Department of
Environment and Conservation

Our environment, our future

Resource Condition Report for Significant Western Australian Wetland

Wetlands of the Fortescue River System

2009

Figure 1 – A view across the water body at Moorimoordinina Pool, a site within the Fortescue Marshes.

This report was prepared by:

Jennifer Jackson, Technical Officer, Department of Environment and Conservation, PO Box 51, Wanneroo 6946

Stephen Kern, Botanist, Department of Environment and Conservation, Locked Bag 104 Bentley Delivery Centre 6983

Adrian Pinder, Senior Research Scientist, Department of Environment and Conservation, PO Box 51, Wanneroo 6946

Anna Nowicki, Technical Officer, Department of Environment and Conservation, PO Box 51, Wanneroo 6946

Glen Daniel, Environmental Officer, Department of Environment and Conservation, Locked Bag 104 Bentley Delivery Centre 6983

Invertebrate sorting and identification was undertaken by:

Nadine Guthrie, Research Scientist, Department of Environment and Conservation, PO Box 51, Wanneroo 6946

Ross Gordon, Technical Officer, Department of Environment and Conservation, PO Box 51, Wanneroo 6946

Prepared for:

Inland Aquatic Integrity Resource Condition Monitoring Project, Strategic Reserve Fund, Department of Environment and Conservation

Version 2.0 (June 2009)

Suggested Citation:

DEC (2009) *Resource Condition Report for Significant Western Australian Wetland: Fortescue Marshes.* Department of Environment and Conservation. Perth, Australia.

Contents

1. Introduction

This Resource Condition Report (RCR) was prepared by the Inland Aquatic Integrity Resource Condition Monitoring (IAI RCM) project. It describes the ecological character and condition of six wetlands within the Fortescue River system. These include three sites within the Fortescue Marshes, a floodplain in the middle reaches of the river, and three river pools (Figure 2).

The Fortescue Marshes sites were selected for study because the marshes are listed as a wetland system of national significance in the Directory of Important Wetlands in Australia (DIWA) (Environment Australia 2001). One of the river pools, Palm Pool, is also a DIWA listed site, while the other two have regional level significance.

1.1. Site Code

Directory of Important Wetlands in Australia: WA066 (Fortescue Marshes)

WA069 (Millstream Pools)

Register of the National Estate Place ID: 101319 (Fortescue Marshes)

DEC surveys: Inland Aquatic Integrity Resource Condition Monitoring (RCM) and Pilbara Biological Survey, Pilbara Surface Water Survey (PSW):

Dales Gorge:	RCM001, PSW006
Fortescue Marsh West:	RCM002, PSW003
Moorimoordinina Pool:	RCM003, PSW002
Lower Fortescue Pool:	RCM004 (not sampled by PSW)
Palm Pool:	RCM005, PSW010
Fortescue Marsh West:	RCM006, PSW076

1.2. Purpose of Resource Condition Report

The objective of the RCR is to summarise available ecological information relevant to the wetlands of the Fortescue River system and to present the results of surveys conducted by the IAI RCM project in 2008. It will describe the drivers of, and threats to, the system and the wetlands within it. This 'snapshot' of ecological character will provide context for future monitoring of the sites and allow the effectiveness of management planning and actions to be assessed.

1.3. Relevant Legislation and Policy

The following is a summary of legislation and policy that may be relevant to the management of the wetlands of the Fortescue River system.

International

Migratory bird bilateral agreements and conventions

Australia is party to a number of bilateral agreements, initiatives and conventions for the conservation of migratory birds. These are likely to be relevant to wetlands within the Fortescue River system. In particular, these bilateral agreements are important to management of the Fortescue marshes, due to its use by migratory birds. The bilateral agreements are:

JAMBA - The Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment, 1974;

CAMBA - The Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment, 1986;

ROKAMBA - The Agreement between the Government of Australia and the Republic of Korea for the Protection of Migratory Birds and their Environment, 2006;

The Bonn Convention on Migratory Species (CMS) - The Bonn Convention adopts a framework in which countries with jurisdiction over any part of the range of a particular species co-operate to prevent migratory species becoming endangered. For Australian purposes, many of the species are migratory birds.

National legislation

The Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

The EPBC Act is the Australian Government's central piece of environmental legislation. It provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places. These are defined in the Act as matters of national environmental significance.

There are seven matters of national environmental significance to which the EPBC Act applies. Two of these are relevant to the Fortescue River system:

- nationally threatened species and ecological communities; and
- migratory species listed under international treaties JAMBA, CAMBA and CMS.

The Fortescue Marshes are also a proposed Ramsar site and, if this listing is achieved, the site will be further protected under the EPBC Act as a wetland of international significance.

Australian Heritage Council Act 2003

The Fortescue Marshes have been placed on the Register of the National Estate (Indicative Place). The Australian Heritage Council Act protects places of National and Commonwealth significance.

Western Australian state policy

Wildlife Conservation Act 1950

This Act provides for the protection of wildlife. All fauna in Western Australia is protected under section 14 of the *Wildlife Conservation Act 1950*. The Act establishes licensing frameworks for the taking and possession of protected fauna, and establishes offences and penalties for interactions with fauna.

Conservation and Land Management Act 1987

This Act is administered by the State Department of Environment and Conservation (DEC) and applies to public lands. It sets the framework for the creation and management of marine and terrestrial parks, reserves and management areas in Western Australia, and deals with the protection of flora and fauna within reserve systems.

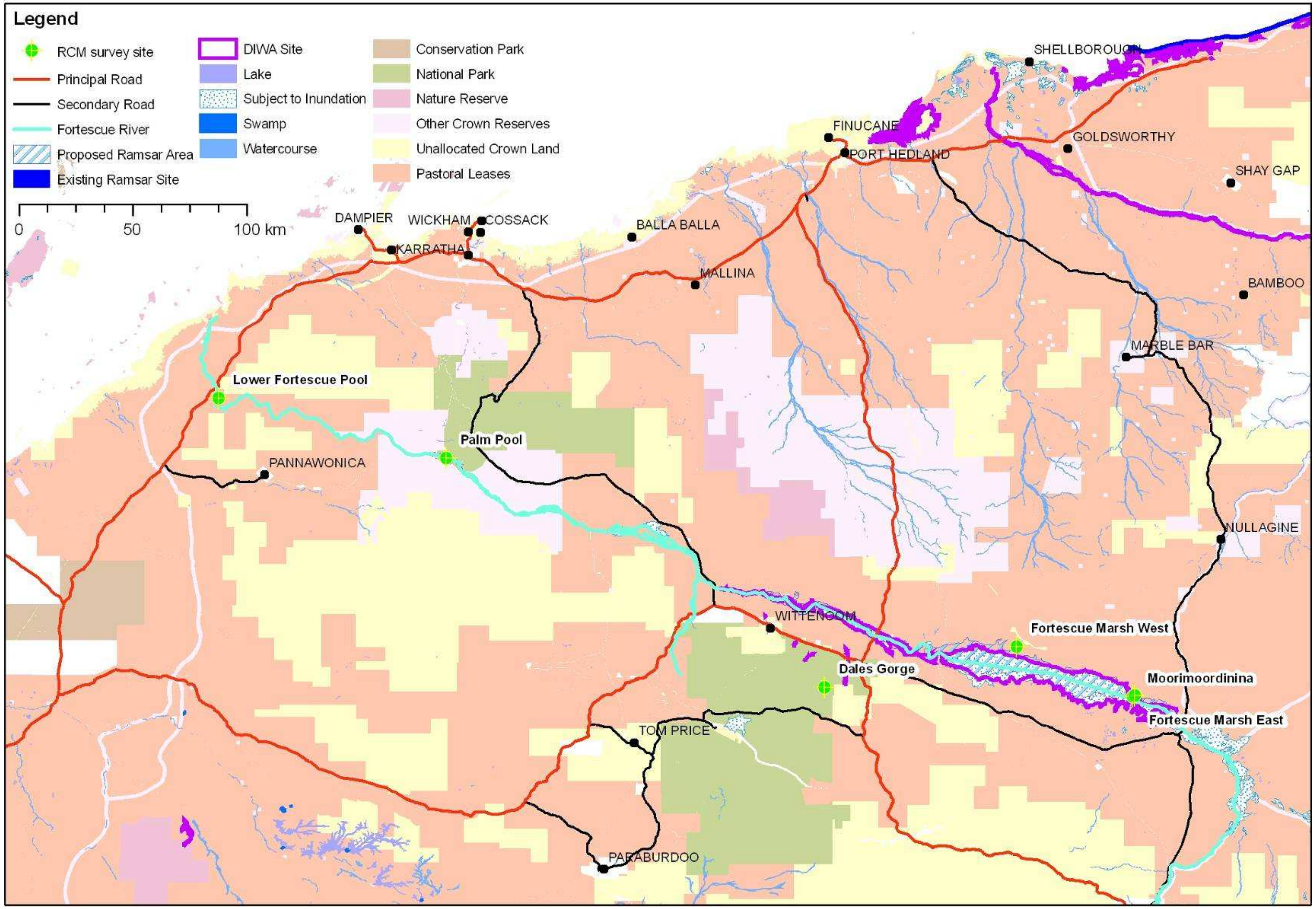

Figure 2 – The locations of sampling sites RCM001-RCM006 in relation to the Fortescue River System. Note that Dales Gorge is a tributary of the Fortescue River.

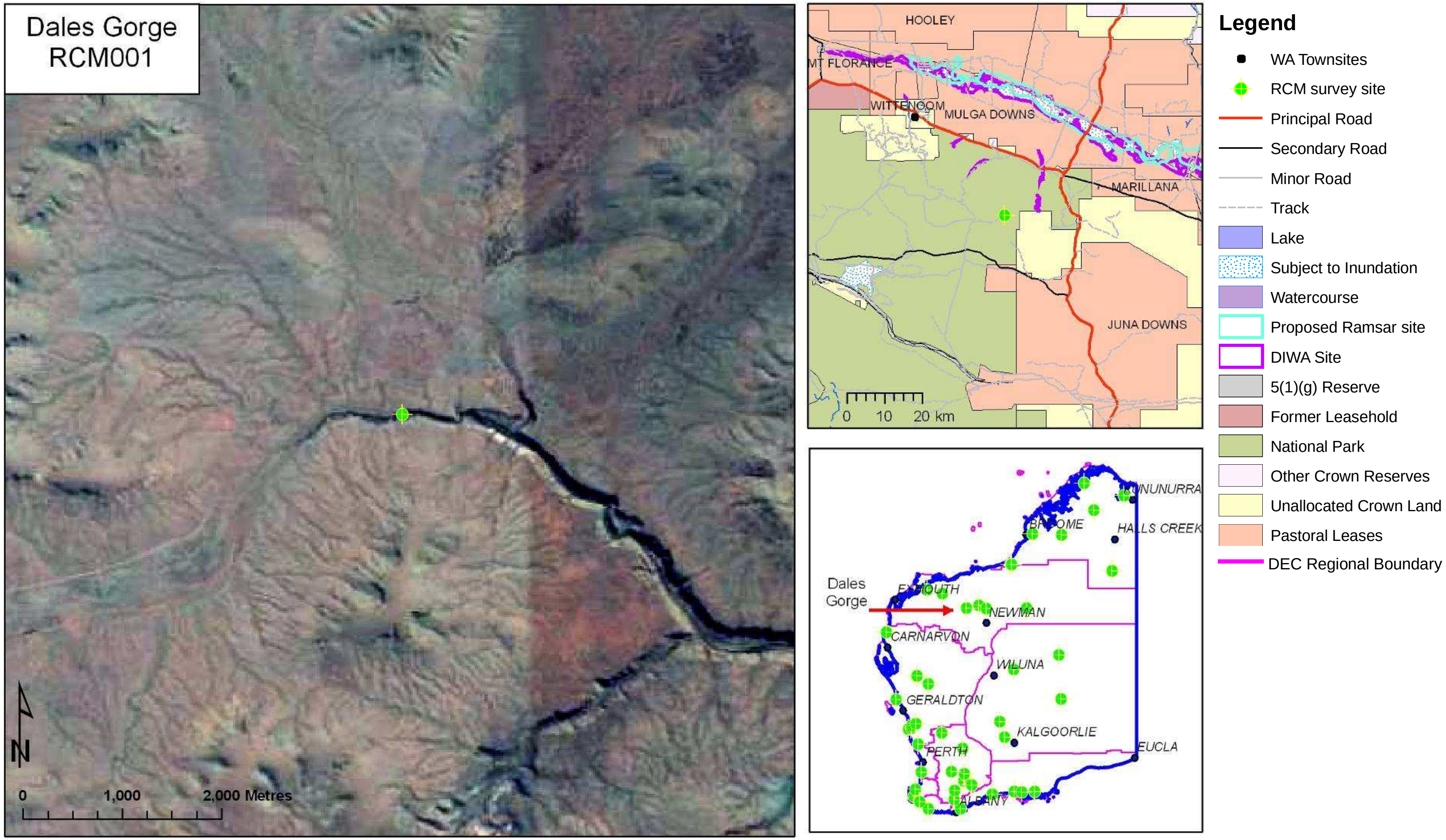

Figure 3 – Aerial photograph showing the location of the sampling site at Dales Gorge. The upper insert shows the tenure of surrounding land. The lower insert shows the location of the site in Western Australia and proximity to other RCM sites.

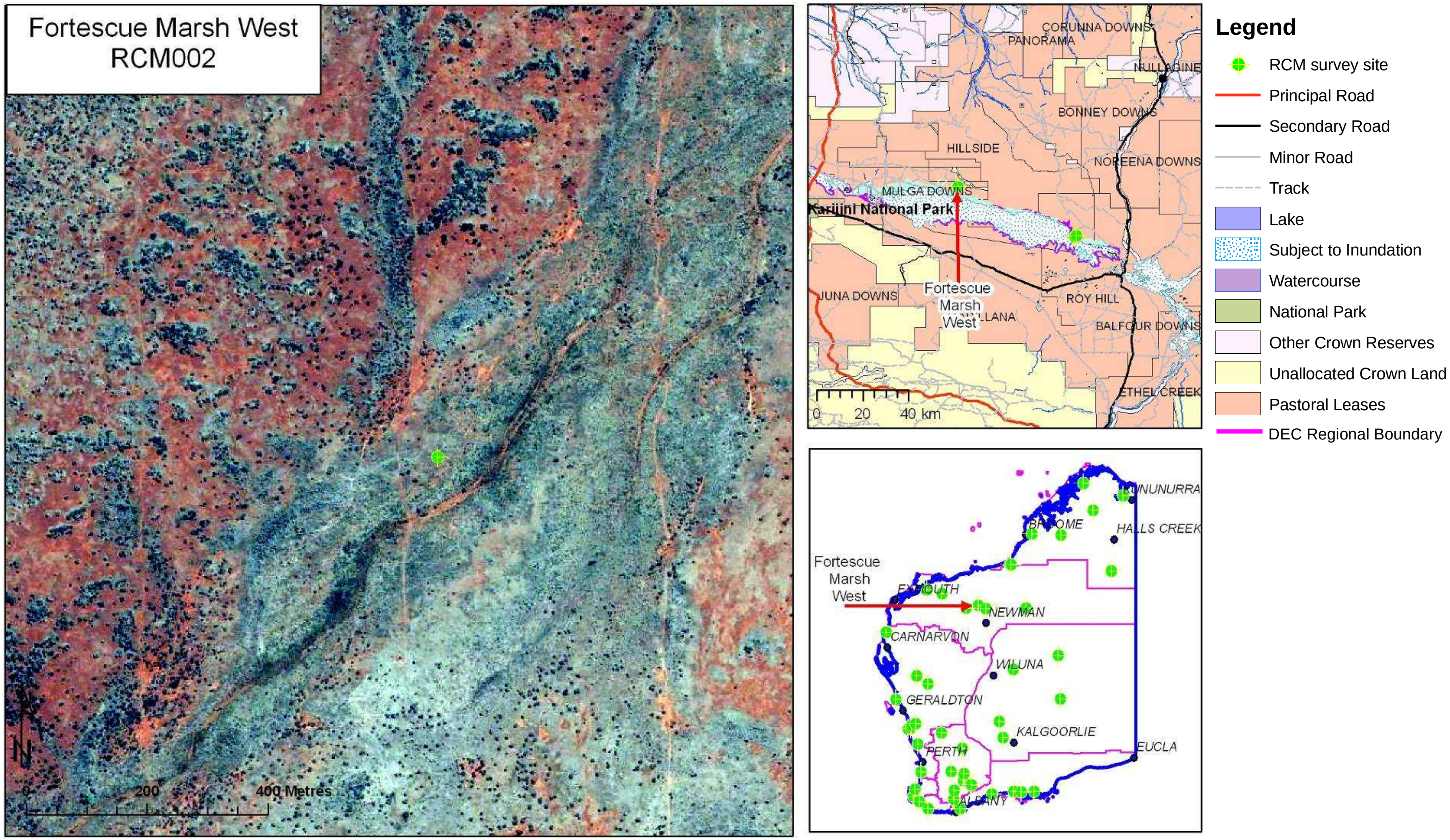

Figure 4 – Aerial photograph showing the location of the sampling site at Fortescue Marsh West. The upper insert shows the tenure of surrounding land and the boundaries of the DIWA listed and proposed Ramsar areas. The lower insert shows the location of the site in Western Australia and proximity to other RCM sites.

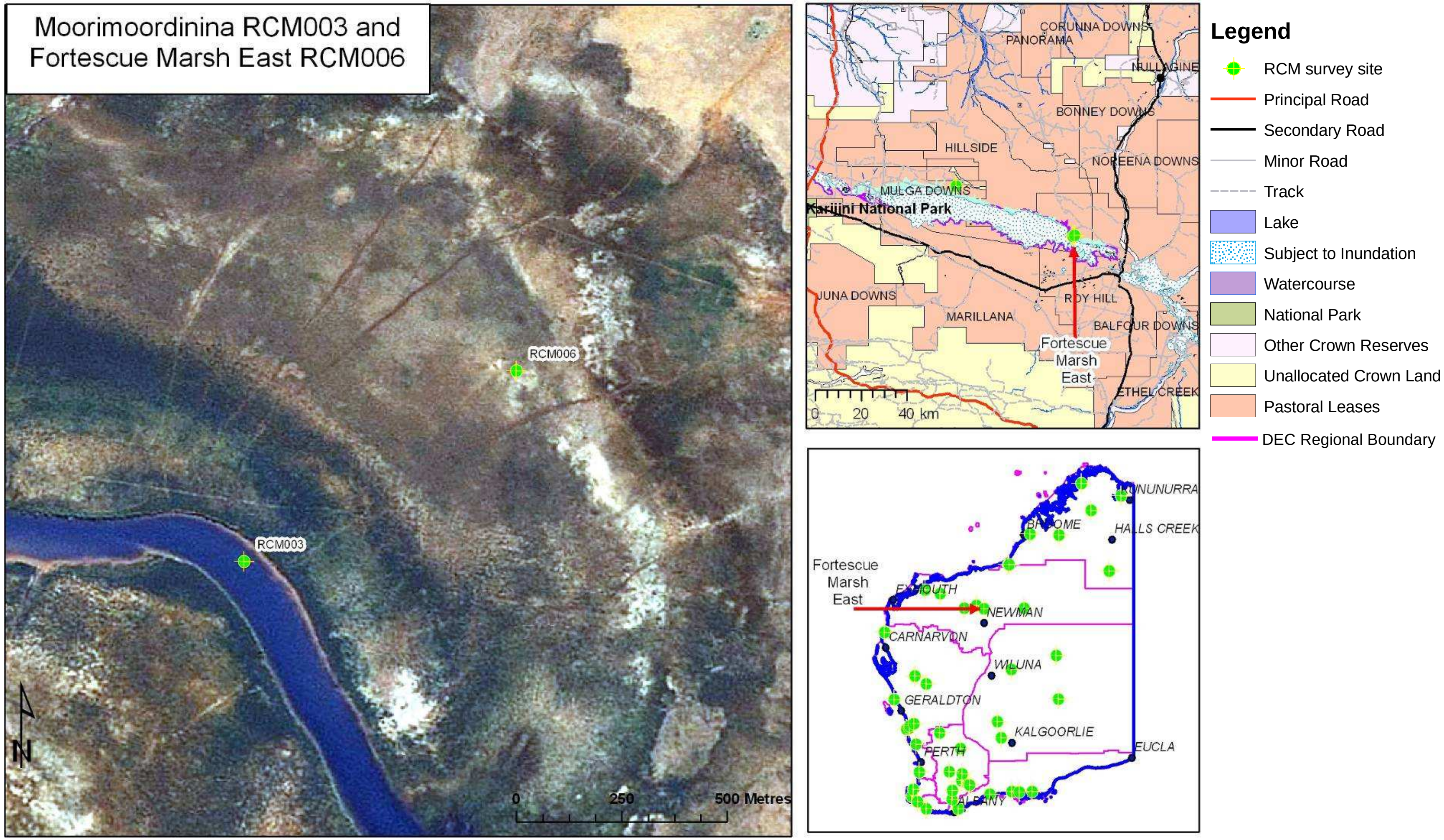

Figure 5 – Aerial photograph showing the location of the sampling site at Moorimoordinina Pool and Fortescue Marsh East. The upper insert shows the tenure of surrounding land. Note that, due to the scale of that map, the site markers sit on top of one another. The lower insert shows the location of the sites in Western Australia and proximity to other RCM sites.

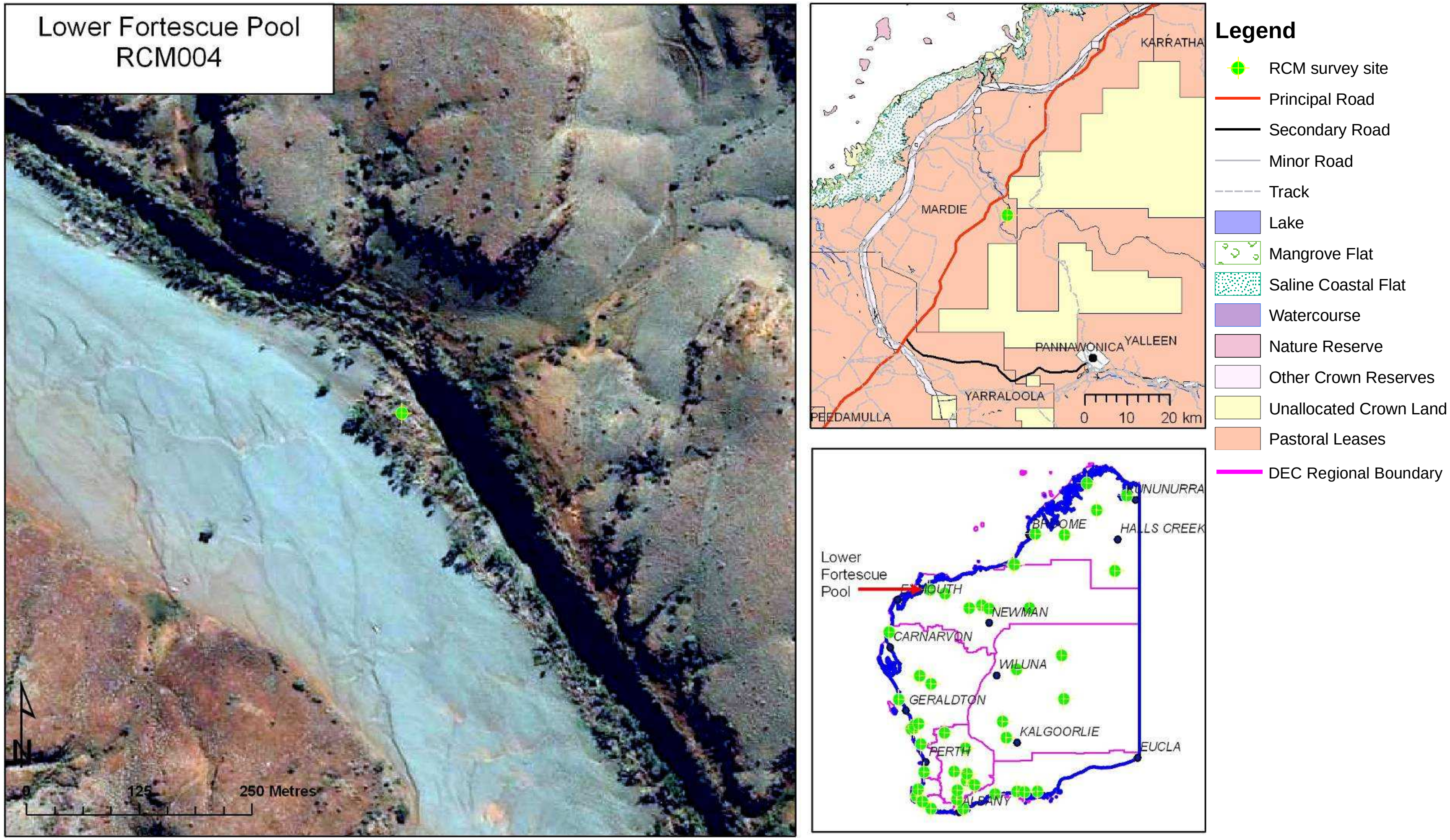

Figure 6 – Aerial photograph showing the location of the sampling site at Lower Fortescue Pool. The upper insert shows the tenure of surrounding land. The lower insert shows the location of the site in Western Australia and proximity to other RCM sites.

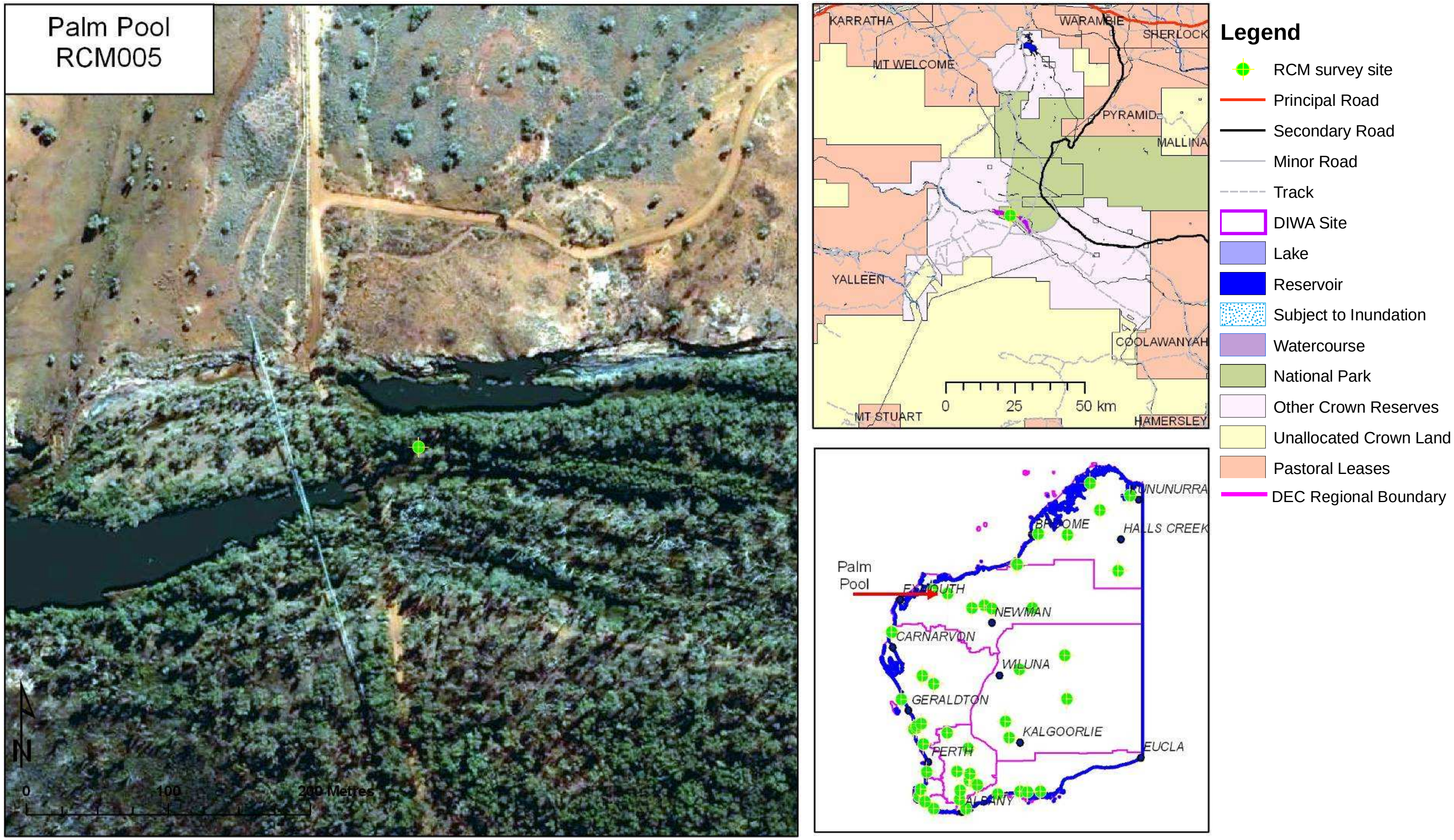

Figure 7 – Aerial photograph showing the location of the sampling site at Palm Pool. The upper insert shows the tenure of surrounding land and the boundary of the DIWA listed area. The lower insert shows the location of the site in Western Australia and proximity to other RCM sites.

2. Overview of the Wetlands of the Fortescue River

2.1. Location and Cadastral Information

The Fortescue River is the State's third longest river at a total length of 760 km. The river arises in the Ophthalmia Range near Newman and enters the Indian Ocean at Mardie Station (Figure 3 – 7). Like all Pilbara rivers, the Fortescue is reduced to a series of disconnected pools during the dry season and flows only after heavy rains. The river pools are important refuge sites during periods of drought and support significant flora and fauna taxa. The six sites selected for survey along the Fortescue River are representative of the geographic extent of the system and also of the range of habitats found in it.

The three easternmost sites are all within the Fortescue Marshes, in the middle reaches of the river system. Of these, Fortescue Marsh East and Moorimoordinina are in close proximity to one another on the Roy Hill pastoral lease. Fortescue Marsh West is approximately 50 km northwest on the Mulga Downs pastoral lease. The Fortescue Marshes are bordered in the south by the Newman-Port Headland railway line. Mine sites and another railway line lie directly north of the Fortescue Marshes area. Approximately 177,000 ha of land have been identified for relinquishment from four pastoral stations as part of the 2015 pastoral lease renewal process and are to be vested as the Fortescue Marsh Conservation Reserve (van Leeuwen 2004).

The Dales Gorge and Palm Pool sites are located within Karijini National Park and Millstream-Chichester National Park respectively. Dales Gorge is a tributary of the Fortescue River, lying approximately 30 km south of the Fortescue Marshes. Palm Pool is approximately 120 km downstream of the marshes. The final site is situated approximately 35 km from the mouth of the Fortescue River, within the Mardie pastoral lease.

2.2. IBRA Region

The majority of the Fortescue River system lies within the Fortescue Plains subregion of the Pilbara Interim Bioregionalisation of Australia (IBRA) region. The lower reaches of the river, including the Lower Fortescue survey site, are within the Chischester subregion. The Palm Pool site is close to the junction of these two subregions.

The Fortescue Plains subregion comprises alluvial plains and river frontage. In the east of the subregion, there are extensive areas of salt marsh, mulga-bunch grass, and short grass communities. In its west, there are deeply incised gorge systems. River gum woodlands fringe the drainage lines. An extensive calcrete aquifer feeds numerous permanent springs in the central Fortescue, supporting large, permanent wetlands with extensive stands of river gum and cadjeput *Melaleuca* woodlands (Kendrick, 2001). The proposed Fortescue Marsh Conservation Reserve would significantly address deficiencies in reserve land of the Fortescue IBRA subregion (van Leeuwen 2004).

The Chichester subregion comprises the northern section of the Pilbara Craton. Undulating Archaean granite and basalt plains include significant areas of basaltic ranges. Plains support a shrub steppe characterised by *Acacia inaequilatera* over *Triodia wiseana* hummock grasslands, while *Eucalyptus leucophloia* tree steppes occur on ranges (Kendrick and MacKenzie, 2001).

2.3. Climate

The area that the Fortescue system covers is so extensive that the weather differs appreciably between the upper and lower reaches.

The Bureau of Meteorology weather station that is most representative of conditions in the upper reaches of the Fortescue system is located at Wittenoom (Bureau of Meteorology 2009). The Wittenoom station is approximately 30 km northwest of Dales Gorge, 100 km west of Fortescue Marsh West and 150 km west-northwest of Fortescue Marsh East. Climatic conditions at the Fortescue Marshes would not be expected to differ appreciably from those at Wittenoom.

Wittenoom receives an annual mean of 460.9 mm of rain. The majority of this falls between December and March and is associated with the passage of tropical cyclones. As such, rainfall is unreliable and shows a large degree of inter-annual variation. Temperatures are high all year round, peaking in December/January when the mean maximum is 39.6 ºC and minimum 26.1 ºC (25.4 ºC in December). The lowest temperatures are experienced in July, when the mean daily maximum and minimum are 24.2 ºC and 11.5 ºC respectively (Figure 8). Mean annual evaporation is 3,139 mm.

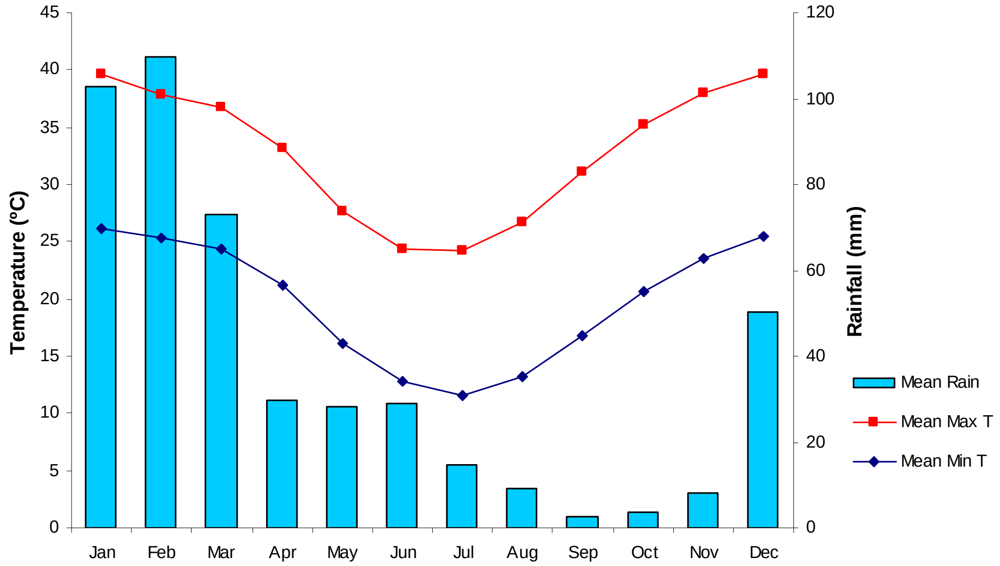

Figure 8 – Climatic means at Wittenoom.

Climatic conditions in the lower reaches of the Fortescue River system are best represented by the Pannawonica weather station. This is sited approximately 40 km southeast of the Lower Fortescue survey site and 75 km west-southwest of Palm Pool. Pannawonica receives an annual mean of 406.6 mm rainfall. As at Wittenoom, this rain is commonly associated with cyclones and is concentrated between December and March. Mean daily maxima and minima are 45.0 ºC/25.2 ºC in December and 26.7 ºC/12.6 ºC in July (Figure 9). Evaporation is not recorded at this site.

The Fortescue River system wetlands were surveyed by the IAI RCM project between the 11th and 14th of April 2008. In the five months preceding the survey, Wittenoom received 273.4 mm of rain. The majority of this (139 mm) fell during February.

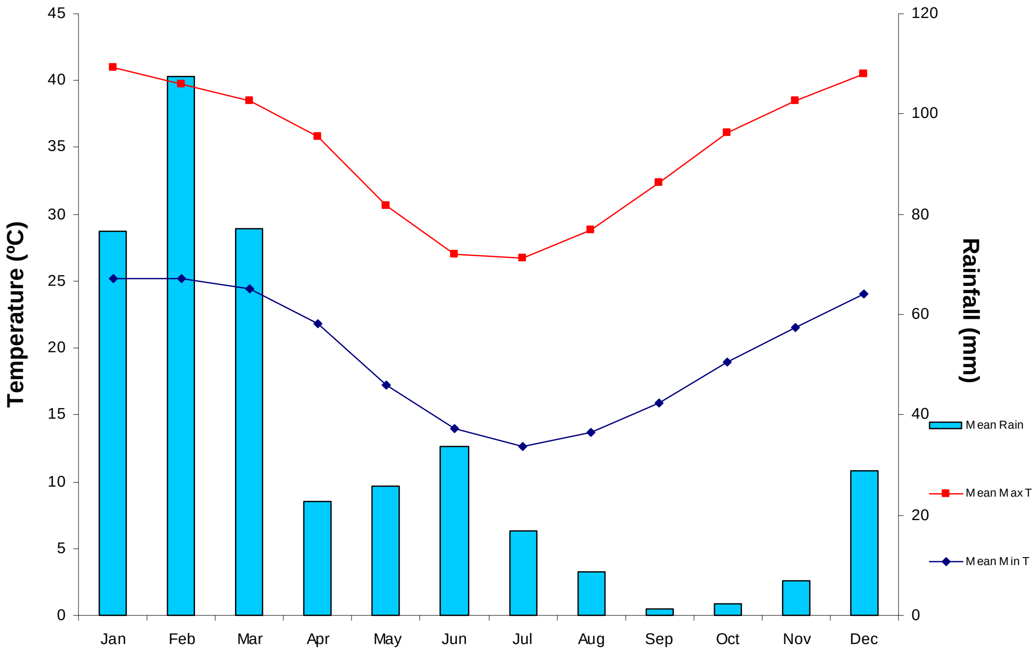

Figure 9 – Climatic means at Pannawonica.

2.4. Wetland Type

Dales Gorge is a permanent stream (DIWA type B1). The survey location is in a pool, approximately 15 m in diameter, at the bottom of the Fortescue Falls.

The Fortescue Marshes are a floodplain (DIWA type B4) with lakes (DIWA type B6), marshes and pools. The Fortescue West and East sites lie on the floodplain, while Moorimordinina is an intermittent lake.

Palm Pool is part of the Millstream Pools suite of wetlands. These include permanent rivers and streams (DIWA type B1), freshwater springs, oases and rock pools (DIWA type B17) and permanent freshwater ponds (DIWA type B9). Palm Pool is a permanent river pool. The Lower Fortescue site is also a permanent river pool, approximately 100 m in diameter.

2.5. Directory of Important Wetlands in Australia Criteria

The Fortescue Marshes are designated as a wetland of national importance under criteria 1, 2, 3 and 6 of the Directory of Important Wetlands in Australia. These criteria are as follows:

1. It is a good example of a wetland type occurring within a biogeographic region in Australia. *It is the largest ephemeral wetland in the Pilbara and the only feature of this type in the Pilbara bioregion.*
2. It is a wetland that plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex.
3. It is a wetland that is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail. *It is a significant drought refuge area for native vertebrate fauna in the bioregion. It is also known to support migratory waterbird species, including Clamorous Reed-warbler (*Acrocephalus

stentoreus*), Great Egret (*Ardea alba*), Swamp harrier (*Circus approximans*) and Whiskered Tern (*Chlidonias hybridus*), as well as Sacred Kingfisher (*Todiramphus sanctus*). It is a major breeding area for the Australian Pelican (*Pelecanus conspicillatus*) and Black Swan (*Cygnus atratus*).*

6. The wetland is of outstanding historical or cultural significance. *Moorimoordinina Pool is of cultural significance to the local Aboriginal people.*

The Millstream Pools are also designated as wetlands of national significance under criteria 1, 2, 3 and 6 of the Directory of Important Wetlands in Australia. These criteria are as follows:

1. It is a good example of a wetland type occurring within a biogeographic region in Australia. *An outstanding example of a system of permanent river pools and springs in the semi-arid tropics and the best known in north-western Australia.*
2. It is a wetland that plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex.
3. It is a wetland that is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail. *Millstream Fan Palm (*Livistona alfredii*), a relict of a humid tropical palaeoclimate in this area, is endemic to north-western Australia and the main occurrence is at Millstream. Fortescue grunter* (Leiopotherapon apheneus*) is endemic to the Fortescue River system and relies on permanent river pools for refuge in times of aridity.*
6. The wetland is of outstanding historical or cultural significance. *The site is especially significant to Aboriginal people due to permanent water and food resources, its significance reaching people in the western and central deserts.*

2.6. Values of the Fortescue River Wetlands

Values are the internal principles that guide the behaviour of an individual or group. Value systems determine the importance people place on the natural environment and how they view their place within it. Divergent values may result in people pursuing different objectives in relation to nature conservation, having different reasons for desiring a commonly agreed outcome, or favouring different mechanisms to achieve that outcome. Because of this, it is important to be explicit about the values that are driving conservation activities at a wetland.

The Conceptual Framework for Managing Natural Biodiversity in the Western Australian Wheatbelt (Wallace 2003) identified eight reasons that humans value natural biodiversity:

a. Consumptive use

Consumptive use is gaining benefit from products derived from the natural environment, without these products going through a market place, for example, the collection and personal use of firewood or ‘bush tucker’. Local Aboriginal people (belonging to several different language groups) evidently value the consumptive use of the Fortescue Marshes. One of the surveyed wetlands, Moorimoordinina, is known as a ‘native well’, an important source of fresh water where the Aboriginal people would scoop out the sand until clean water gathered in the base of the hole. The Millstream Pools are also valued for consumptive use by local Aboriginal people.

b. Productive use

Productive use values are derived from market transactions involving products taken from the natural environment. The same firewood that is collected for personal use may be exchanged for money or another commodity. The use of the Fortescue Marshes as a source of freshwater and fodder for stock is a productive use value. In this instance, the wetland is valued because it is able to contribute to the productivity of a commercial enterprise. The Lower Fortescue site is also within an active pastoral lease.

c. Opportunities for future use

Not all uses of the natural environment may be apparent at present. The potential for future benefit from the natural environment is maximised by maintaining the greatest possible biodiversity. Every lost taxa or ecosystem represents lost opportunities. The Fortescue River system supports endemic and rare taxa. Such unique features increase the potential for unique opportunities in the future.

d. Ecosystem services

There are many naturally occurring phenomena that bring enormous benefit to mankind. For instance, plants generate oxygen, insects pollinate food crops and wetlands mitigate floods by regulating water flows. The term ‘ecosystem services’ is used as a broad umbrella to cover the myriad of benefits delivered, directly or indirectly, to humankind by healthy ecosystems. The Wetlands of the Fortescue River system are important to the functioning of the river system and all contribute to ecosystem services delivered by the river system.

e. Amenity

Amenity describes features of the natural environment that make life more pleasant for people, for instance, pleasant views and shade or wind shelter from a stand of trees. Both Palm Pool and Dales Gorge are popular tourist destinations, largely because of their amenity value. It is more difficult to quantify the amenity value of the Fortescue Marshes, but they are certainly valued by the local and visiting community for the amenity they provide.

f. Scientific and educational uses

Parts of the natural environment that remain relatively unmodified by human activity represent great educational opportunities. Such sites allow us to learn about the changes that have occurred to the natural world. They can also be considered ‘control’ sites that allow us to benchmark other, altered habitats. The wetlands of the Fortescue River are a relatively unmodified suite of freshwater wetlands that may present opportunities for advancing the science of wetland ecology.

g. Recreation

Many recreational activities rely on the natural environment (bird watching, canoeing, wildflower tourism, etc.) or are greatly enhanced by it (hiking, cycling, horse riding, etc.). Recreation may deliver economic benefit derived from tourism and also delivers spiritual and physical health benefits to the recreator. Palm Pool and Dales Gorge are located within national parks and are popular recreation sites. The other four of the surveyed wetlands are within pastoral leases, currently prohibiting recreational usage. A portion of the Fortescue Marshes is proposed to be vested as a conservation reserve as part of the 2015 pastoral lease renewal process. The wetlands will then be more likely to be used for passive recreation activities such as bush walking, nature-viewing and photography.

h. Spiritual/philosophical values

People’s spiritual and philosophical reasons for valuing the natural environment are numerous and diverse. One commonly cited is the ‘sense of place’ that people derive from elements of their environment. This is evident in many Aboriginal and rural Australians, who strongly identify themselves with their natural environment. Many people also believe that nature has inherent value or a right to exist that is independent of any benefit delivered to humans. A sense of spiritual well-being may be derived from the knowledge of healthy environments, even if the individual has no contact with them. The Fortescue River system and the wetlands within it are of cultural significance to the local Aboriginal people. Sources of permanent freshwater in an otherwise arid region are an important resource. Weeli Wolli Creek, which flows into the Fortescue River, is also believed to be the home of a serpent spirit. Wetlands such as this are certainly still valued by indigenous groups today.

The intent of nature conservation is usually to maintain the ecosystem service values, opportunity values and scientific and educational values at a given site. Doing so is likely to have positive effects on the amenity values, recreational values and spiritual/philosophical values to which the site's natural environment contributes. Consumptive and productive uses of the natural environment are not usually considered, as these are often incompatible with nature conservation. That said, the Fortescue Marshes and Lower Fortescue Pool lie within active pastoral leases, and are most likely esteemed by the lessees for their productive values. These conflicting value sets should be considered when attempting to implement conservation management at the site. The values may change in 2015 with the change in tenure from pastoral lease to conservation estate and should be subject to a ten year reassessment.

3. Critical Components and Processes of the Ecology of Fortescue Marshes

The objective of the Fortescue River Wetlands RCR is to identify, describe and quantify the components and processes that drive the wetland's ecosystems. These components and processes determine the site's ecological character and are the variables that should be addressed in any ongoing monitoring. Climate and geomorphology are the most important drivers of wetland ecosystems. Between them, these factors determine the position of a wetland in the landscape and the type and hydrological regime of that wetland. In turn, a wetland's position, type and hydrology exert a strong influence on its biota and biochemical properties and processes.

A summary of the systems critical ecosystem components is presented in Table 1, followed by a detailed description of the results of the IAI RCM 2008 survey as well as findings of previous studies conducted on the wetlands.

Table 1 - Summary of critical ecosystem components at Fortescue Marshes.

Component	Summary description
Geomorphology	**Fortescue Marsh**: An extensive, episodically inundated samphire marsh, ~100 km long and 10 km wide. Constricted at the western (downstream) end by the Goodiadarrie Hills, which separate the Fortescue into two separate drainages. The marsh represents the terminus for the upper Fortescue. **Millstream wetlands**: Extensive permanent springfed streams, pools and river flow that extend for up to 40 km below the springs. Large areas of wetland community, including large, deep (up to 2 km long and 15+ m deep) riverine pools, springs, riffle streams, marshes and swamps.
Hydrology	Surface inflow from upper reaches of the Fortescue River and Kulkinbah Creek, Weeli Wolli Creek and numerous other short creeks. Most catchments are moderately disturbed. Numerous springs discharge along the northern edge of the Millstream aquifer, which is recharged during flood events.
Water Quality	Fortescue Marsh is fresh to saline, poikilohaline (705 µs/cm – 2.92mS/cm); pH 7.83 - 8.84 is basic/alkaline. Other sites are fresh with pH 7.5 - 8.5 and no water quality issues apparent.
Benthic Plants	Several species recorded, including *Najas marina*, *Potamogeton tricarinatus*, *Ruppia polycarpa* and, *Chara* sp.
Littoral Vegetation	Marshes dominated by samphire shrublands. Other areas fringed with *Melaleuca leucadendra*, *M. argentea, Eucalyptus camaldulensis*, *M. linophylla, Cladium procerum*, Cyperaceae sp., *Schoenoplectus subulatus*, *Cyperus vaginatus and Fimbristylis sieberiana*. Vegetation mostly in good condition.
Invertebrates	High species diversity, several rare or restricted species.
Fish	Fish were sighted at 3 sites during this survey. A number of fish are known from the area, including the endemic Fortescue grunter (*Leiopotherapon apheneus*)
Birds	47 species of waterbird counted during three surveys of the Fortescue Marshes after flooding events between 1999 - 2003 (van Leeuwen, 2004). That area is known to support migratory waterbird species, including Clamorous Reed-warbler, Great Egret, Swamp Harrier, Whiskered Tern, and Sacred Kingfisher. It is a major breeding area for the Australian Pelican and Black Swan.

3.1. Geology and Soils

The Pilbara bioregion contains some of the earth's oldest rock formations, thought to be around 3.5 billion years old. There are four major geological components of the Pilbara bioregion: the Hamersley Basin, the Hamersley Range, the Chichester Range and the Roebourne Plain. The three Fortescue Marshes survey sites are situated in the Hamersley Basin, in alluvial and lacustrine deposits in a broad valley between the roughly parallel Chichester and Hamersley Ranges. Dales Gorge is within the Hamersley Range, a mountainous area of Proterozoic sedimentary ranges and plateaus. Palm Pool is in the Chichester Range, which comprises Archaean granite and basalt plains. Lower Fortescue Pool is sited in the Roebourne Plain, which consists of Quaternary alluvial plains (CALM 1999).

3.2. Hydrology

The Fortescue River catchment is defined to the north by the Chichester Range and to the south by the Hamersley Range. The river is surface water fed with inflows from tributaries that emerge from the Hamersley and Chichester ranges. Significant stream flow is generated for short periods after intense rainfall. The system floods, inundating the Fortescue Marshes, on average once every five to seven years. The river's catchment is divided into upper and lower portions by the Goodiadarrie Hills. These hills also constrict the lower end of the Fortescue Marshes. The Fortescue River recharges the Millstream aquifer, an extensive calcrete aquifer that covers around 400 km^2. This aquifer is of regional significance because it discharges into a number of permanent wetlands along its northern margin.

3.3. Water Quality and Sediments

RCM001. Dales Gorge

The water quality variables measured (Table 2) indicate good water quality, though contamination from insect repellents and sunscreen from tourists could potentially compromise water quality. Salinity was low (0.33 g/L), as were both nitrogen and phosphorus levels. Sediments were mostly bedrock/boulder (57%), cobble/pebble (22%) and gravel (18%).

Table 2 - Water quality parameters at Dales Gorge (RCM001) in April 2008.

pH	7.9
Alkalinity (mg/L)	145
TDS (g/L)	0.33
Turbidity (NTU)	Not measured
Colour (TCU)	Not measured
Total nitrogen (μ/L)	470
Total phosphorus (μ/L)	20
Total soluble nitrogen (μ/L)	250
Total soluble phosphorus (μ/L)	10
Chlorophyll (μ/L)	2
Na (mg/L)	55.4
Mg (mg/L)	30
Ca (mg/L)	32
K (mg/L)	9.1
Cl (mg/L)	97
SO_4 (mg/L)	23.7
HCO_3 (mg/L)	177
CO_3 (mg/L)	0.5

RCM002. Fortescue Marsh West

Water quality data was not collected, as the site was dry at the time of survey.

RCM003. Moorimoordinina Pool

This freshwater pool (linear claypan) had good water quality (Table 3). The pool was fresh and naturally turbid, though turbidity was mild compared to wetlands with other similar characteristics; this favors a distinctive fauna. Nutrients are hard to measure in turbid waters, as nutrients bind to suspended clay particles. In the collected samples, nutrients in the filtered samples (total soluble phosphorus and nitrogen) were higher than in unfiltered samples, which is unusual. This may indicate contamination of the filtered sample, mis-handling in the lab or inadequate centrifugation of the filtered sample. Sediments were dominated by silt/clay (69%), sand (22%) and some gravel (4%) and pebbles (5%).

Table 3 - Water quality parameters at Moorimoordinina Pool (RCM003) in April 2008.

pH	8.46
Alkalinity (mg/L)	90
TDS (g/L)	1.65
Turbidity (NTU)	8.8 in lab (14 in field)
Colour (TCU)	-
Total nitrogen (µ/L)	780
Total phosphorus (µ/L)	50
Total soluble nitrogen (µ/L)	3,100
Total soluble phosphorus (µ/L)	210
Chlorophyll (µ/L)	9.5
Na (mg/L)	385
Mg (mg/L)	40.5
Ca (mg/L)	104
K (mg/L)	51.6
Cl (mg/L)	546
SO_4 (mg/L)	413
HCO_3 (mg/L)	110
CO_3 (mg/L)	0.5

RCM004. Lower Fortescue Pool

This pool is permanent, maintained by hyporheic inflow, with a fast flowing riffle at its downstream end. The pool was fresh and alkaline, with low turbidity and colour, and low nutrient levels (Table 4). There were no indications of water quality problems; good water quality is probably aided by the continual through flow of water.

In 2008, sediments were dominated by cobble (57%), with the rest being gravel (20%) and sand (22%). This was finer than when sampled for the Pilbara survey where sediments were almost all cobble, bedrock and boulder, showing the temporal variability of flood deposited sediments.

Table 4 - Water quality parameters at Lower Fortescue Pool.

	Pilbara Biological Survey PSW076		RCM Survey RCM004
	Aug 2005	**May 2006**	**Apr 2008**
pH	8.31	8.84	8.30
Alkalinity (mg/L)	175	215	145
TDS (g/L)	0.84	0.53	0.57
Turbidity (NTU)	0.6	0.7	8.6
Colour (TCU)	20	5	-
Total nitrogen (μ/L)	-	-	240
Total phosphorus (μ/L)	-	-	5
Total soluble nitrogen (μ/L)	110	90	150
Total soluble phosphorus (μ/L)	10	5	5
Chlorophyll (μ/L)	-	-	3.5
Na (mg/L)	127	86	99.9
Mg (mg/L)	62.5	33.3	35
Ca (mg/L)	75	46.2	45.9
K (mg/L)	9.4	7	8.4
Cl (mg/L)	322	137	163
SO_4 (mg/L)	117	45.5	78.7
HCO_3 (mg/L)	214	262	177
CO_3 (mg/L)	1	1	0.5

RCM005. Palm Pool

The permanence of this pool is due to its depth, regular floods, seepage into the pool from the Millstream aquifer and flows from Chindawarrina Spring via the 'Delta'. The pool is fresh, slightly to moderately alkaline and consistently has low nutrient and chlorophyll concentrations (Table 5). In 2008, salinity and nutrients were lower than sampled during the Pilbara Biological Survey. Sediments were mostly medium-grained (78% gravel, 16% sand) other than near the road crossing where cobbles and boulders were present from the crossing construction.

Table 5 - Water quality parameters at Palm Pool.

	Pilbara Biological Survey PSW010			RCM Survey RCM005
	Aug 2003	**May 2005**	**Aug 2006**	**Apr 2008**
pH	7.83	8.24	7.83	7.95
Alkalinity (mg/L)	370	350	350	210
TDS (g/L)	1.5	1.3	1.3	0.77
Turbidity (NTU)	0.2	1.3	0.6	9.7
Colour (TCU)	2.5	2.5	2.5	-
Total nitrogen (μ/L)	-	-	-	90
Total phosphorus (μ/L)	-	-	-	5

	Pilbara Biological Survey PSW010			RCM Survey RCM005
	Aug 2003	**May 2005**	**Aug 2006**	**Apr 2008**
Total soluble nitrogen (μ/L)	140	140	140	70
Total soluble phosphorus (μ/L)	5	10	5	5
Chlorophyll (μ/L)	2	3.5	2	2
Na (mg/L)	278	302	234	123
Mg (mg/L)	108	106	92.1	49.7
Ca (mg/L)	113	111	55.7	53.1
K (mg/L)	27	30.1	23.9	14.3
Cl (mg/L)	480	541	395	195
SO_4 (mg/L)	247	241	210	98.5
HCO_3 (mg/L)	451	464	427	256
CO_3 (mg/L)	1	1	1	0.5

RCM006. Fortescue Marsh East

Water quality data was not collected, as the site was dry at the time of survey.

3.4. Benthic Plants

The 2008 IAI RCM survey recorded several benthic plants at the Fortescue system (Figure 10, Figure 11).

Figure 10 – Benthic plants collected at Fortescue Marshes by the RCM survey in April 2008.

Site	Benthic plant species
Dales Gorge	*Najas marina* *Potamogeton tricarinatus*
Moorimoordinina Pool	*Ruppia polycarpa*
Lower Fortescue Pool	*Chara* sp. *Najas* sp. (opportunistically collected near transect)
Palm Pool	*Potamogeton tricarinatus* *Chara sp.*
Fortescue Marsh East	*Ruppia sp.*
Fortescue Marsh West	None

Figure 11 – The aquatic vegetation of Palm Pool with *Potamogeton tricarinatus* evident in the water (Photo A. Pinder).

3.5. Littoral Vegetation

RCM001. Dales Gorge

A 40 m transect, comprised of eight consecutive 5 m x 5 m quadrats, was established along the margins of Dales Gorge on the 12th April 2008 (Figure 12). Percentage cover was recorded for all species occurring within the quadrats (Table 6).

Figure 12 - Northwest corner of the vegetation transect at Dales Gorge.

Table 6 - Vegetative cover across the transect at Dales Gorge.

Species	Quadrat (m) / % layer cover							
	0-5	**5-10**	**10-15**	**15-20**	**20-25**	**25-30**	**30-35**	**35-40**
* *Cynodon dactylon*	10	5	0	15	5	0	0	10
* *Sonchus oleraceus*	0	41	0	<1	0	0	0	0
? Cyperaceae sp.	0	5	60	20	20	10	0	0
Cladium procerum	15	15	10	10	30	70	25	30
Cymbopogon procerus	0	0	0	0	0	0	1	1
Cyperus vaginatus	0	1	0	0	0	0	0	0
Eucalyptus camaldulensis	0	5	0	0	0	10	0	2
Eucalyptus sp.	0	1	0	5	0	0	0	0
Ficus sp.	0	0	20	0	0	0	0	0
Fimbristylis sieberiana (P3)	2	0	0	0	0	0	0	0
Melaleuca leucadendra	60	50	15	15	20	40	75	20
Melaleuca linophylla	10	10	40	15	15	10	15	40
Phragmites vallatoria	0	0	0	1	2	5	0	0
Schoenoplectus subulatus	0	1	0	0	0	0	0	0

* Introduced species.
? Limited confidence in identification.

According to the National Vegetation Information System (NVIS), the vegetation community may be described as (ESCAVI 2003):

U1+^*Melaleuca leucadendra*, *Eucalyptus camaldulensis*, *Eucalyptus* sp.\tree\7\c; M1 ^*Melaleuca linophylla*\shrub\4\r; G1 ^ *Cladium procerum*, ?Cyperaceae sp., *Schoenoplectus subulatus*, *Cyperus vaginatus*, *Fimbristylis sieberiana*\sedge\3\i.

The weeds *Cynodon dactylon* and *Sonchus oleraceus* were recorded on the transect.

Fimbristylis sieberiana is a species of conservation significance, known from limited collections across the Pilbara and Kimberley. It is currently listed as ‘Priority Three’ (Atkins 2008).

A further five species were recorded opportunistically nearby the transect. These were **Conyza bonariensis*, Poaceae sp., *Pteris vittata*, *Stemodia* sp. and *Themeda* sp. Mt Barricade (M.E. Trudgen 2471).

RCM002. Fortescue Marsh West

Two 40 m transects, each comprised of eight consecutive 5 m x 5 m quadrats, were established at Fortescue Marsh West on the 11th April 2008 (Figure 13, Figure 14). Percentage cover was recorded for all species occurring within the quadrats (Table 7, Table 8).

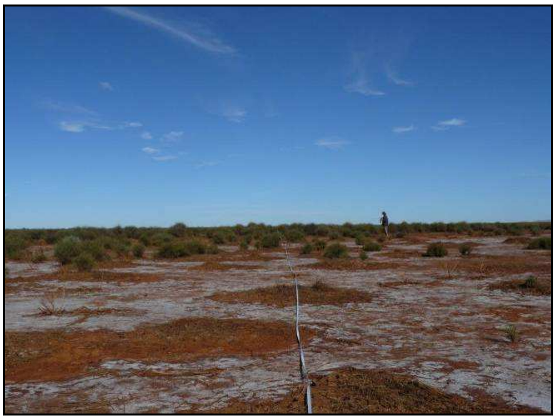

Figure 13 - Fortescue Marsh West vegetation transect RCM002-1 facing southeast.

Table 7 - Vegetative cover across transect RCM002-1 at Fortescue Marsh West.

Species	Quadrat (m) / % layer cover							
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
Tecticornia indica	0	<1	2	2	0	2	0	2
Muellerolimon salicorniaceum	2	0	2	5	5	10	5	15
Tecticornia auriculata	0	0	0	0	0	0	0	2
Sclerolaena uniflora	0	<1	0	0	0	0	0	0
Dysphania plantaginella	0	0	2	0	0	0	0	<1

According to the National Vegetation Information System (NVIS), the vegetation community at transect RCM002-1 may be described as (ESCAVI 2003):

M1+ *Muellerolimon salicorniaceum*, *Tecticornia indica*, *Tecticornia auriculata*, *Sclerolaena uniflora*, *Dysphania plantaginella*\shrub, samphire shrub\1\r.

This transect (RCM002-1) was largely devoid of vegetative cover (~5%), with the bare soil mostly covered by a thin salt crust. There was evidence of regeneration for all recorded taxa. No weed species were recorded along the transect. Whilst cattle were present in the area, there was no evidence of trampling or grazing along the transect.

Figure 14 - Fortescue Marsh West transect RCM002-2 looking from the northwest.

Table 8 - Vegetative cover across transect RCM002-2 at Fortescue Marsh West.

Species	Quadrat (m) / % layer cover							
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
Muellerolimon salicorniaceum	30	60	15	60	40	40	40	10
Tecticornia auriculata	2	5	2	2	2	5	10	5
Tecticornia indica	30	20	40	10	10	20	10	20

According to the National Vegetation Information System (NVIS), the vegetation community at transect RCM002-2 may be described as (ESCAVI 2003):

M1+ *Muellerolimon salicorniaceum*, *Tecticornia indica*, *Tecticornia auriculata*\shrub, samphire shrub\2\c.

There were no weeds recorded along transect 2. Regeneration was evident for all species.

Tecticornia sp. Roy Hill (H. Pringle 62) was collected opportunistically near the transects. This is a species of conservation significance, known from limited range around the Fortescue Marsh area and an outlier population near Wiluna. It is currently listed as 'Priority Three' (Atkins 2008).

RCM003. Moorimoordinina Pool

A 20 m transect, comprised of four consecutive 10 m x 5 m quadrats, was established at Moorimoordinina on the 12th April 2008. Percentage cover was recorded for all species occurring within the quadrats (Table 9).

Figure 15 – Moorimoordinina Pool vegetation transect.

Table 9 - Vegetative cover across the transect at Moorimoordinina Pool.

Species	Quadrat (m) / % layer cover			
	0-5	5-10	10-15	15-20
Acacia ampliceps	10	15	15	15
Tecticornia auriculata	15	5	2	2
Tecticornia sp.	1	2	2	0
Eragrostis leptocarpa	0	1	0	0
Samolus sp. Millstream (MIH Brooker 2076)	15	20	20	30
Cyperaceae sp.	1	1	1	2

Species	Quadrat (m) / % layer cover			
	0-5	5-10	10-15	15-20
* *Heliotropium curassavicum*	<1	1	1	0
Frankenia ambita	5	1	0	2
Poaceae sp.	2	0	0	2
Nicotiana sp.	5	5	5	5
? *Atriplex* sp.	0	2	2	2
~ Unidentified sp. (annual small blue-mauve flower, 5 cm)	2	5	5	5
~ Poaceae sp.(perennial grass, couch-like, 10 cm)	1	2	5	5
~ Poaceae sp. (perennial grass, weed?, 20 cm)	2	5	5	5
~ Unidentified sp. (small bipinnate annual, 10 cm)	0	1	0	0
~ Unidentified sp. (clover-like, 5 cm)	0	1	1	2
~ Unidentified sp. (clover-like annual, 10 cm)	0	2	0	2

* Introduced species.
? Limited confidence in identification.
~ Sufficient samples were unavailable to allow species identification.

According to the National Vegetation Information System (NVIS), the vegetation community may be described as (ESCAVI 2003):

U1+ ^*Acacia ampliceps*\shrub\4\r; M1 ^*Samolus* sp. Millstream (MIH Brooker 2076), *Tecticornia auriculata*, *T.* sp.\shrub, samphire shrub\1\i; G1 ^*Nicotiana* sp. *Poaceae* spp.\forb, grass\1\r.

The weed, *Heliotropium curassavicum*, was recorded in low density. Approximately 50% of the site was affected by cattle grazing and trampling.

RCM004. Lower Fortescue Pool

Two transects were established at Lower Fortescue Pool on the 14th April 2008 (Figure 16). The first was a 50 m long aquatic transect comprised of five 10 m x 2 m quadrats. The second transect, established in fringing vegetation, was 40 m in length and comprised of eight consecutive 5 m x 5 m quadrats. Percentage cover was recorded for all species occurring within the quadrats (Table 10,

Table 11).

Figure 16 – Vegetation of Lower Fortescue Pool.

Table 10 - Vegetative cover across riparian transect RCM004-1 at Lower Fortescue Pool.

	Quadrat (m) / % layer cover							
Species	**0-5**	**5-10**	**10-15**	**15-20**	**20-25**	**25-30**	**30-35**	**35-40**
? *Sesbania formosa*	0	0	0	0	2	0	0	0
Cyperus ?vaginatus	2	2	2	2	2	2	2	5
Eucalyptus camaldulensis var. *obtusa*	5	0	0	5	5	15	15	5
Melaleuca argentea	5	5	5	5	10	15	15	70
dead *Melaleuca argentea*	0	0	0	0	2	0	0	0
Petalostylis labicheoides	4	0	0	10	10	0	0	0
Ipomoea muelleri	0	0	4	0	0	0	4	0
Bare soil	77	78	72	63	60	58	53	10

? Limited confidence in identification.

According to the National Vegetation Information System (NVIS), the vegetation community at RCM004-1 may be described as (ESCAVI 2003):

U1+ ^*Melaleuca argentea*, *Eucalyptus camaldulensis* var. *obtusa*\tree\7\r; M1 ^*Cyperus ?vaginatus*\sedge\3\r.

Approximately 90% of the site has recently been heavily disturbed by flooding. This is evident from the abundant debris, broken trunks and scouring of the riparian zone. Bare soil is exposed across more than half the site. Both vegetative strata show signs of regeneration and no weeds were recorded across the riparian transect.

Table 11 - Vegetative cover across aquatic transect RCM004-2 at Lower Fortescue Pool.

	Quadrat (m) / % layer cover									
Species	**0-5**	**5-10**	**10-15**	**15-20**	**20-25**	**25-30**	**30-35**	**35-40**	**40-45**	**45-50**
Chara sp.	5	5	0	0	0	0	0	0	0	0
Eleocharis sp.	0	0	0	0	0	0	2	2	20	20
dead *Eleocharis* sp.	10	10	10	10	10	10	10	10	0	0
? Aquatic sp.	5	5	5	5	5	5	5	5	5	5

? Limited confidence in identification.

According to the National Vegetation Information System (NVIS), the vegetation community at RCM004-2 may be described as (ESCAVI 2003):

M1+^*Eleocharis* sp.\sedge\2\r; G1 *Chara* sp., ?Aquatic sp.\aquatic\1\r.

There were no weeds recorded on the aquatic transect.

RCM005. Palm Pool

Two 40 m transects, each comprised of eight consecutive 5 m x 5 m quadrats, were established at Palm Pool on the 13th April 2008 (Figure 17). Percentage cover was recorded for all species occurring within the quadrats (Table 12, Table 13).

Figure 17 - Vegetation of the Palm Pool transect.

Table 12 - Vegetative cover across transect RCM005-1 at Palm Pool.

	Quadrat (m) / % layer cover							
Species	**0-5**	**5-10**	**10-15**	**15-20**	**20-25**	**25-30**	**30-35**	**35-40**
Acacia ampliceps	2	0	0	2	5	0	0	0
Cyperus vaginatus	25	25	10	15	15	5	10	0
Eucalyptus camaldulensis var. *obtusa*	0	0	5	0	0	0	0	0
Fimbristylis ferruginea	10	5	5	0	0	2	5	5
Melaleuca argentea	5	5	20	20	5	10	0	0
** Passiflora foetida*	5	5	5	5	10	0	0	0
Potamogeton tricarinatus	2	2	5	5	2	2	2	5
? Sesbania formosa	6	0	0	5	5	5	0	0
Schoenoplectus subulatus	30	30	20	50	20	50	20	15
Sesbania cannabina	0	0	2	0	0	2	0	0
Typha domingensis	0	0	0	0	0	0	0	15

* Introduced species.
? Limited confidence in identification.

According to the National Vegetation Information System (NVIS), the vegetation community at transect RCM005-1 may be described as (ESCAVI 2003):

U1+ ^*Melaleuca argentea*, *Eucalyptus camaldulensis* var. *obtusa*\tree\7\r; M1 ^*Schoenoplectus subulatus*, *Cyperus vaginatus*, *Fimbristylis ferruginea*, *Typha domingensis*\sedge\3\c; *Potamogeton tricarinatus*\aquatic\1\r.

The vine, *Passiflora foetida*, was the only weed species recorded along transect RCM005-1. All vegetation was healthy and regeneration was evident for all species.

Table 13 - Vegetative cover across transect RCM005-2 at Palm Pool.

Species	Quadrat (m) / % layer cover							
	0-5	**5-10**	**10-15**	**15-20**	**20-25**	**25-30**	**30-35**	**35-40**
Sesbania cannabina	0	0	1	0	0	0	0	0
** Cynodon dactylon*	0	0	2	0	0	0	0	0
Melaleuca argentea	50/100	20/50	20/40	5/5	0	5/5	0	5/50
Schoenus falcatus	0	0	2	2	1	0	0	0
Melaleuca linophylla	0	0	0	0	0	2	0	0
Chara sp.	0	0	0	10	2	5	0	0
Eleocharis geniculata	0	0	0	2	5	5	0	0
Schoenoplectus subulatus	20	20	5	15	40	15	25	35
** Phoenix dactylifera*	0	<1	0	0	0	0	0	0
Cyperus vaginatus	30	30	40	30	15	15	65	55
Potamogeton tricarinatus	5	0	0	0	0	0	0	0
Fimbristylis ferruginea	0	2	2	5	5	15	0	0
Typha domingensis	0	0	1	0	0	5	10	10
Acacia ampliceps	0	0	<1	0	0	0	0	0
young *Eleocharis geniculata*	15	15	0	10	10	5	0	2
Algae sp.	0	0	0	2	5	2	0	0
Bare soil	15	20	10	30	10	0	2	0

* Introduced species.

According to the National Vegetation Information System (NVIS), the vegetation community at transect RCM005-2 may be described as (ESCAVI 2003):

U1+ ^*Melaleuca argentea*\tree\7\i; M1 ^*Cyperus vaginatus*, *Schoenoplectus subulatus*, *Typha domingensis*, *Eleocharis geniculata*\sedge\2\c;

Two species of weeds were recorded along the transect in low density (*Cynodon dactylon*, *Phoenix dactylifera*). All vegetative layers were in healthy condition, with the exception of approximately 15% that had recently been flooded. Regeneration was evident for all species.

Hibiscus austrinus var. *austrinus* was recorded opportunistically as occurring in the area.

RCM006. Fortescue Marsh East

A 40 m transect, comprised of eight consecutive 5 m x 5 m quadrats, was established at Fortescue Marsh East on 12th April 2008 (Figure 18). Percentage cover was recorded for all species occurring within the quadrats (Table 14).

Figure 18 – Low-lying vegetation of Fortescue Marsh East.

Table 14 - Vegetative cover across the transect at Fortescue Marsh East.

Species	**Quadrat (m) / % layer cover**							
	0-5	**5-10**	**10-15**	**15-20**	**20-25**	**25-30**	**30-35**	**35-40**
~ Unidentified sp. (floreted mimosa-like, 10 cm)	<1	<1	<1	2	2	2	2	2
?Cressa australis	0	2	2	1	0	0	<1	0
~ Cyperaceae sp. (small sedge)	0	0	0	0	0	0	<1	0
Chloris pectinata	0	0	0	<1	5	2	0	0
Cressa australis	0	0	<1	2	5	2	2	0
Dactyloctenium radulans	<1	0	0	0	0	0	0	0
* *Heliotropium curassivicum*	<1	<1	<1	0	<1	0	<1	<1
Leptochloa fusca	<1	<1	<1	<1	0	<1	0	0
Muellerolimon salicorniaceum	5	5	0	5	0	0	0	5
Nicotiana rosulata subsp. *Rosulata*	0	0	0	0	0	<1	1	<1
~ Poaceae sp. (small annual grass, 5 cm, many florets)	<1	<1	<1	<1	0	<1	0	0
Ptilotus gomphrenoides	0	0	0	0	0	0	0	<
Unidentified seedling (small serrated edge herb, 2 cm)	0	0	0	5	0	2	<1	<1
Swainsona sp.	<1	<1	<1	0	0	<1	<1	<1
Tecticornia sp.	30	40	40	30	30	40	40	50

* Introduced species.
? Limited confidence in identification.
~ Sufficient samples were unavailable to allow species identification.

According to the National Vegetation Information System (NVIS), the vegetation community may be described as (ESCAVI 2003):

vM1+ ^*Tecticornia* sp. *Muellerolimon salicorniaceum*\samphire shrub, shrub\2\i; G1 *Cressa australis*, Unidentified sp., **Heliotropium curassavicum*, *Chloris pectinata*\forb, grass\1\r.

Heliotropium curassavicum was the only weed recorded along the transect. Approximately 30% of the transect was impacted by cattle trampling and grazing.

A further two species were recorded opportunistically nearby the transect. These were *Aeschynomene indica* and *Eragrostis pergracilis*.

3.6. Aquatic Invertebrates

The Fortescue River system has been sparsely surveyed in the past so relatively little is known about the invertebrate fauna. The results of the RCM IAI survey are presented here and compared to the findings of the 2003 and 2005 Pilbara biological surveys.

RCM001. Dales Gorge

Macroinvertebrates were sampled in three habitats at Dales Gorge:

1. Bedrock and Channel
2. Macrophyte
3. Riffle - Fortescue Falls

A comparison of invertebrate diversity recorded at Dales Gorge during the Pilbara Biological Survey and the IAI RCM survey is presented below (Table 15).

Table 15 – Aquatic invertebrate diversity at Dales Gorge.

Diversity measure	Pilbara Biological Survey PSW006		RCM Survey RCM001
	Aug 2003	May 2005	Apr 2008
Total invertebrate species richness	128	108	-
Macroinvertebrate species richness	100	77	53
Total invertebrate family richness	66	58	-
Macroinvertebrate family richness	53	47	32

The series of streams, cascades and pools at Dales Gorge is generally in very good condition, though fewer species were collected in 2008 than during the Pilbara Biological Survey. The reason for this is not clear. The same habitats were sampled on each occasion by the same collector and the falls, pools and streams appeared to have the same habitats. There may have been recent high flows, which may have reduced invertebrate richness. In any case, future monitoring work should involve quantifying aquatic invertebrate richness to see if this is a trend or just normal variation. The latter is the most likely given the low level of threat to the wetland (mostly tourism).

Several of the species recorded at Dales Gorge are rare or restricted in distribution. These include the oligochaetes *Insulodrilus lacustris* s.l. Pilbara type 4 and a *Tympanogaster* beetle (Figure 19), both of which are known only from this site to date. Other species (the caddisfly *Notalina* AV17, the mayfly *Wundacaenis dostini* and the Pyralid moth *Eoophyla argyrilinale* appear to be restricted to a small number of spring fed wetlands such as Dales Gorge. There has been no reduction in the number of these rarer species; in fact, the records of *Tympanogaster* are the first for northwestern Australia. The genus is otherwise known only from the Great Dividing Ranges in Australia, other than records of one species (*T. novicia*) from the Central Ranges (Perkins 2006).

Figure 19 – An example of the aquatic invertebrate fauna present at Dales Gorge, *Tympanogaster* (Hydraeinidae).

RCM002. Fortescue Marsh West

This site was dry at the time of the IAI RCM survey and, as such, no aquatic invertebrate samples were collected.

RCM003. Moorimoordinina Pool

Three replicates of habitat consisting of unvegetated clay sediments and water column were sampled at Moorimoordinina Pool.

A total of twenty-three macroinverbetrate species belonging to thirteen families were identified from Moorimoodinina Pool. Macroinvertebrate species richness in this turbid pool was low but about average for such wetlands. Two of the *Micronecta* species do not closely match previously known species and may be new. Other species recorded (listed in Table 22 in Appendix 2) are widespread. Endemic and turbid water specific taxa tend to be microinvertebrates (especially ostracods and rotifers) but these were not surveyed as part of this project. An exception is *Caenestheriella packardi* which is typical of turbid waters. The *Haliplus* sp. P1 was known only from the Fortescue Valley in the Pilbara but is now also known from the western Kimberley (Watts and McRae in prep.), see the Resource Condition report for RCM009 - Lake Eda.

RCM004. Lower Fortescue Pool

This good condition pool on the Lower Fortescue River was sampled twice during the Pilbara Biological Survey, recording very different richness values (Table 16). The higher values were after a dry 2004/5 summer, whereas the 2006 sampling occurred after two massive cyclonic flood events in summer early 2006. The resulting lower richness in 2006 is probably a result of the loss of the original fauna during the floods and insufficient time for a similarly rich fauna to have re-established. Richness was still fairly low in 2008 but there had also been significant flows in early 2008. The lower richness values in 2006 and 2008 are probably normal for the pool following a wet summer.

Table 16 - Aquatic invertebrate diversity at Lower Fortescue Pool.

	Pilbara Biological Survey PSW076		RCM Survey RCM004
Diversity measure	**Aug 2005**	**May 2006**	**Apr 2008**
Total invertebrate species richness	123	58	-
Macroinvertebrate species richness	101	51	71
Total invertebrate family richness	64	35	-
Macroinvertebrate family richness	53	28	35

RCM005. Palm Pool

Aquatic invertebrates (including microinvertebrates) have previously been sampled at Palm Pool during the Pilbara Biological Survey. As part of the RCM survey, macroinvertebrates were sampled in three habitats at Palm Pool:

1. Macrophyte: Emergent macrophytes on eastern side of road crossing in flowing water
2. Submerged macrophytes along northern bank
3. Submerged macrophytes along southern bank

Palm Pool has a very high taxonomic diversity and species richness, with 227 species in 90 families known to date (Table 17). Wetlands of the south-west corner of Millstream National Park contain a couple of species (*Nososticta Pilbara* and *Coxelmis* elmids) that appear to be absent from elsewhere in the Pilbara and many others which occur at Millstream and are rare elsewhere, occurring mostly in the gorges at Karijini and a few other significant springs (including Running Waters, Skull Springs, Weeli Wolli). Examples of the latter are *Wundacaenis* and *Thraulus* mayflies and *Aspidiobates* and *Momoniella* water mites. Significant new records include a species of the water mite genus *Procorticacarus* (sp. P3) and a species of *Notalina* caddisfly not previously recorded in the Pilbara.

The number of families recorded for the RCM survey was similar to that recorded for the Pilbara Biological Survey. However, the number of species recorded was much lower in 2008. This is partly due to differences in level of identification and sampling area. Specifically, some groups (Nematodes, Ceratopogonods) were not identified to species for the RCM project and a smaller sampling effort was made (45 m of benthic sampling for RCM versus 50 m of benthic sampling plus 50 m of plankton sampling for the Pilbara Survey). Also, floods in early 2008 may have reduced diversity prior to sampling in April. The lower diversity is unlikely to be due to any disturbance at the wetland.

Table 17 - Aquatic invertebrate diversity at Palm Pool.

Diversity measure	Pilbara Biological Survey PSW010		RCM Survey RCM005
	Aug 2003	May 2005	Apr 2008
Total invertebrate species richness	144	114	-
Macroinvertebrate species richness	117	88	52
Total invertebrate family richness	66	65	-
Macroinvertebrate family richness	42	49	40

RCM006. Fortescue Marsh East

This site was dry at the time of the IAI RCM survey and, as such, no aquatic invertebrate samples were collected.

3.7. Fish

Fish were seen at Dales Gorge, Palm Pool and Fortescue Marsh East during the IAI RCM surveys, but specimens were not collected or identified. Previously, nine species of fish have been recorded in the Millstream Pools, including Fortescue Grunter (*Leiopotherapon aheneus*) (endemic to this and nearby rivers), Spangled Perch (*Leiopotherapon unicolour*) and catfishes.

3.8. Waterbirds

The Fortescue Marshes are an important stop-over and breeding ground for migratory waterbirds, Forty-seven species of waterbird (mainly ducks, herons and allies) were counted at the marshes during three surveys following flooding events between 1999 and 2003 (van Leeuwen 2004). In particular, the marshes are a major breeding area for Australian Pelican (*Pelecanus* *conspicillatus*) and Black Swan (*Cygnus atratus*). This is one of only two inland breeding colonies of pelicans in WA. There are also breeding records for Great Egret (*Ardea alba*), Straw-necked Ibis (*Threskiornis spinicollis*) and Yellow-billed Spoonbill (*Platalea flavipes*). This is one of only two known breeding localities for Great Egret in north-western Australia (Jaensch, 1993a).

Thirty eight species of waterbird have also been recorded at the Millstream pools; including Spotless Crake (*Porzana tabuensis*) and Baillon's Crake (*Porzana pusilla*), which are uncommon in north- western Australia; Cattle Egret (*Ardea ibis*), Magpie Goose (*Anseranas semipalmate*) and Plumed Whistling-Duck (*Dendrocygna eytoni*) which are at the southern extent of their range. Eight species found breeding here, including Australasian Grebe (*Tachybaptus novaehollandiae*), Black Bittern (*Dupetor flavicollis*) and Purple Swamphen (*Porphyrio porphyrio*) and this one of few locations of known occurrence for the isolated Pilbara populations of both these species (Jaensch, 1993b).

Waterbirds were recorded at four of the five sites surveyed as part of the Pilbara Biological Survey (DEC, unpublished data). Twenty-five waterbird species were recorded at Fortescue Marsh West, eleven at Moorimoordinina Pool, twelve at Palm Pool and seven species at Fortescue Marsh East. Waterbirds were not recorded during the IAI RCM surveys but good records from 5 years prior to the RCM surveys provide a good baseline/point of reference.

3.9. Terrestrial Vertebrates

There are few records of terrestrial vertebrates on the Fortescue Marshes, other than birds. Bilbies (*Macrotis lagotis*; Schedule 1 fauna: rare or likely to become extinct) were thought to persist on several of the pastoral leases of the Fortescue Marshes area up until the 1980s (van Leeuwen 2004), but no definitive sightings have been made since. Other Schedule 1 fauna known to occur within the Fortescue bioregion is the Orange Leaf-nosed Bat (*Rhinonicteris aurantius*) and the Pilbara Olive Python (*Liasis olivaceus barroni*). Two unconfirmed sightings of the critically endangered Night Parrot (*Pezoporus occidentalis*) were recorded in the Fortescue Marshes area in 2003 and 2005 (van Leeuwen 2004). Turtles were sighted at Lower Fortescue Pool during IAI RCM survey. They were not identified but are most likely to be the flat-shelled turtle (*Chelodina steindachneri*) according to distribution maps (Cogger 1975). A Long-nosed Water Dragon (Figure 20) was observed at the same site.

Figure 20 – Long-nosed Water Dragon (*Lophognathus longirostris*) sighted at Lower Fortescue Pool (A. Pinder, DEC).

4. Interactions between Ecological Components

An appreciation of the interactions between the elements of a wetland ecosystem is essential to understanding the condition of the system. Although components of a wetland are often monitored and managed as discrete entities, they exist as nodes in a complex ecological web. Documenting the full extent of the interactions that occur at a wetland would be impractical. However, it is essential to identify key interactions that define the system's ecological character.

Hale and Butcher (2007) justified the equivalence of Ramsar nomination criteria and primary determinants of ecological character. This justification may also be extended to nomination for the Directory of Important Wetlands in Australia, as the criteria are very similar. Accordingly, the primary determinants of ecological character at both Fortescue Marshes and Millstream Pools are:

- The characteristics that make the sites good example of wetland types occurring within a biogeographic region in Australia.
- The contribution the sites make to the ecological and hydrological functioning of the wetland system.
- The animal taxa that utilise the sites as habitat at a vulnerable stage in their life cycles, or as refuge when adverse conditions such as drought prevail; and the characteristics of the sites that allow them support these populations.
- The sites' outstanding historical and cultural significance.

Table 18 summarises the interactions between key components and processes at Fortescue Marshes and Millstream Pools. The table lists the components that are directly responsible for the provision of each service or benefit of the wetland and the biotic and abiotic factors that support or impact these components. Also listed are the key threats that may affect the components or processes. This information assists in the identification of the primary determinants of ecological character.

Table 18 - The relationship between the services and benefits delivered by the Fortescue Marshes and the key components and processes that support them.

Benefit or Service	Component	Factors Influencing Component		Threats and Threatening Activities
		Biotic	Abiotic	
Fortescue Marshes & Millstream Pools *Consumptive Value* Bush tucker and water consumption	Palatable plants and animals Fresh water	Plant pollinators Animal food sources	Water quality Hydrological regime Fire regime Habitat requirements	Overexploitation Changes to vegetation due to pastoralism Changed fire regimes Altered hydrology due to climate change, water extraction or catchment perturbation Weeds
Fortescue Marshes *Productive Value* Beef production	Cattle	Plants palatable to stock	Water quality Hydrological regime (including periodic inundation events) Groundwater level	Loss of access to water points due to conservation activities Changes to hydrology affecting fodder availability Grazing competition from feral pests Groundwater extraction for agriculture Changes to vegetation due to inappropriate fire regimes
Fortescue Marshes & Millstream Pools *Opportunity Value* Potential future use of unique flora and fauna	Endemic flora Endemic fauna	Pollinators Food sources	Habitat extent and distribution Hydrological regime Fire regime Water quality	Grazing by cattle and introduced pest animals Alteration to hydrology due to damming in the upper catchment, climate change or mining practices Inappropriate fire regimes Weeds Predation of fauna, loss of habitat
Fortescue Marshes *Ecosystem Service Value* It is a good example of a wetland type occurring within a biogeographic region in Australia	It is the largest ephemeral wetland in the Pilbara and the only feature of this type in the Pilbara bioregion	Vegetation communities	Hydrological regime	Alteration to hydrology due to damming in the upper catchment, climate change or mining practices Grazing by cattle or introduced pest animals Erosion
Millstream Pools *Ecosystem Service Value* It is a good example of a wetland type occurring within a biogeographic region in Australia	An outstanding example of a system of permanent river pools and springs in the semi-arid tropics and the best known in north-western Australia.	Vegetation communities	Soil Hydrological regime	Alteration to hydrology due to damming in the upper catchment, climate change or mining practices Grazing by cattle or introduced pest animals Erosion

Benefit or Service	Component	Factors Influencing Component		Threats and Threatening Activities
		Biotic	Abiotic	
Fortescue Marshes *Ecosystem Service Value* It is a wetland which plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex	Fortescue Marsh, Fortescue River and the creeks that feed into the system	Vegetation communities	Soil Hydrological regime	Alteration to hydrology due to damming in the upper catchment, climate change or mining practices Grazing by cattle or introduced pest animals Erosion
Millstream Pools *Ecosystem Service Value* It is a wetland which plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex	Fortescue River, Millstream Pools, connecting channels and Millstream aquifer	Vegetation communities	Substrate Hydrological regime Aquifer	Alteration to hydrology due to damming in the upper catchment, climate change or mining practices Erosion Groundwater extraction Recreational impacts
Fortescue Marshes *Ecosystem Service Value* It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail	Forty-seven species of waterbird, including Australian Pelican, Black Swan, Great Egret, Straw-necked Ibis and Yellow-billed Spoonbill.	Invertebrate populations (food source) Phytoplankton (food source) Benthic plant biomass	Soils Nutrient concentrations Water salinity pH Groundwater level	Grazing by cattle and introduced pests Pugging by cattle Alteration to hydrology due to damming in the upper catchment, climate change or mining practices Inappropriate fire regimes Excessive nutrient inputs from stock Weeds Predation of fauna Loss of migratory bird populations due to offsite factors
Millstream Pools *Ecosystem Service Value* It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail	Millstream Fan Palm, Fortescue grunter and38 species of waterbird, including Spotless Crake, Baillon's Crake; Cattle Egret, Magpie Goose, Plumed Whistling-Duck, Australasian Grebe, Black Bittern and Purple Swamphen	Invertebrate populations (food source) Phytoplankton (food source) Benthic plant biomass	Soils Nutrient concentrations Water salinity pH Groundwater level	Alteration to hydrology due to damming in the upper catchment, climate change or mining practices Inappropriate fire regimes Weeds Predation of fauna Loss of migratory bird populations due to offsite factors Recreational impacts

Benefit or Service	Component	Factors Influencing Component		Threats and Threatening Activities
		Biotic	Abiotic	
Fortescue Marshes & Millstream Pools *Recreational Value* Bird watching Bush walking Wildlife photography	Landscape amenity Waterbird populations Vegetation communities Significant flora Significant fauna	Invertebrate populations (food source) Phytoplankton (food source) Benthic plant biomass	Soils Nutrient concentrations Water salinity pH Groundwater level	Grazing by cattle and introduced pests Pugging by cattle Alteration to hydrology due to damming in the upper catchment, climate change or mining practices Inappropriate fire regimes Excessive nutrient inputs from stock Weeds Predation of fauna Loss of migratory bird populations due to offsite factors
Fortescue Marshes & Millstream Pools *Spiritual Value* The wetlands within Karijini and Millstream-Chichester National Parks, Moorimoordinina Pool, Weeli Wolli Creek and others are of outstanding historical or cultural significance	Geomorphology of lake and surrounds Native flora and fauna communities	Flora and fauna populations Pollinators and food sources for above	Soils Hydrology Water quality	Grazing by cattle and introduced pests Pugging by cattle Alteration to hydrology due to damming in the upper catchment, climate change or mining practices Inappropriate fire regimes Excessive nutrient inputs from stock Weeds Predation of fauna Erosion

5. Threats to the Ecology of the Fortescue River System

In the context of the current document, the ambition for management of the Fortescue River system is to maintain those elements of the ecology that resulted in the nomination of the Fortescue Marshes and Millstream Pools as DIWA sites. A secondary objective is to maintain the ecological functionality of the survey sites that are outside the DIWA nominated areas. Achieving these objectives is likely to contribute significantly to protecting the integrity of the overall river system and put it in better standing for listing under Ramsar Convention.

The critical components of the ecology are the geomorphologic, hydrologic and water quality factors that make the wetlands a suitable stopover for migratory birds and refuge site for domestic waterbirds and endemic fauna. These factors are the primary determinants of the wetlands' ecological character.

The primary determinants of ecological character interact with the plant communities that surround the water bodies, the aquatic invertebrate and benthic plant communities that inhabit them, and the threatening processes that affect all of these. It is this set of influencing factors that are most likely to be targeted by management actions.

Also of importance are the elements of the system that contribute to its cultural, scientific and recreational value. These are the same as the above listed influences on the primary determinants of ecological character, with the addition of landscape amenity.

Threats to the wetlands of the Fortescue River system must be considered in relation to their likelihood of causing the failure of the above management goal for the wetlands. An assessment is made of the probability that goal failure will result due to the impacts of each threatening process identified at the site, or potentially acting there. The results of this assessment are presented in two tables: Table 19 discusses the threats to the Fortescue Marshes, while Table 20 discusses those at the Millstream Pools. Threats to the Lower Fortescue and Dales Gorge sites are not provided in detail. In brief, the Lower Fortescue site is not currently showing any signs of degradation due to stock or feral animals. Reduced water flows are likely to be the biggest threat to the site. Dales Gorge shows no signs of any deleterious impacts and none are expected. The area is a very popular tourist destination, but visitation is well managed and the site is highly resilient, so this is not expected to be problematic. Some pollution of the waterbody from sunscreen is likely.

Failure to achieve the management goal for Fortescue Marshes is most likely to result due to the impacts of cattle pastoralism, altered hydrology and surrounding mining operations. Weeds and climate change are also significant threats, whilst the impacts of drought, flood and eutrophication of the water body should also be considered. The Millstream Pools are most threatened by altered hydrology, caused by the damming of the Fortescue River and extraction of groundwater from the Millstream aquifer. Drought is another potentially serious threat, particularly in combination with altered hydrology. Climate change, weeds and fire are of less concern.

The impact of cattle on the Fortescue Marshes is a major threat, given that the entire marsh area is currently within pastoral leases. Cattle are currently having a major impact on the area with 31 to 70% of the emergent and/or riparian plants grazed. Such disturbance creates an opportunity for weed species to become established, with cattle acting as a vector for the transport of plant propagules. Soil disturbance also increases the likelihood of erosion and increases the turbidity of the water body. There is also the possibility that cattle excrement would contribute excessive nutrients to the system, leading to algal blooms and eutrophication.

Cattle will continue to graze the area until 2015 when the pastoral lease renewal process will see part of the area vested as conservation estate. After this, water sources on neighbouring properties must be maintained to discourage stock from straying onto the marshes. Stock exclusion fencing may also be considered, although these would also need to exclude other feral animals such as camels. Although costly in terms of both construction and maintenance, these measures will be essential for the conservation of an environment with so many values.

Altered hydrology is another major threat to the Fortescue Marshes. The Ophthalmia Dam was constructed in 1981 by the Mt Newman Mining Company to provide water for the town of Newman and nearby mining operations. The dam is in the upper reaches of the Fortescue River and so affects the hydrology of almost the entire river system. In 2004, the Department of Agriculture released a report detailing the impact of the dam on the Fortescue Marshes (Payne and Mitchell 1999). That report found that, in flooding events, the dam reduced the flow volume downstream by 52%. In non-flood years, there has been little downstream flow since the dam's construction. This threat, together with the projected outcomes of climate change, may result in a reduction in the frequency and longevity of inundation of the Fortescue Marshes.

Altered hydrology is also a threat to the Millstream Pools. It is the permanence of these pools that makes them so important to flora and fauna. This permanence is threatened by reduced river flows and ground water abstraction. The pools receive water from flows of the Fortescue River and from springs that emerge from the Millstream aquifer. Surface water flows have been reduced by the construction of the Ophthalmia Dam. The reduced river flow also impacts the Millstream aquifer, as this is recharged during flooding events. Meanwhile, the aquifer is being rapidly depleted due to its use to provide water for both drinking and industrial purposes in the western Pilbara. Although it is no longer the sole source of drinking water for the region, the aquifer continues to be used, particularly during periods of drought when dam levels are low.

Mining is another threat to the hydrology of the Fortescue Marshes. Surrounding mining operations utilise various processes that may alter the hydrology to the system. For example, mining operations such as the Hope Downs project, managed jointly by Rio Tinto Iron Ore and Hancock Prospecting, are extracting groundwater while the ore body is being removed. This water is then pumped into the nearby Weeli Wollie Creek, which flows into the Fortescue Marsh. This procedure could change the creek from an intermittently flooded wetland to a permanent wetland, impacting on both the flora and fauna communities that are present in the creek. Once the ore body has been removed, the water will then be re-injected back into the aquifer (RTIO undated). Other mining operations in the area are likely to be damming smaller creeks for on-site water usage, therefore restricting the flows into the Fortescue River, but the extent of these operations is unknown/unquantified.

Altered fire regimes are a major threat to biodiversity across the Pilbara region. In the context of both the Fortescue Marshes and Millstream Pools, fire has the potential to facilitate the establishment of weed species, expose soils to erosion, cause the loss of fire sensitive flora taxa and negatively impact on fauna. Late dry season fires can also have significant impacts on soil loss, loss of nitrogen in smoke, and increased greenhouse gas emissions, and impacts on air quality and human health. It is very difficult to manage fire in a setting such as the Pilbara region due to the vastness of the area.

The CSIRO (2001) predicts that climate change will make the north-western area of Australia significantly warmer and slightly drier in the future. Periods of aridity are likely to be longer and the rainfall events that end them more extreme. Some of the potential effects of these changes include the replacement of the current floral communities with more drought resistant assemblages, the occurrence of more intense fires and longer recovery times for vegetation following them, leading to greater erosion risk in the catchment. Altered hydrology due to less rainfall, and hotter days leading to higher evaporation rates, will make the Fortescue River a drier system overall. This would have a detrimental impact on the fauna species that rely on the wetlands as habitat. Algal blooms are also expected to become more frequent and widespread as a result of rising temperatures.

Wetlands are highly productive environments, but also easily disturbed. Fires, pest animals, stock and human activities may all disturb native vegetation and allow exotic plants to become established. Weed propagules are introduced via the vectors of inflowing water, grazing stock, exotic animals, visiting waterbirds or wind. Once established, the productivity of the ecosystem often allows weed populations to flourish and exclude native plants. An additional problem is the difficulty in implementing weed control in wetland environments. The fragility of the system and fluxes of water often make chemical weed control inappropriate. Mechanical control is often complicated by difficulty in accessing infestations and is likely to be prohibitively labour intensive.

Fortunately, there is currently minimal evidence of weed invasion at the Fortescue Marshes. Although some exotic species were identified by the IAI RCM project, these did not appear to be impacting heavily. Date palms, cotton palms, buffel grass, Parkinsonia, Indian water fern and water lilies are all present at Palm Pool but management is ongoing. The potential for new weed propagules to be introduced to both sites remains a concern, particularly as cattle and camels are accessing the water bodies. Future exclusion fencing is the best management tool available to prevent future weed outbreaks and pollution of the wetlands.

Human visitation to some of the Fortescue River wetlands is common and there is always the risk that these visitors could carry seed propagules, plant pathogens or even exotic fauna such as cane toads, on their person or vehicles and introduce them to the site. There is also an increased risk of wildfire due to deliberate ignition or the failure to extinguish campfires. Contamination from insect repellents and sunscreen used by tourists are a potential (but probably not significant) problem in wetlands used for swimming.

Table 19 - Threat assessment for the Fortescue Marshes.

An estimate is provided of the perceived likelihood of goal failure resulting from the impacts of each identified threat category.

Goal: to maintain the geomorphology, hydrology and water quality of the Fortescue Marshes, thus ensuring it remains a suitable drought refuge and migratory stopover for waterbirds and retains its cultural and scientific values.

Threat category	Management issue	Probability (%) that threat will cause goal failure with:		Assumptions underlying initial probability assessment and explanatory notes
		Existing management	Extra management	
Altered biogeochemical processes	Altered hydrological processes	30	10	There is evidence of alteration to the hydrology of the Fortescue Marshes area as a result of the Ophthalmia Dam, with reductions in river flows downstream.
	Carbon cycle and climate change	5	5	Predicted rise in temperature in the Pilbara (as much as $7^{0}C$) would lead to higher evaporation rates and water consumption. Changes to rainfall are expected to be fairly minor in the Pilbara, perhaps as little as 1% over the next 50 years, but may lead to slight decreases in stream flow. This would cause changes to the ecology of the Fortescue Marshes (CSIRO 2001).
Impacts of introduced plants and animals	Herbivory, wallowing and trampling by introduced species	40	5	Significant impacts of cattle are already evident. Cattle wallowing around the wetland margins kill vegetation and makes soil susceptible to erosion. Over-grazing has similar impacts. This threat is readily addressed by fencing the lake to exclude cattle. Pigs, donkey, camel and horses are also having significant impacts.
	Environmental weeds	10	5	Weeds are identified as one of the primary threats to the ecology of the Fortescue sub-region. Although the Fortescue Marshes are not currently heavily impacted by weeds, ongoing grazing activities and tourist visitation make the site highly susceptible to further weed invasion. Alteration to natural fire regimes may facilitate the further establishment of weed species in the area.
Detrimental regimes of physical disturbance events	Fire regimes	10	5	Altered fire regimes are a major threat to biodiversity across the Pilbara region. In the context of the Fortescue Marshes, fire has the potential to facilitate the establishment of weed species, expose soils to erosion, cause the loss of fire sensitive flora taxa and negatively impact on fauna. Late dry season fires can also have significant impacts on soil loss, loss of nitrogen in smoke, and increased greenhouse gas emissions; and impacts on air quality and human health. It is very difficult to manage fire in a setting such as the Pilbara Region due to the size and isolation of the area.

Threat category	Management issue	Probability (%) that threat will cause goal failure with:		Assumptions underlying initial probability assessment and explanatory notes
		Existing management	**Extra management**	
	Drought	20	5	Rainfall projections for the Pilbara show that climate change may result in warmer weather with less but more intense rainfall (CSIRO 2001). The impacts of this on the ecology and geomorphology of the Fortescue Marshes are difficult to predict. It is possible that it may lead to some alteration in the composition of flora and fauna at the site.
	Flood	5	5	Alteration to rainfall and hydrological fluxes, associated with global climate change may impact on the flora and fauna of the Fortescue Marshes The nature of the impacts are not clear and should be monitored.
Impacts of pollution	Herbicide, pesticide or fertiliser use and direct impacts	0	0	Pastoralism usually does not make use of such chemicals and, at present, no intensive agriculture or broadscale cropping is practiced in the Fortescue catchment.
Impacts of competing land uses	Mines and quarries	10	5	The Fortescue Marshes are lined in the south with the Newman-Port Headland railway line, associated with nearby mining operations. Mine sites and an additional railway line are currently in operation directly north of the Fortescue Marshes area. These sites, and associated infrastructure, have the potential to interfere with the local hydrology and are a potential source of pollutants.
	Recreation management	1	0	Recreational usage of the Fortescue Marshes is minimal. Weed introduction, pollution and wildfire ignition by visitors are all potential impacts from recreation.
	Nutrient enrichment of water body	5	1	It is likely that cattle accessing the lake, together with the projected impacts of climate change, will result in nutrient enrichment of the water body. Regular flushing of the system by flood flows are likely to largely counteract this.
	Urban and industrial development (apart from mining)	0	0	The remoteness of the area makes it an inappropriate site for any urban or industrial development. The low population density of the region makes it unlikely that any development in the area would be pursued.
	Consumptive uses	0	0	Consumptive use of the Fortescue Marshes by local Aboriginal people is most probably sustainable in the long-term due to the small number of people involved.
	Illegal activities	0	0	No evidence of any threat.
Insufficient ecological resources to maintain viable populations	Habitat, genetic exchange	1	1	The Fortescue Marshes are well connected to extensive areas of natural or near-natural environment. Populations are likely to be self-supporting in this setting. Off-site impacts on migratory birds could potentially reduce their population size to unsustainable levels, but this could not be addressed at a site level.

Table 20 - Threat assessment for the Millstream Pools.

An estimate is provided of the perceived likelihood of goal failure resulting from the impacts of each identified threat category.

Goal: to maintain the geomorphology, hydrology and water quality of the Millstream Pools, thus ensuring they remain a suitable drought refuge and migratory stopover for waterbirds and retains cultural and scientific values.

Threat category	Management issue	Probability (%) that threat will cause goal failure with:		Assumptions underlying initial probability assessment and explanatory notes
		Existing management	Extra management	
Altered biogeochemical processes	Altered hydrological processes	30	5	These pools receive water from surface water flows (primarily the Fortescue River) and seepage from the Millstream aquifer. Water is extracted from the Millstream aquifer to supply drinking water to the west Pilbara, when the Harding Dam is unable to meet demands. Local pastoralists probably also extract groundwater, although the magnitude of this usage is not known. Groundwater extraction from the Millstream aquifer has previously been shown to have deleterious impacts on the health of the pools, particularly through periods of drought. The Ophthalmia Dam is exacerbating this issue by reducing water flows in the Fortescue River. Groundwater use by mines is a major area for concern in the region.
	Carbon cycle and climate change	5	5	Predicted rise in temperature in the Pilbara (as much as 7^{0}C) would lead to higher evaporation rates and water consumption. Changes to rainfall are expected to be fairly minor in the Pilbara, perhaps as little as 1% over the next 50 years, but may lead to slight decreases in stream flow. This would cause changes to the ecology of the Millstream Pools (CSIRO 2001)
Impacts of introduced plants and animals	Herbivory, wallowing and trampling by introduced species	2	1	The Millstream Ponds still show some impacts from grazing that occurred when the area was part of a pastoral lease. Grazing pressure has now been removed, with the exception of some feral herbivores.
	Environmental weeds	5	2	Date palms, cotton palms, buffel grass, Parkinsonia, Indian water fern and water lilies are all present but management is ongoing.
Detrimental regimes of physical disturbance events	Fire regimes	5	2	Altered fire regimes are a major threat to biodiversity across the Pilbara region. In the context of the Millstream Pools, fire has the potential to facilitate the establishment of weed species, expose soils to erosion, cause the loss of fire sensitive flora taxa and negatively impact on fauna. Late dry season fires can also have significant impacts on soil loss, loss of nitrogen in smoke, and increased greenhouse gas emissions; and impacts on air quality and human health.

Threat category	Management issue	Probability (%) that threat will cause goal failure with:		Assumptions underlying initial probability assessment and explanatory notes
		Existing management	**Extra management**	
	Drought	15	5	As noted under 'altered hydrological processes' additional pressure is placed on the Millstream aquifer during periods of drought. In addition, recharge of the aquifer occurs only when the River system floods. As such, the predicted trend toward hotter conditions in the Pilbara will place pressure on this site.
	Flood	0	0	Regular flooding is a natural feature of Pilbara rivers and is unlikely to have long lasting deleterious impacts.
Impacts of pollution	Herbicide, pesticide or fertiliser use and direct impacts	0	0	Chemicals of this sort are not used in the Fortescue catchment, except as part of weed control operations..
Impacts of competing land uses	Mines and quarries	0	0	Mines in the catchment may be causing changes to local hydrology, but this issue is addressed under 'altered hydrological processes'. There are no direct landuse conflicts with mines.
	Recreation management	2	1	The Millstream pools are very heavily visited by tourists. Recreation is low impact and well managed. Weed introduction, pollution and wildfire ignition by visitors are all potential impacts from recreation
	Nutrient enrichment of water body	0	0	No sources of nutrient enrichment exist. Regular flushing of the pools (including sediments) discourages nutrient accumulation.
	Urban and industrial development (apart from mining)	0	0	The pools are within a National Park and no development is likely.
	Consumptive uses	0	0	Consumptive use of the pools is light and, most probably, sustainable in the long term.
	Illegal activities	0	0	
Insufficient ecological resources to maintain viable populations	Habitat, genetic exchange	2	1	The Millstream Pools are well connected to extensive areas of natural or near-natural environment. Populations are likely to be self-supporting in this setting. However, some of the taxa found in the Millstream area are endemic to that locality. As such, there is limited potential for genetic exchange. Off-site impacts on migratory birds could potentially reduce their population size to unsustainable levels, but this could not be addressed at a site level.

6. Knowledge Gaps and Recommendations for Future Monitoring

The Fortescue River system is relatively well known, partly due to surveys conducted as part of the Pilbara Biological Survey (data still to be published), and more recently as part of this IAI RCM project. However, there is a need for ongoing data collection as part of a surveillance program. This would allow trends in condition to be identified and may lead to the discovery of new, rare or endemic taxa. Further surveys would also help to address anomalies between the Pilbara Biological Survey and the RCM survey results such as discrepancies in invertebrate taxa diversity at Dales Gorge. Future survey work should investigate aquatic invertebrate richness to determine if such differences in data are part of a trend or are natural variation.

Any future surveillance of the Fortescue Marshes should concentrate on the components of the site that contribute to its outstanding ecological character, as outlined in Section 3. Therefore, future monitoring should concentrate on the following:

- Changes to hydrology due to the surrounding land uses (dam) groundwater level and quality monitoring and flow rates/volumes calculated.
- Water quality, as this is valuable in providing a resource to the native fauna and the local indigenous people as well as maintaining habitat for aquatic invertebrates.
- Aquatic invertebrates, as the site supports many rare taxa or taxa of restricted distribution, and there is potential for the discovery of more.
- Vegetation surveys to ensure that the native vegetation is being maintained and continues to provide refuge and habitat for birds and other fauna, and to provide water quality services.
- Bird diversity and abundance, particularly to assess compliance with Ramsar criteria.
- Fish, as one significant species (grunter) is known from the area. There is a need to survey fish systematically to provide baseline data.

References

Atkins, K. J. (2008) *Declared Rare and Priority Flora List for Western Australia*. Department of Environment and Conservation, Perth, Australia. 26 February 2008.

Bureau of Meteorology. (2009) Climate Statistics for Australian Locations. Bureau of Meteorology. <http://www.bom.gov.au/climate/averages/> Accessed on 5 January 2009.

CALM. (1999) *Karijini National Park: Management Plan, 1999-2009* Department of Conservation and Land Management, Perth, Australia.

Cogger, H. G. (1975) *Reptiles and amphibians of Australia*. Reed Books, London, United Kingdom.

CSIRO. (2001) *Climate change projections for Australia*. Two page brochure. CSIRO, Canberra, Australia.

Environment Australia. (2001) *A Directory of Important Wetlands in Australia, Third Edition*. Environment Australia, Canberra.

ESCAVI. (2003) *National Vegetation Information System: Australian Vegetation Attribute Manual*. Department of Environment and Heritage, Canberra, Australia. August 2003.

Hale, J., and Butcher, R. (2007) *Ecological Character Description for the Peel-Yalgorup Ramsar Site*. Department of Environment and Conservation and the Peel-Harvey Catchment Council, Perth, Australia.

Jaensch, R. P. (1993a) Fortescue Marshes - WA066. In *Australian Wetlands Database*. Department of Environment, Heritage and the Arts. Accessed on 18 December 2008.

Jaensch, R. P. (1993b) Millstream Pools - WA069. In *Australian Wetlands Database*. Department of Environment, Heritage and the Arts. Accessed on 24 July 2009.

Jaensch, R. P., and Watkins, D. (1999) *Nomination of additional Ramsar wetlands in Western Australia: final report to the Western Australian Department of Conservation and Land Management*. Department of Conservation and Land Management.

Kendrick, P. (2001) Pilbara 2 (Pil2-Fortescue Plains subregion). In *A Biodiversity Audit of Western Australia's 53 Biogeographic Subregions in 2002*. (McKenzie, N. L., May, J. E., and McKenna, S., eds). Department of Environment and Conservation, Perth, Australia.

Kendrick, P., and MacKenzie N. (2001) Pilbara 1 (Pil1-Chichester subregion). In *A Biodiversity Audit of Western Australia's 53 Biogeographic Subregions in 2002*. (McKenzie, N. L., May, J. E., and McKenna, S., eds). Department of Environment and Conservation, Perth, Australia.

Payne, A. L., and Mitchell, A. A. (1999) *An assessment of the impact of Ophthalmia Dam on the floodplains of the Fortescue River on Ethel Creek and Roy Hill Stations*. Department of Agriculture, Perth, Australia

Perkins, P. D. (2006) A revision of the Australian humicolous hygropetric water beetle genus *Tympanogaster* Perkins, and comparative morphology of the Meropathina (Coleoptera: Hydraenidae). *Zootaxa* **1346**: 1-396.

RTIO. (not dated) *On the Waterline*. Available online: http://www.riotinto.com/documents/ReportsPublications/Issue86_On_the_waterline.pdf.

van Leeuwen, S. (2004) *Background documentation: Fortescue Marsh visit: Conservation Commission, Western Australia, Friday 1 July 2005*. Unpublished report by the Department of Conservation and Land Management, Karratha, Australia.

Wallace, K. J., B.C. Beecham., B.H. Bone. (2003) *Managing Natural Biodiversity in the Western Australian Wheatbelt: a conceptual framework*. Department of Conservation and Land Management, Perth, W.A.

Watts, C. H. S., and McRae, J. M. (in prep.) *The identity of Haliplus Latreille (Coleoptera: Haliplidae) from the Pilbara region of Australia including the description of four new species*. To be submitted to the Records of the South Australian Museum.

Appendix 1 – Vegetation Data

Plant specimens submitted to the Western Australian Herbarium

RCM001 - Dales Gorge:

Cladium procerum (P1aQR1MC07)

Fimbristylis sieberiana (P1aQR1MC09)

Themeda sp. Mt Barricade (M.E. Trudgen 2471) (P1aQO1MC05)

RCM002 - Fortescue Marsh West:

Tecticornia sp. Roy Hill (H. Pringle 62) (P2aQO1MC01)

RCM003 - Moorimoordinina Pool:

Samolus sp. Millstream (MIH Brooker 2076) (P3aQR1MC05)

RCM004 - Lower Fortescue Pool:

Chara sp. (P4aQA1MC01)

Melaleuca argentea (P4aQR1MC01)

RCM005 - Palm Pool:

Chara sp. (P5aQA2MC06)

No specimens were submitted for Fortescue Marsh east (RCM006).

Appendix 2 – Aquatic Invertebrate Data

Table 21 – Aquatic invertebrates sampled at Dales Gorge.

Class	Order	Family	Lowest ID	PSW006 Aug 2003	PSW006 May 2005	RCM001 Apr 2008
Lobosea	Arcellinida	Arcellidae	*Arcella gibbosa* (ex P2)		1	
			Arcella sp. P1		1	
		Centropyxidae	*Centropyxis* sp.		1	
		Difflugiidae	*Difflugia* sp. P2		1	
	Euglyphida	Euglyphiidae	*Euglypha* sp.		1	
Turbellaria	-	-	Turbellaria		1	1
	-	-	Microturbellaria	1	1	
Nematoda	-	-	Nematoda	1	1	
Rotifera	Bdelloidea	-	*Bdelloidea* sp. 2:2		1	
	Ploimida	Lepadellidae	*Colurella* sp.	1		
			Lepadella ovalis		1	
			Lepadella (H.) *ehrenbergii*		1	
			Lepadella patela similis	1		
		Dicranophoridae	*Dicranophorus epicharis*	1		
		Euchlanidae	*Euchlanis dilatata*	1		
		Lecanidae	*Lecane bulla*	1	1	
			Lecane haliclysta	1		
			Lecane hamata	1		
			Lecane levistyla	1		
			Lecane lunaris	1	1	
			Lecane quadridentata		1	
			Lecane ruttneri	1		

Class	Order	Family	Lowest ID	PSW006 Aug 2003	PSW006 May 2005	RCM001 Apr 2008
Rotifera	Ploimida	Lecanidae	*Lecane thalera*		1	
			Lecane unguitata		1	
		Mytilinidae	*Mytilina ventralis macracantha*	1		
		Notommatidae	*Cephalodella forficula*		1	
			Monommata sp.		1	
		Proalidae	*Proales* cf. *similis*	1		
		Trichocercidae	*Trichocerca myersi*		1	
		Trichotriidae	*Macrochaetus altamirai*		1	
			Macrochaetus collinsi		1	
		Scaridiidae	*Scaridium bostjani*	1		
Gastropoda	Neotaenioglossa	Thiaridae	*Plotiopsis australis*		1	2
			Melanoides (*Stenomelania*) *tuberculata*	1	1	
	Basommatophora	Lymnaeidae	*Austropeplea vinosa*	1	1	
			Austropeplea lessoni			2
		Ancylidae	*Ferrissia* sp.	1	1	
Bivalvia	Veneroida	Corbiculidae	*Corbicula* sp.	1		
Oligochaeta	Tubificida	Phreodrilidae	*Insulodrilus lacustris* s.l. Pilbara type 4			1
			Phreodrilid with dissimilar ventral chaetae	1		
		Naididae	*Nais variabilis*	1		2
			Dero pectinata		1	
			Allonais pectinata		1	
			Allonais ranauana	1	1	2
			Allonais paraguayensis			1,2
			Pristina longiseta			2
			Pristina aequiseta	1	1	
	Opisthopora	-	Opisthopora			2
Arachnida	Acariformes	Hydrachnidae	*Hydrachna* sp. 3			2

Class	Order	Family	Lowest ID	PSW006 Aug 2003	PSW006 May 2005	RCM001 Apr 2008
Arachnida	Acariformes	Hydrachnidae	*Hydrachna* sp. 6			2
		Hydryphantidae	*Hydryphantes meridianus*			2
			Pseudohydryphantes sp. P1		1	2
		Hydrodromidae	*Hydrodroma* sp.	1	1	1
		Oxidae	*Frontipoda spinosa*	1	1	1,2
			Oxus orientalis			1
		Limnesiidae	*Limnesia maceripalpis*	1	1	2
			Limnesia parasolida	1	1	1,2
		Hygrobatidae	*Aspidiobates pilbara*	1		
			Australiobates vertriscutatus		1	
			Australiobates queenslandensis			1
			Australiobates sp. P4	1	1	
			Coaustraliobates minor		1	2
			Procorticacarus sp. P1	1		
		Unionicolidae	*Koenikea* sp. 2/3 (Pilbara)			1
			Unionicola crassipalpis	1	1	1
			Unionicola neoaffinis		1	1
			Unionicola nr *minutissima*			2
		Pionidae	*Piona cumberlandensis*			2
		Aturidae	*Albia rectifrons*			2
			Axonopsella sp.	1		2
			Axonopsella nr *truza*		1	
			Axonopsella sp. P2		1	
		Momoniidae	*Momoniella* nr *australica*			2
		Mideopsidae	*Gretacarus* sp.		1	
			Gretacarus sp. P2 (nr oldus)	1		1,2
		Arrenuridae	*Arrenurus tripartitus*			2

Class	Order	Family	Lowest ID	PSW006 Aug 2003	PSW006 May 2005	RCM001 Apr 2008
Arachnida	Acariformes	Arrenuridae	*Arrenurus vanderpalae*			1,2
			Arrenurus sp.	1	1	
		-	*Oribatida*	1	1	1,3
		-	*Oribatida* group 5 (PSS)			
		-	*Oribatida* sp. 4		1	
Crustacea	Cladocera	Chydoridae	*Alona clathrata*	1		
			Alona cf. *verrucosa*	1		
			Chydorus eurynotus	1		
			Ephemeroporus barroisi s.l.		1	
			Armatalona macrocopa	1		
	Ostracoda	Limnocytheridae	*Limnocythere dorsosicula*	1	1	
		Darwinulidae	*Darwinula stevensoni*	1		
			Vestalenula marmonieri	1	1	
		Candonidae	*Candonopsis tenuis*	1		
		Cyprididae	*Cypretta* sp. PSW074		1	
			Isocypris williamsi (ex *Ilyodromus* sp. 413)	1		
			Ilyodromus viridulus		1	
			Ilyodromus sp. BOS25	1		
			Cypricercus sp. 422 (CB)	1	1	
	Copepoda	Cyclopidae	*Microcyclops varicans*		1	
			Macrocyclops albidus	1		
			Mesocyclops notius		1	
			Mesocyclops darwini		1	
			Eucyclops australiensis	1	1	
			Paracyclops chiltoni	1	1	
			Australoeucyclops karaytugi		1	
Insecta	Coleoptera	Noteridae	*Neohydrocoptus subfasciatus*	1	1	

Class	Order	Family	Lowest ID	PSW006 Aug 2003	PSW006 May 2005	RCM001 Apr 2008
Insecta	Coleoptera	Dytiscidae	*Hydrovatus rufoniger*			2
			Hydrovatus weiri		1	
			Hyphydrus lyratus	1		
			Hydroglyphus leai	1		
			Hydroglyphus grammopterus (=*trilineatus*)	1		
			Allodessus bistrigatus	1		
			Tiporus tambreyi			1
			Sternopriscus pilbarensis			2
		Dytiscidae	*Cybister tripunctatus*	1		
		Gyrinidae	*Macrogyrus darlingtoni*	1	1	
		Hydrophilidae	*Berosus pulchellus*	1		
			Helochares percyi			1,2
			Helochares tatei	1		
			Paracymus spenceri	1		
		Hydraenidae	*Hydraena barbipes*	1		
			Hydraena sp.			
			Ochthebius sp. K1			2
			Tympanogaster sp.			3
		Scirtidae	Scirtidae sp.	1	1	
		Elmidae	*Austrolimnius* WA sp. 1 (larvae only)	1	1	1
			Austrolimnius WA sp. 4 (larvae only)			1,3
			Austrolimnius WA sp. 3 (larvae only)		1	
			Austrolimnius WA sp. 3 (adult)		1	
			Austrolimnius WA sp. 1 (adult only)			1,3
		Hydrophilidae	*Hydrochus eurypleuron*	1	1	2
		Hydrochidae	*Hydrochus obscuroaeneus*	1		2
	Diptera	Tipulidae	Tipulidae type P1	1		

Class	Order	Family	Lowest ID	PSW006 Aug 2003	PSW006 May 2005	RCM001 Apr 2008
Insecta	Diptera	Culicidae	*Anopheles* (Cellia) sp.		1	
		Ceratopogonidae	*Bezzia* sp.	1	1	1,2,3
			Culicoides sp.		1	1,3
			Nilobezzia sp. P1	1		
			Forcypomyia sp. P1	1		
			Dasyhelea sp.			3
			Dasyheleinae sp. P1	1		
			Dasyheleinae sp. P2	1	1	
		Simuliidae	*Simulium clathrinum*		1	
			Cnephia nr *aurantiacum*	1		
		Simuliidae	Simuliidae			1,3
		Psychodidae	*Psychodinae* sp. 5	1		
		Stratiomyidae	Stratiomyidae	1	1	2
		Chironomidae	*Coelopynia pruinosa*	1		
			Fittkauimyia disparipes	1	1	
			Procladius Pilbara sp. 1	1	1	
			Procladius paludicola P1 (no U-claws)			2
			Ablabesmyia hilli	1		
			Ablabesmyia notabilis	1	1	
			Paramerina sp. A (*parva*?) (SAP)	1	1	
			Paramerina sp. C	1		
			Nilotanypus sp. P1	1		
			Larsia albiceps	1	1	2
			Pentaneurini sp. P1	1	1	
			Pentaneurini sp. P6		1	
			Rheocricotopus sp. P1	1		
			Parakiefferiella? nr *variegatus*	1		

Class	Order	Family	Lowest ID	PSW006 Aug 2003	PSW006 May 2005	RCM001 Apr 2008
Insecta	Diptera	Chironomidae	*Parakiefferiella* sp. P1		1	
			Stictocladius uniserialis			2
			Corynoneura sp.	1		
			Corynoneura sp. P2		1	
			Thienemanniella sp. P1	1		3
			Cricotopus albitarsus			3
			Cladotanytarsus aff K4	1	1	
			Tanytarsus sp. G (SAP)	1		
			Tanytarsus sp. P2	1		
			Tanytarsus sp. P1	1	1	
			Tanytarsus aff K10			3
			Rheotanytarsus sp.	1	1	
			Stenochironomus watsoni	1	1	
			Dicrotendipes 'CA1' Pilbara type 3	1	1	
			Dicrotendipes sp P4		1	
			Dicrotendipes P5 (=*balciunasi*?)		1	
			Dicrotendipes sp. K4			2,3
			Polypedilum watsoni		1	
			Polypedilum nr *vespertinus* (M2) (SAP)	1		
			Polypedilum sp. S1	1		2
			Polypedilum sp. K1	1		
			Cladopelma curtivalva	1		
			Cladopelma sp. P1			2
			Parachironomus 'K2'			2
	Ephemeroptera	Baetidae	*Cloeon* sp.	1		
			Offadens sp.		1	2,3
		Caenidae	*Tasmanocoenis arcuata*	1	1	1,2

Class	Order	Family	Lowest ID	PSW006 Aug 2003	PSW006 May 2005	RCM001 Apr 2008
Insecta	Ephemeroptera	Baetidae	*Wundacaenis dostini*			1,2
	Hemiptera	Mesoveliidae	*Mesovelia vittigera*		1	
		Hebridae	*Merragata hackeri*	1		
		Veliidae	*Veliidae*		1	
		Gerridae	*Limnogonus luctuosus*	1		1,2
			Limnogonus sp.		1	
		Nepidae	*Ranatra diminuta*		1	
		Belostomatidae	*Diplonychus eques*	1		
		Corixidae	*Micronecta* sp.		1	
			Micronecta nsp. P1	1		1,2
		Notonectidae	*Enithares woodwardi*	1	1	
			Anisops hackeri	1	1	
			Anisops sp.			1
		Pleidae	*Paraplea* n. sp. (ANIC 6)	1		
	Lepidoptera	Pyralidae	?*Eoophyla argyrilinale*	1	1	2,3
			Pyralidae Pilbara sp 5	1	1	
	Odonata	Coenagrionidae	*Argiocnemis rubescens*	1		
			Ischnura sp.		1	
			Pseudagrion microcephalum			2
			Xanthagrion erythroneurum			2
		Isostictidae	*Eurysticta coolawanyah*	1		
		Aeshnidae	*Aeshna brevistyla*	1		
			Aeshnidae		1	
		Gomphidae	*Austroepigomphus (Xerogomphus) gordoni*	1	1	
			Austrogomphus mjobergi	1	1	
			Austrogomphus turneri			1,2
		Libellulidae	*Diplacodes haematodes*	1	1	3

Class	Order	Family	Lowest ID	PSW006 Aug 2003	PSW006 May 2005	RCM001 Apr 2008
Insecta	Odonata	Libellulidae	*Orthetrum caledonicum*	1	1	
			Orthetrum pruinosum migratum	1	1	
		Lindeniidae	*Ictinogomphus australis*			1,2
			Ictinogomphus dobsoni	1	1	
		Hemicorduliidae	*Hemicordulia tau*		1	
			Hemicordulia intermedia			1
			Hemicordulia koomina	1		
	Trichoptera	Hydroptilidae	*Hellyethira* sp.	1		1,2
			Orthotrichia sp.	1		
		Philopotamidae	*Chimarra* sp. AV17	1		1,3
		Hydropsychidae	*Cheumatopsyche wellsae*	1		3
			Cheumatopsyche sp. AV3			1
		Polycentropodidae	*Paranyctiophylax* sp. AV5 (KIM-UWA)	1		
		Ecnomidae	*Ecnomina* F group cf. sp. AV16	1		
			Ecnomus pilbarensis			1
		Leptoceridae	*Notalina* sp. AV17			3
			Oecetis sp.			1,3
			Oecetis sp. Pilbara 4	1		
			Oecetis sp. Pilbara 3	1		
			Triplectides ciuskus seductus	1		1,2

* Numbers in the columns on the right indicate habitats in which the taxa were recorded:
  1. Bedrock and Channel
  2. Macrophyte
  3. Riffle - Fortescue Falls

Note: Microinvertebrates were not sampled during the RCM survey in keeping with the rapid assessment methodology employed.

Table 22 – Aquatic invertebrate diversity at Moorimoordinina Pool.

Class	Order	Family	Lowest ID	RCM003 Apr 2008
Arachnida	Acariformes	Unionicolidae	*Neumania* sp.	1
Crustacea	Conchostraca	Cyzicidae	*Caenestheriella packardi*	1,2,3
Insecta	Coleoptera	Haliplidae	*Haliplus* nsp. P1	1,3
		Dytiscidae	Hyphydrus sp.	3
			Hydroglyphus grammopterus (=*trilineatus*)	2
		Hydrophilidae	*Berosus australiae*	3
			Berosus dallasi	2
			Berosus macumbensis	1,2,3
	Diptera	Ceratopogonidae	*Bezzia* sp.	1,2,3
		Chironomidae	*Coelopynia pruinosa*	1,2,3
			Procladius paludicola	1,2,3
			Procladius paludicola P1 (no U-claws)	2
			Tanytarsus fuscithorax/semibarbitarsus	1
			Polypedilum nubifer	1,2,3
	Ephemeroptera	Baetidae	*Cloeon* sp.	1
			Offadens WA sp. 1	2,3
		Caenidae	*Tasmanocoenis* sp. P	1
	Hemiptera	Corixidae	*Micronecta robusta*	3
			Micronecta virgata	3
			Micronecta sp. P6 nr *gracilis*	3
			Micronecta sp. P5	2
	Odonata	Libellulidae	Libellulidae	1
	Trichoptera	Ecnomidae	*Ecnomus pilbarensis*	2

* Numbers in the columns on the right indicate habitats in which the taxa were recorded:
1 - 3 Three replicates of unvegetated clay sediments and water column

Table 23 – Aquatic invertebrate diversity at Lower Fortescue Pool.

Class	Order	Family	Lowest ID	RCM004 Apr 2008
Arachnida	Acariformes	-	Oribatida	1,3
		Arrenuridae	Arrenurus ensifer	2
			Arrenurus purpureus	2
			Arrenurus tripartitus	1,2
			Arrenurus vanderpalae	2
		Hydrachnidae	Hydrachna nr. approximata (SAP)	1
			Australiobates queenslandensis	3
		Limnesiidae	Limnesia maceripalpis	2
			Limnesia parasolida	1,2
		Mideopsidae	Gretacarus nsp. P1 (PSW)	1
		Oxidae	Oxus orientalis	1,2
		Unionicolidae	Koenikea distans	1
			Koenikea sorpresa	1
			Koenikea sp.	2
			Unionicola crassipalpis	2
			Unionicola neoaffinis	2
Bivalvia	Unionida	Hyriidae	Velesunio sp.	1
Crustacea	Decapoda	Atyidae	Caridina indistincta	2
Crustacea	Isopoda	Amphisopodidae	Pilbarophreatoicus platyarthricus	3
Gastropoda	Basommatophora	Planorbidae	Ameriana sp. P3 (cf bonushenricus) (PSW)	2
	Neotaeniglossa	Hydrobiidae	Hydrobiidae sp. P2 (RCM)	3
		Thiaridae	Plotiopsis sp.	3
			Thiaridae sp. P1 (RCM)	3
			d.o.c. Melanoides (stenomelania) tuberculata	2
			Melanoides (Stenomelania) tuberculata	3
Insecta	Coleoptera	Dytiscidae	Batrachomatus wingi	3

Class	Order	Family	Lowest ID	RCM004 Apr 2008
Insecta	Coleoptera	Dytiscidae	Limbodessus compactus	1
		Elmidae	Austrolimnius WA sp. 2 (= adult sp WA 2) (PSW)	1,3
		Elmidae	Austrolimnius WA sp. 4 (adult only not = larvae sp. WA4?) (RCM)	1,3
		Hydrochidae	Hydrochus eurypleuron	1
	Diptera	Ceratopogonidae	Bezzia sp. P1 (PSW)	1,3
			Bezzia sp. P2 (PSW)	3
			Monohelea sp.	1
			Monohelea sp. P1 (PSW)	3
			Nilobezzia sp.	1
			Nilobezzia sp. P1 (PSW)	3
		Chironomidae	Ablabesmyia hilli	1,2
			Cricotopus albitarsus	3
			Dicrotendipes 'CA1' Pilbara type 3 (= 'K4', P3)) (PSW)	1,2,3
			Dicrotendipes sp P4 (PSW)	1
			Harnischia K1 (PSW)	1
			Larsia albiceps	1,2,3
			Paramerina sp.A (parva?) (SAP)	1,2,3
			Polypedilum leei	1,2,3
			Procladius paludicola P1 (no U-claws)	1,2
			Rheotanytarsus sp.	3
			Tanytarsus 'K12' (PSW)	1
			Xenochironomus sp P2 (PSW)	3
		Simuliidae	Cnephia tonnoiri	3
		Tabanidae	Tabanidae	1
	Ephemeroptera	Baetidae	Cloeon sp.	3
		Caenidae	Tasmanocoenis arcuata	1,2,3
			Wundacaenis dostini	1,2

Class	Order	Family	Lowest ID	RCM004 Apr 2008
Insecta	Hemiptera	Pleidae	Paraplea n. sp. (ANIC 6)	1,2
	Lepidoptera	Pyralidae	Pyralidae Pilbara sp 4 (PSW)	2
	Odonata	Coenagrionidae	Pseudagrion microcephalum	2
			Xanthagrion erythroneurum	2
		Gomphidae	Austrogomphus mjobergi	1
		Hemicorduliidae	Hemicordulia intermedia	1
		Isostictidae	Eurysticta coolawanyah	1
	Trichoptera	Ecnomidae	Ecnomus pilbarensis	1,3
		Hydropsychidae	Cheumatopsyche wellsae	3
		Hydroptilidae	Orthotrichia sp.	1,2
		Leptoceridae	Leptocerus sp. AV2 (atsou?) (PSW)	2
			Oecetis sp. Pilbara 4 (PSW)	1,2,3
			Triplectides ciuskus seductus	2
		Polycentropodidae	Paranyctiophylax sp AV5 (KIM-UWA)	3
Oligochaeta	Tubificida	Naididae	Allonais pectinata	1
			Allonais ranauana	2
			Branchiura sowerbyi	1,2,3
			Dero furcata	1
			Pristina longiseta	1,2,3

* Numbers in the columns on the right indicate habitats in which the taxa were recorded:
1. Bare sediment
2. Macrophyte, *Eleocharis*
3. Riffle

Formatted: Danish

Table 24 - Aquatic invertebrate diversity at Palm Pool.

Class	Order	Family	Lowest ID	PSW010 Aug 2003	PSW010 May 2005	RCM005 Apr 2008
Lobosea	-	-	Ciliate P1		1	
	Arcellinida	Centropyxidae	*Centropyxis* sp.		1	
	Euglyphida	Euglyphiidae	*Euglypha* sp.	1		
Desmospongiae	-	Spongillidae	Spongillidae		1	
Hydrozoa	-	Hydridae	*Hydra* sp.		1	
Turbellaria	-	-	Turbellaria	1		
	-	-	Microturbellaria	1	1	
Nemertini	-	-	Nemertini	1	1	
Nematoda	-	-	Nematoda			3
	-	-	Nematoda sp. P1 (PSW)	1		
	-	-	Nematoda sp. P2/P4 (PSW)	1		
	-	-	Nematoda sp. P3 (PSW)	1		
	-	-	Nematoda sp. P6 (PSW)		1	
Rotifera	Bdelloidea	-	Bdelloidea sp. 2:2	1	1	
	Ploimida	Brachionidae	*Platyias quadricornis*	1		
		Lepadellidae	*Colurella* sp.	1	1	
			Lepadella ovalis	1		
		Euchlanidae	*Euchlanis dilatata*	1		
		Lecanidae	*Lecane batillifer*	1		
			Lecane bulla	1	1	
			Lecane hornemanni		1	
			Lecane obtusa		1	
			Lecane ruttneri	1		
			Lecane stenroosi		1	
			Lecane subulata	1		
			Lecane thalera		1	

Class	Order	Family	Lowest ID	PSW010 Aug 2003	PSW010 May 2005	RCM005 Apr 2008
Rotifera	Ploimida	Lecanidae	*Lecane* cf. *clara* (PSW)	1		
		Mytilinidae	*Mytilina ventralis macracantha*		1	
		Synchaetidae	*Synchaeta oblonga*	1		
		Trichotriidae	*Macrochaetus altamirai*		1	
			Macrochaetus subquadratus	1		
Gastropoda	Neotaeniglossa	Thiaridae	*Plotiopsis australis*	1	1	1,2
			Sermyla retracta	1	1	1,2
			Melanoides (*Stenomelania*) *tuberculata*	1		1
		Assiminaeidae	*Aviassiminea palitans*	1	1	2
	Basommatophora	Lymnaeidae	*Austropeplea vinosa*	1	1	
		Ancylidae	*Ferrissia* sp.		1	
		Planorbidae	*Gyraulus hesperus*	1	1	1,2
	Veneroida	Corbiculidae	*Corbicula* sp.	1	1	1,2,3
Oligochaeta	Tubificida	Naididae	*Nais variabilis*	1		
			Dero nivea			1
			Dero furcata			1
			Allonais pectinata		1	
			Pristina longiseta	1	1	
			Pristina aequiseta	1		
			Chaetogaster diastrophus	1		
			Naididae (ex Tubificidae)			2
Arachnida	Acariformes	Hydrachnidae	*Hydrachna* sp.	1		
		Limnocharidae	*Limnochares australica*	1		
		Hydryphantidae	*Diplodontus* sp.	1		
		Hydrodromidae	*Hydrodroma* sp.		1	3
		Limnesiidae	*Limnesia parasolida*			1
		Hygrobatidae	*Australiobates* sp. P4 (PSW)		1	2

Class	Order	Family	Lowest ID	PSW010 Aug 2003	PSW010 May 2005	RCM005 Apr 2008
Arachnida	Acariformes	Hygrobatidae	*Coaustraliobates minor*			1,2
			Procorticacarus P2/Groonabates P2 (PSW)			2
			Procorticacarus P3 (RCM)			2
		Unionicolidae	*Koenikea* sp. 2/3 (Pilbara) (PSW)	1	1	1,3
			Unionicola crassipalpis		1	1,3
			Unionicola neoaffinis	1	1	1,3
		Aturidae	*Albia rectifrons*			1,3
			Axonopsella sp.		1	
		Momoniidae	*Momoniella* nr *australica*	1		1,3
		Mideopsidae	*Gretacarus* sp. P2 (nr oldus) (PSW)			2,3
		Arrenuridae	*Arrenurus purpureus*	1	1	
			Arrenurus sp. 9 (nr *pseudaffinis*) (PSW)	1	1	3
	Acariformes	-	Oribatida			1,2,3
		-	Oribatida group 1 (PSS)	1		
		-	Trombidioidea		1	
		-	Oribatida group 5 (PSS)	1	1	
		-	Oribatida sp. 4 (PSW)	1		
Crustacea	Cladocera	Sididae	*Latonopsis australis*		1	
		Chydoridae	*Alona clathrata*		1	
			Alona rigidicaudis		1	
			Alona cf. *verrucosa*	1		
			Dunhevedia crassa	1		
			Armatalona macrocopa	1		
		Daphniidae	*Ceriodaphnia cornuta*		1	
			Simocephalus heilongjiangensis		1	
	Ostracoda	Limnocytheridae	*Limnocythere dorsosicula*	1	1	
		Darwinulidae	*Darwinula stevensoni*	1		

Class	Order	Family	Lowest ID	PSW010 Aug 2003	PSW010 May 2005	RCM005 Apr 2008
Crustacea	Ostracoda	Darwinulidae	*Vestalenula marmonieri*	1	1	
		Candonidae	*Candonopsis tenuis*		1	
		Cyprididae	*Cypretta* sp. PSW074		1	
			Cypretta sp. BOS18		1	
			Ilyodromus viridulus		1	
			Ilyodromus sp. BOS25	1		
			Plesiocypridopsis sp.	1		
		Cypridopsidae	*Cypridopsis* sp.	1		
	Copepoda	Diaptomidae	*Eudiaptomus lumholtzi*		1	
			Diaptomidae	1		
		Cyclopidae	*Microcyclops varicans*	1		
			Ectocyclops rubrescens		1	
			Mesocyclops notius		1	
			Mesocyclops brooksi		1	
			Mesocyclops darwini	1	1	
			Paracyclops sp. 6 (PSW)	1	1	
		Diosaccidae	*Schizopera weelumurra*	1		
	Decapoda	Atyidae	*Caridina indistincta*	1	1	1,2,3
Insecta	Coleoptera	Dytiscidae	*Laccophilus sharpi*	1		
			Hydrovatus sp.	1	1	
			Bidessodes denticulatus		1	1,2
			Hydroglyphus leai	1	1	
			Limbodessus compactus	1		
			Tiporus tambreyi	1	1	
			Sternopriscus sp.	1		
			Necterosoma regulare	1		
			Onychohydrus sp.	1		

Class	Order	Family	Lowest ID	PSW010 Aug 2003	PSW010 May 2005	RCM005 Apr 2008
Insecta	Coleoptera	Gyrinidae	*Macrogyrus darlingtoni*	1	1	
			Macrogyrus gibbosus	1		
			Gyrinidae			3
		Hydrophilidae	*Regimbartia attenuata*	1		
			Paranacaena horni		1	
			Enochrus elongatus	1		
			Helochares tatei	1	1	
			Paracymus spenceri	1		
			Cercyon sp.		1	
			Unknown hydrophillid P1 (PSW)		1	
		Hydraenidae	*Hydraena barbipes*	1		
			Hydraena nr *rudallensis* (PSW)	1		
			Ochthebius sp. P4 (PSW)		1	
		Scirtidae	*Scirtidae* sp.		1	
		Elmidae	*Austrolimnius* WA sp. 1 (larvae only) (PSW)	1		
			Austrolimnius WA sp. 2 (= adult sp WA 2) (PSW)			1
			Coxelmis v.fasciatus	1	1	1,2
		Limnichidae	Limnichidae sp. P3		1	
		Hydrochidae	*Hydrochus burdekinensis*	1		
			Hydrochus eurypleuron	1	1	1
			Hydrochus interioris		1	
			Hydrochus obscuroaeneus		1	1,3
			Hydrochus sp.	1		
			Hydrochus sp. P2 (RCM)			2
	Diptera	Tipulidae	Tipulidae	1	1	2
		Culicidae	*Anopheles annulipes* s.l.	1	1	
			Aedeomyia catasticta	1		

Class	Order	Family	Lowest ID	PSW010 Aug 2003	PSW010 May 2005	RCM005 Apr 2008
Insecta	Diptera	Culicidae	*Culex* (*Culex*) *annulirostris*		1	
			Culex crinicauda		1	
		Ceratopogonidae	*Alluaudomyia* sp.	1		
			Bezzia sp.			1,2,3
			Bezzia sp. P1 (PSW)	1		
			Bezzia sp. P2 (PSW)	1	1	
			Monohelea sp. P1 (PSW)	1	1	
			Forcypomyia sp. P2 (PSW)	1		
			Forcypomyia sp. P4 (PSW)		1	
			Dasyheleinae sp. P1 (PSW)	1	1	
			Dasyheleinae sp. P2 (PSW)	1	1	
		Simuliidae	*Cnephia tonnoiri*		1	
			Simuliidae			2
		Stratiomyidae	*Stratiomyidae*	1		2
		Empididae	*Empididae*	1		
		Ephydridae	*Ephydridae* sp. 6 (SAP)	1		
		Muscidae	Muscidae	1	1	
		Chironomidae	*Coelopynia pruinosa*	1		1
			Fittkauimyia disparipes			1
			Procladius Pilbara sp. 1 (PSW)	1		1
			Ablabesmyia notabilis	1		3
			Paramerina sp. A (*parva*?) (SAP)	1		
			Thienemannimyia sp.			2
			Larsia albiceps	1		1,2,3
			Rheocricotopus sp. P1 (PSW)	1		2
			Nanocladius sp. 1 (VCD7)		1	
			Corynoneura sp. P1 (PSW)	1		

Class	Order	Family	Lowest ID	PSW010 Aug 2003	PSW010 May 2005	RCM005 Apr 2008
Insecta	Diptera	Chironomidae	*Corynoneura* sp. P2 (PSW)		1	
			Corynoneura sp.			2
			Thienemanniella sp. P1 (PSW)	1		2
			Parametriocnemus ornaticornis	1		
			Cricotopus albitarsus	1	1	
			Tanytarsus fuscithorax/semibarbitarsus		1	1
			Tanytarsus richardsi			3
			Tanytarsus sp. D (SAP)	1	1	
			Tanytarsus sp. P3 (PSW)	1		
			Tanytarsus sp. P2 (PSW)		1	
			Tanytarsus sp. P1 (PSW)		1	
			Rheotanytarsus sp.	1	1	1,2,3
			Stenochironomus watsoni			1,2,3
			Chironomus aff. *alternans* (V24) (CB)	1		
			Dicrotendipes 'CA1' Pilbara type 3 (= 'K4', P3)) (PSW)	1	1	3
			Dicrotendipes sp. P4 (PSW)			2
			Polypedilum leei			3
			Polypedilum watsoni			1,2
			Polypedilum nr *vespertinus* (M2) (SAP)	1	1	2
			Polypedilum sp. K1 (PSW)			1
			Paratendipes sp. 'K1' (PSW)	1		
	Ephemeroptera	Baetidae	*Cloeon* sp.		1	1,2,3
			Cloeon sp. P1 (PSW)	1		
			Pseudocloeon hypodelum (ex Baetid genus3 WA sp. 2) (PSW)	1	1	
			Offadens (ex genus 1) *soror* (ex WA sp. 1) (PSW)			3
		Leptophlebiidae	Leptophlebiidae	1		
		Caenidae	*Tasmanocoenis arcuata*	1	1	

Class	Order	Family	Lowest ID	PSW010 Aug 2003	PSW010 May 2005	RCM005 Apr 2008
Insecta	Ephemeroptera	Caenidae	*Tasmanocoenis* sp. P (PSW)			1,3
			Tasmanocoenis sp. E (PSW)	1	1	
			Wundacaenis dostini	1		2
	Hemiptera	Mesoveliidae	*Mesovelia vittigera*		1	
		Hebridae	*Merragata hackeri*	1	1	
		Veliidae	*Microvelia* (*Austromicrovelia*) *peramoena*		1	
			Veliidae	1		
		Gerridae	*Rhagadotarsus anomalus*		1	
			Limnogonus fossarum gilguy		1	
			Limnogonus luctuosus	1		1
		Nepidae	*Ranatra diminuta*	1		
		Belostomatidae	*Diplonychus eques*	1	1	
		Ochteridae	*Ochterus* nr *eurythorax*		1	
		Corixidae	*Micronecta micra* (ex P2)		1	
		Naucoridae	*Naucoris subaureus*	1		1
			Naucoris sp.			3
		Pleidae	*Paraplea* n. sp. (ANIC 6)	1	1	1
	Lepidoptera	Pyralidae	*Pyralidae* sp. 45 of JHH (PSW) (= *Margarosticha ?euprepialis*)	1	1	3
			Pyralidae sp. 3 of JHH (PSW) (= *Margarosticha ?repetitalis*)	1		
			Pyralidae nr sp. 36 of JHH (RCM)			1
	Odonata	Coenagrionidae	*Argiocnemis rubescens*	1	1	
			Ischnura aurora aurora	1		
			Ischnura sp.	1		3
			Pseudagrion aureofrons			1,2,3
			Pseudagrion microcephalum	1	1	1
			Austroagrion pindrina/Ischnura heterosticta	1		
		Isostictidae	*Eurysticta coolawanyah*			3

Class	Order	Family	Lowest ID	PSW010 Aug 2003	PSW010 May 2005	RCM005 Apr 2008
Insecta	Odonata	Protoneuridae	*Nososticta baroalba*		1	
			Nososticta pilbara	1		1
		Aeshnidae	Aeshnidae	1	1	
		Gomphidae	*Austroepigomphus (Xerogomphus) gordoni*	1		
			Austrogomphus sp.	1	1	1,2,3
		Libellulidae	*Crocothemis nigrifrons*	1		
			Diplacodes haematodes	1		
			Nannodiplax sp.			2
		Urothemistidae	*Macrodiplax cora*		1	3
	Trichoptera	Hydroptilidae	*Hellyethira* sp. 1 (PSW)	1		
			Hellyethira sp. 2 (PSW)	1		
			Orthotrichia sp.		1	3
		Hydropsychidae	*Cheumatopsyche wellsae*		1	3
		Polycentropodidae	*Paranyctiophylax* sp. AV5 (KIM-UWA)	1	1	
		Ecnomidae	*Ecnomus pilbarensis*	1		
			Ecnomus sp. AV16 (PSW)	1		2
		Leptoceridae	*Leptocerus* sp. AV2 (*atsou*?) (PSW)	1		
			Notalina sp. AV17 (RCM)			3
			Oecetis sp.			1,3
			Oecetis sp. Pilbara 2 (PSW)	1		
			Oecetis sp. Pilbara 1 (PSW)	1		
			Oecetis sp. Pilbara 3 (PSW)	1		
			Triaenodes sp. P3 (RCM)			2
			Triplectides ciuskus seductus	1	1	1,2,3

Note: Shading indicates microinvertebrates, which were not collected during the RCM survey in keeping with the rapid assessment methodology employed by the survey.
* Numbers in the columns on the right indicate habitats in which the taxa were recorded:

1. Macrophyte: Emergent macrophytes on eastern side of road crossing in flowing water
2. Submerged macrophytes along northern bank
3. Submerged macrophytes along southern bank

Formatted: Danish