration.

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