Department of
Environment and Conservation
Our environment, our future

Resource Condition Report for a Significant Western Australian Wetland

Lake Eda

2009

Figure 1 – A view across the water body at Lake Eda.

This report was prepared by:

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

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

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 3 (August 2009)

Suggested Citation:

DEC (2009) *Resource Condition Report for Significant Western Australian Wetland: Lake Eda.* Prepared for Inland Aquatic Integrity Resource Condition Monitoring (IAI RCM) Project. 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 Lake Eda, a near-permanent freshwater lake on the Roebuck Plains. The Roebuck Plains is an extensive floodplain that contains several different types of wetland, including seasonally flooded grassland, permanent freshwater lakes and seasonal/intermittent freshwater lakes and marshes. The entire floodplain is inundated once every five to ten years, but the relative permanence of Lake Eda makes it an important waterbird refuge in the southern Kimberley (Morton *et al.* Undated). Lake Eda was selected as a study site in the current project because of its significance to migratory waterbird populations and as a refuge for non-migratory taxa during periods of aridity.

1.1. Site Code

Directory of Important Wetlands in Australia: WA021 (Roebuck Plains system)

Register of the National Estate 'Registered' Place ID: 17321

Inland Aquatic Integrity Resource Condition Monitoring Project: RCM009 (plant specimens K2)

Transect Codes: RCM009-RQ1
RCM009-AQ1

1.2. Purpose of Resource Condition Report

The objective of the RCR is to summarise of all available ecological information relevant to Lake Eda and describe the key drivers of, and threats to, the system. This 'snapshot' of ecological character will provide context for future monitoring of the site and allow the effectiveness of management planning and actions to be gauged.

1.3. Relevant International Agreements and Legislation

This section provides a summary of international agreements and important pieces of legislation that are relevant to the management of Lake Eda.

International Agreements

Migratory bird bilateral agreements and conventions

Australia is party to a number of bilateral agreements, initiatives and conventions for the conservation of migratory birds that are relevant to Lake Eda. 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; and

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. Three of them are applicable to Lake Eda. These are:

- wetlands of international importance ('Ramsar' wetlands);
- nationally threatened species and ecological communities; and
- migratory species listed under international treaties JAMBA, CAMBA and CMS.

The EPBC Act regulates actions that will have or are likely to have a significant impact on any matter of national environmental significance. Such actions are subject to environmental assessment and approval under the EPBC Act. An 'action' includes a project, a development, an undertaking, or an activity or series of activities (http://www.environment.gov.au/epbc/index.html).

Western Australian legislation

Wildlife Conservation Act 1950

This Act provides for the protection of wildlife. All fauna (animals native to Australia) in Western Australia is protected under section 14 and all flora (plants native to Western Australia) are protected under section 23 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.

Aboriginal Heritage Act 1972

The purpose of this Act is to protect Aboriginal remains, relics and sites from undue interference, and to recognise the legitimate pursuit of Aboriginal customs and traditions. Under the Act, it is an offence for a person to excavate, destroy, damage or alter any Aboriginal site. The Act applies to all objects which are of sacred, ritual or ceremonial significance to persons of Aboriginal descent, or which are or were used for any purpose connected with the traditional cultural life of the Aboriginal people and the places where such objects are found. It also protects any sacred, ritual or ceremonial site, which is of importance and special significance to persons of Aboriginal descent. Finally, the Act states that, where a representative body of persons of Aboriginal descent who usually live subject to Aboriginal customary law has an interest in a place, that place shall be available to that body for purposes sanctioned by the Aboriginal tradition relevant to that place.

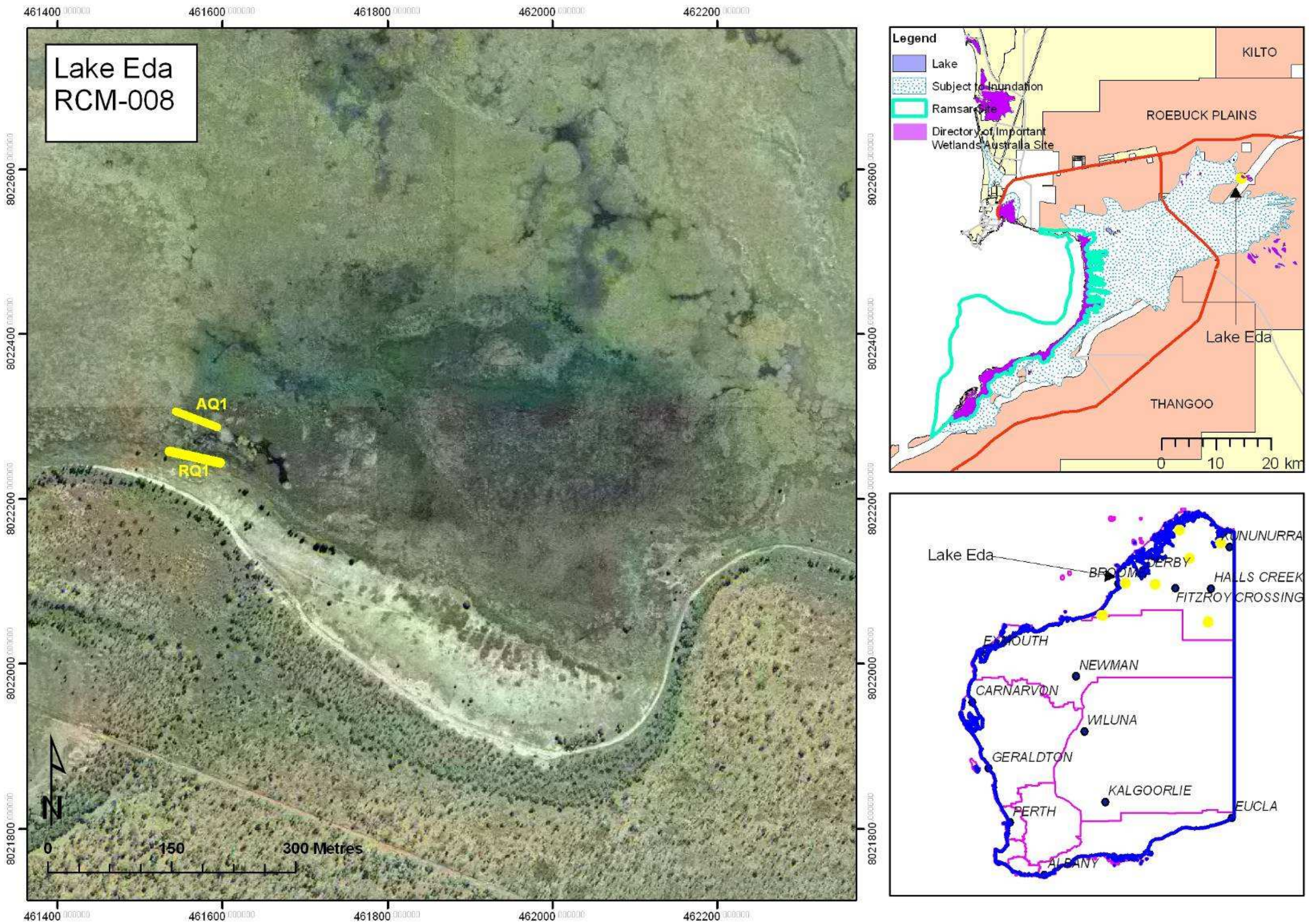

Figure 2 – Aerial photograph showing the location of the riparian (RCM009-RQ1) and aquatic (RCM009-AQ1) vegetation transects at Lake Eda. Water quality and aquatic invertebrate samples were collected immediately adjacent to the vegetation transects. The upper insert shows the location of the Roebuck Bay Ramsar site. The lower insert shows the location of Lake Eda in relation to other IAI RCM sites in the Kimberley and its location in the state of Western Australia. Department of Environment and Conservation regional boundaries are shown in pink.

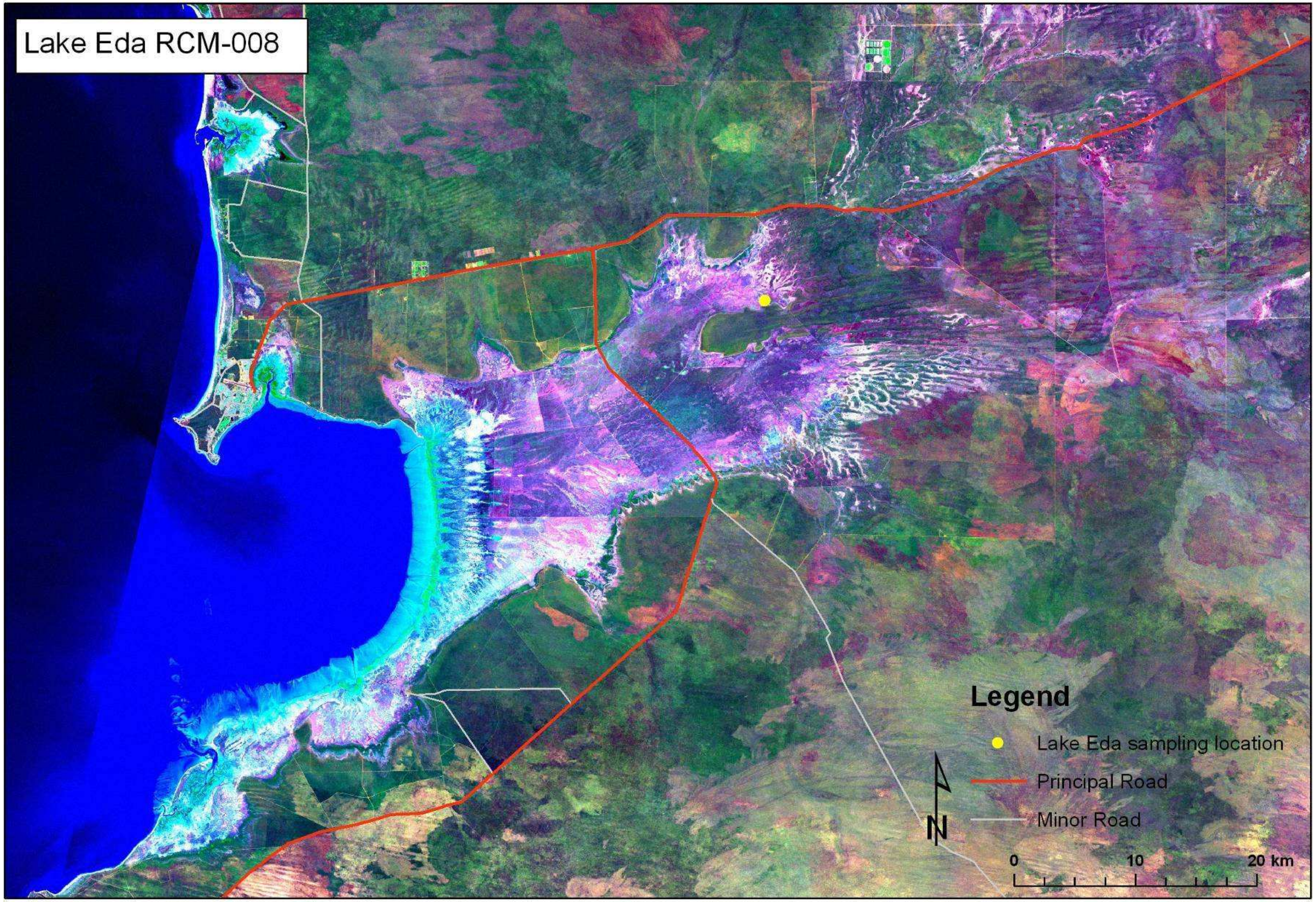

Figure 3 – Satellite image of the Roebuck Plains showing the location of the Lake Eda sampling site.

2. Overview of Lake Eda

2.1. Location and Cadastral Information

Lake Eda lies approximately 40 km east of Broome on the south side of the Great Northern Highway. Lake Eda represents the north-eastern extent of the Roebuck Plains, an area subject to periodic inundation that extends approximately 70 km to the southwest. This extensive floodplain meets the coast at Roebuck Bay, one of the state's most significant shorebird stopovers (Figure 2).

Lake Eda is largely contained within the Roebuck Plains pastoral lease. The eastern portion of the lake is within an unnamed crown reserve that was gazetted for the purpose of a stock route and stock watering place.

Access to Lake Eda is through Roebuck Plains Station and landholder permission is required to enter the area. Roebuck Plains is an active cattle pastoral lease, although Lake Eda is fenced to exclude stock.

2.2. IBRA Region

Lake Eda lies within the Pindanland subregion of the Dampierland Interim Biogeographic Regionalisation of Australia (IBRA) region. This is the coastal, semi-arid, north-western margin of the Canning Basin. It is characterised as a fine-textured sand-sheet with subdued dunes and includes the paleodelta of the Fitzroy River (Graham 2001).

The vegetation is described primarily as pindan (Graham 2001). This is an association of scattered eucalypts over tall shrubs of *Acacia eriopoda*, *A. tumida*, *A. monticola*, *Grevillea wickhamii* and *G. refracta*. The understorey contains herbs and grasses. Pindan usually grows on red, sandy soils with high clay content (Start, Undated).

2.3. Climate

The nearest Bureau of Meteorology weather station to Lake Eda is at Broome, where records have been kept since 1939 (Bureau of Meteorology 2009). Climatic conditions at Lake Eda would not differ appreciably from those at Broome, as the two sites are only 40 km apart.

Broome experiences a monsoonal climate. It receives a mean annual rainfall of 602 mm with approximately 85% of that falling between December and March (Figure 4). Rainfall in the area is strongly influenced by cyclonic activity, resulting in a large degree of variability. For instance, total annual rainfall has ranged from 132 mm in 1992 to 1497 mm in 2000. Annual evaporation at Broome airport is 2774 mm. Mean maxima and minima at are 33.9ºC/25.4ºC in March and 28.8ºC/12.4ºC in July.

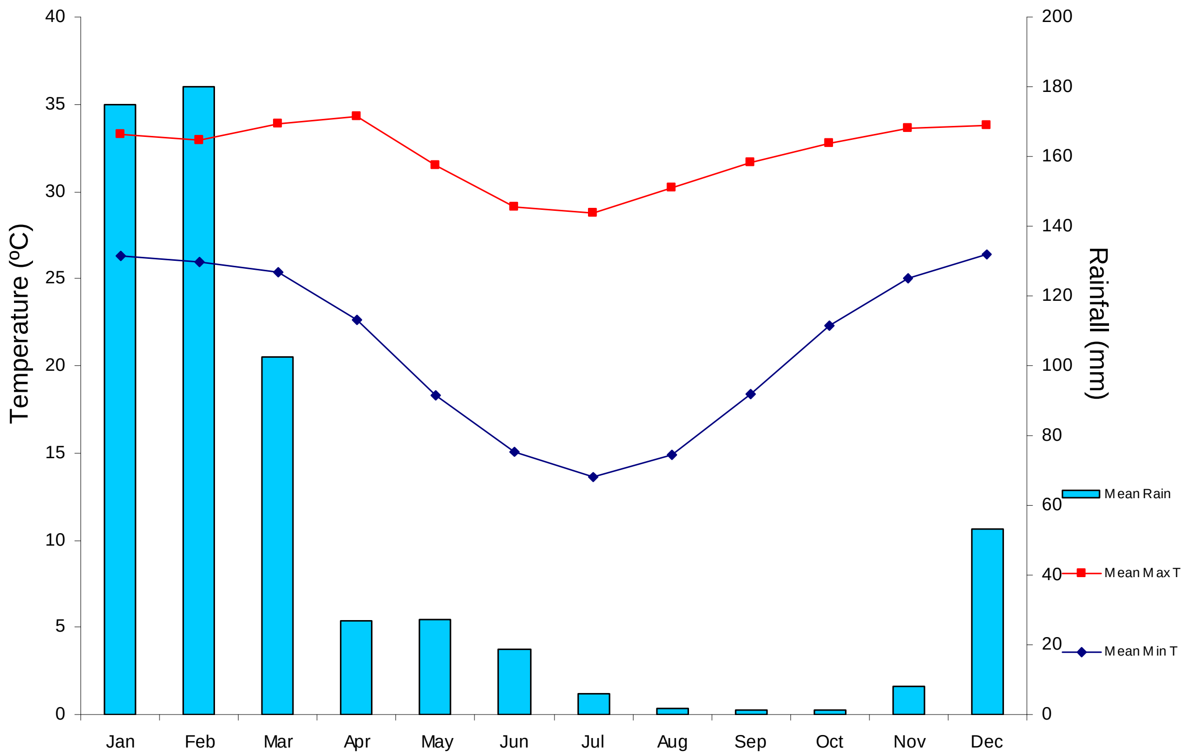

Figure 4 – Climatic averages for Broome Airport, approximately 40 km west of Lake Eda.

Lake Eda was surveyed by the IAI RCM project on the 17th of May 2008. In the twelve months preceding the survey, Broome received 485 mm of rain. The majority of this (283 mm) fell in February, with very little rainfall recorded after the end of March 2007.

2.4. Wetland Type

Lake Eda is a permanent, or near-permanent, freshwater lake (type B5 in the *Directory of Important Wetlands in Australia)*. It lies within a megascale irregular floodplain that includes several mesoscale irregular lakes/sumplands and numerous leptoscale irregular creeks. Mesoscale round/ovoid sumplands are also connected to the plain. Small marshes occur on the southeast of the plain at two (artificial) artesian bore drains (Jaensch 1992).

2.5. *Directory of Important Wetlands in Australia* Criteria

Lake Eda is designated as a wetland of national importance under criteria 1, 2, 3, 4 and 6 of the *Directory of Important Wetlands in Australia*. These criteria are as follows:

- Criterion 1: The wetland is a good example of a wetland type occurring within a biogeographic region in Australia.

  Lake Eda is a good example of a major freshwater floodplain of the bioregion, lacking substantial riverine inflow.

- Criterion 2: The wetland plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex.

  Lake Eda contributes to the ecology and hydrology of the Roebuck Plains wetland system.

- Criterion 3: The wetland 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.

  *Lake Eda is a significant drought refuge area for waterbirds in the bioregion. It is an internationally important migration stopover area for Little Curlew (*Numenius minutus*) and Oriental Pratincole (*Glareola maldivarum*).*

- Criterion 4: The wetland supports 1% or more of the national populations of any native plant or animal taxa.

  *Lake Eda has been known to support significant waterbird species, including Painted Snipe (*Rostratula benghalensis*), Freckled Duck (*Stictonetta naevosa*), Garganey (*Anas querquedula*) Pectoral Sandpiper (*Calidris melanotos*), Long-toed Stint (*Calidris subminuta*), White-browed Crake (*Poliolimnas cinereus*) and Green Pygmy Goose (*Nettapus pulchella*).*

- Criterion 6: The wetland is of outstanding historical or cultural significance.

  Lake Eda is of cultural significance to the Yuwuru language group.

2.6. Values of Lake Eda

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 it. 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 'bushtucker'. Local Aboriginal people, belonging to the Yuwuru language group, evidently value the consumptive use of Lake Eda (Iddarr Buru in the local dialect). Photographs on the webpage of the Rarrdjali Yawuru Aboriginal Corporation show Aboriginal people fishing and gathering traditional foods at the lake (Anugraha Undated).

b. Productive use

Productive use values are derived from market transactions involving products derived from the natural environment. For example, the same firewood that is collected for personal use may be exchanged for money or another commodity. The use of Lake Eda as a source of fresh water 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 pastoral enterprise.

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. Lake Eda may support endemic or rare taxa. Such unique features would increase the potential for future opportunities to present.

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. Lake Eda, in itself, would make a relatively small contribution to the ecosystem services delivered by the broader Roebuck Floodplain. However, the presence of near-permanent fresh water in the lake is certain to deliver benefit to associated ecosystems.

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. It is difficult to quantify the amenity value of a site such as Lake Eda, but it is certainly valued by the local community for the amenity it provides.

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 are also ‘control’ sites that allow us to benchmark other, altered habitats. Lake Eda is a relatively unmodified freshwater wetland 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, photography, etc.). Recreation may deliver economic benefit derived from tourism and also delivers spiritual and physical health benefits to the recreator. Lake Eda is used by the local community as a recreation site. There is anecdotal evidence of its use for fishing, canoeing and bird watching.

h. Spiritual/philosophical values

People’s spiritual and philosophical reasons for valuing 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. Lake Eda is of cultural significance to the local Aboriginal people. Permanent, fresh water in an otherwise arid region is an important resource and the lake and its surrounds were probably utilised by Aboriginal people historically. It is certainly used by indigenous groups today (the Yuwuru language group).

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, Lake Eda forms part of an active pastoral lease, and may be esteemed by the lessees for its productive values. These conflicting value sets should be considered when attempting to implement conservation management at the site.

3. Critical Components and Processes of the Ecology of Lake Eda

The primary objective of the Lake Eda Resource Condition Report (RCR) is to identify, describe and quantify the critical components and drivers of the wetland's natural environment. 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 results of the 2008 Inland Aquatic Integrity Resource Condition Monitoring (IAI RCM) survey is shown in Table 1. This is followed by a more detailed description of results of that survey, as well as of any previous studies conducted on the wetland. This information is used to identify the critical ecosystem components at Lake Eda.

Table 1 – Summary of critical ecosystem components at Lake Eda.

Component	Summary Description
Geomorphology	Mesoscale irregular lake within a floodplain of black cracking clay of marine, aeolian and alluvial origins
Hydrology	Surface inflow from Deep Creek, originating 40 km north-northeast, and numerous unnamed creeks; outflow to Taylor's Lagoon (within Roebuck Plain) via an unnamed creek; groundwater interactions are unknown
Water Quality	Fresh (675 mS/m), alkaline (pH 10.22), low nitrogen and phosphorous concentrations, low turbidity and colour
Benthic Plants	Dense *Chara* sp. with emergent *Eleocharis spiralis*
Littoral Vegetation	Dominated by *Eleocharis spiralis* with significant cover of the weed *Phyla nodiflora* var. *nodiflora*
Invertebrates	65 species from 39 families collected
Birds	Important habitat for 5 significant species and breeding area for 7 waterbird species
Terrestrial Vertebrates	None surveyed

3.1. Geology and Soils

Lake Eda lies on Permian and Triassic sandstone, siltstone and shale of the Fitzroy Trough in the Canning Basin. This geology is overlain by self-mulching cracking clays and red/brown non-cracking clays on the alluvial plains, along with yellow sandy earths and some loamy duplexes (Tille 2006). Sediments collected from the lake were almost entirely gravel (54%) and sand (36%), with some clay and silt (10%).

3.2. Hydrology

The Roebuck Plains is a broad floodplain that experiences intermittent inundation (once every five to ten years) following periods of heavy rain. It is also prone to partial seawater inundation along the western margin during spring tides, storm surges and tropical cyclones. The main inflow of fresh water comes from Deep Creek (part of Roebuck Plain), which enters Lake Eda from the northeast. Several other smaller creeks also discharge onto the floodplain during wet periods. During flow events, water is discharged from Lake Eda via an unnamed creek to Taylor's Lagoon. Lake Eda may be several metres deep when full, but dries to a shallow pond during the dry season. There is no documented study of the interaction of groundwater with this system.

3.3. Water Quality

Lake Eda has very high quality water with relatively low nutrient and chlorophyll concentrations. The water is fresh, very alkaline and has low colour and turbidity (Table 2).

Table 2 – Water quality parameters recorded at Lake Eda by the IAI RCM survey.

	RCM0009 May 2008
pH	10.22
Alkalinity (mg/L)	80
TDS (g/L)	0.33
Turbidity (NTU)	7.4
Colour (TCU)	35
Total nitrogen (ug/L)	810
Total phosphorus (ug/L)	20
Total soluble nitrogen (ug/L)	800
Total soluble phosphorus (ug/L)	5
Chlorophyll (ug/L)	2
Na (mg/L)	82.4
Mg (mg/L)	12.8
Ca (mg/L)	16
K (mg/L)	6.3
Cl (mg/L)	128
SO_4 (mg/L)	4.2
HCO_3 (mg/L)	37
CO_3 (mg/L)	30

3.4. Vegetation

The Roebuck Plains are primarily extensive grasslands of *Sporobolus virginicus, Eragrostis dielsii, Nerochloa barbata, Enneapogon planifolius* and *Triraphis mollis.* The grassland corresponds to the area that is subject to periodic inundation (Figure 6).

Lake Eda lies on the landward side of the floodplain. The terrestrial 'pindan' association begins on the southeast margin of the lake. That association has *Eucalyptus tectifica* and *E. grandifolia* trees over *Acacia tumida, A. holosericea, Dolichandrone heterophylla, Gardenia keartlandii* and *Grevillea refracta* shrubs and *Triodia bitextura, Chrysopogon* sp. hummock and tussock grasses (Figure 5).

Two vegetation transects, composed of sequential 5m x 5m quadrats, were established at Lake Eda. One of these was within the grasses and sedges that cover the lake floor during dry periods (Figure 7 and Table 3). This was the riparian zone at the time of the site visit, although it would be inundated during the wet season. The second transect was an aquatic transect (Figure 8 and Table 4).

Figure 5 – The beginning of the 'pindan' vegetation to the south of Lake Eda.

Figure 6 – The southern margin of Lake Eda, looking northwest (left) and northeast (right).

The riparian zone at Lake Eda was densely vegetated with *Eleocharis spiralis* and the exotic herb *Phyla nodiflora* var. *nodiflora*. Another exotic, *Cynodon dactylon*, was also a significant component of the vegetation. Emergent *Sesbania erubescens* were present only occasionally in the riparian zone, but were much more abundant in wet areas of the lake.

Table 3 – Plant data from the riparian quadrats established at Lake Eda.

Species	**Quadrat (m) / % layer cover**							
	0-5	**5-10**	**10-15**	**15-20**	**20-25**	**25-30**	**30-35**	**35-40**
Eleocharis spiralis	95	90	90	90	80	50	45	75
* *Phyla nodiflora* var. *nodiflora*	5	10	10	10	20	50	30	10
Crushed sedge (*E. spiralis*?)	30	30	40	40	40	50	20	10
Sesbania erubescens	0	0	0	0	0	2	0	2
* *Cynodon dactylon*	0	0	0	10	10	10	25	25
Unidentified grass	0	0	0	0	0	0	2	15
Bare soil	0	0	0	0	0	0	0	5

* Exotic species

Figure 7 – Vegetation of the riparian transect at Lake Eda.

The aquatic zone of Lake Eda was also dominated by *Eleocharis spiralis* with a smaller component of *Phyla nodiflora* var. *nodiflora*. *Sesbania erubescens* was present on the transect in small numbers, but appeared to grow much more densely further from the lakeshore. Total canopy cover varied significantly with water depth and level of disturbance, ranging from 95% to just 20%. The water column was dense with *Chara*. This was not identified to species level and it was unclear if one or two species were present.

Table 4 – Plant data from the aquatic quadrats established at Lake Eda.

Species	**Quadrat (m) / % layer cover**									
	0-5	**5-10**	**10-15**	**15-20**	**20-25**	**25-30**	**30-35**	**35-40**	**40- 45**	**45- 50**
Eleocharis spiralis	95	95	30	30	10	10	90	80	80	80
Phyla nodiflora var. *nodiflora*	5	5	5	5	5	5	30	30	30	30
Chara sp.	30	30	60	60	30	30	70	50	50	50
Chara sp.	70	70	70	70	100	100	30	50	50	50
Sesbania erubescens	1	1	5	5	1	1	0	0	0	0
Exposed water	10	10	30	30	80	80	5	5	5	5

Figure 8 – Vegetation of the aquatic transect at Lake Eda.

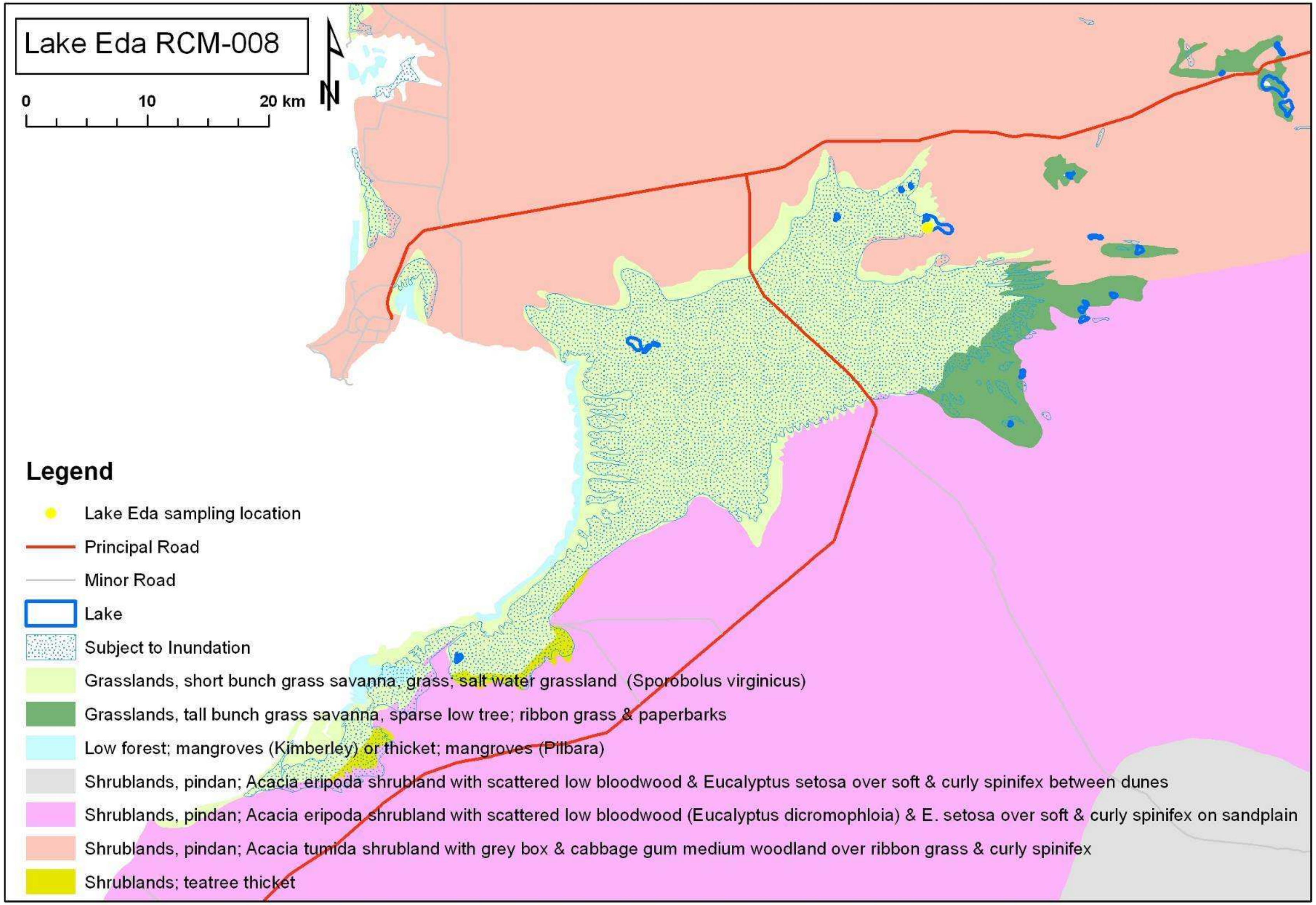

Figure 9 – Vegetation System Association mapping of the Roebuck Plains.

3.5. Aquatic Invertebrates

At the time of sampling, Lake Eda had a high diversity of macroinvertebrates and good representation of taxonomic groups, with a total of 69 species belonging to 35 families. This reflects good water quality and an abundance of macrophytes.

Several taxa were recorded that did not seem to fit known described species and may be new. However, for the present, taxonomic impediments and a lack of survey data for the Kimberley region prevent much further discussion of these. Of particular note are some of the beetles such as "*Hydroglyphus* ?n. sp. K4" and the water boatman "Micronecta K1". Also of note is "*Haliplus* n. sp. P1", which is otherwise known only from the middle to upper Fortescue Valley in the Pilbara. A complete list of taxa collected is shown below.

Table 5 – Invertebrate taxa collected from Lake Eda in May 2008.

Class	Order	Family	Lowest ID	Sample*
Nematoda	-	-	Nematoda	1,2
Gastropoda	Neotaeniglossa	Bithynidae	*Gabbia* sp. K1 (RCM)	3
	Basommatophora	Planorbidae	*Gyraulus* sp.	2,3
Hirudinea	Arhynchobdellida	Richardsonianidae	Richardsonianidae	1,2
Oligochaeta	Tubificida	Naididae	*Dero nivea*	2
			Allonais ranauana	1,2
			Pristina longiseta	1
Arachnida	Acariformes	Hydrachnidae	*Hydrachna* sp.	3
		Eylaidae	*Eylais* sp.	3
		Unionicolidae	*Encentridophorus sarasini*	3
			Neumania K1 (=P1?)	1
		Arrenuridae	*Arrenurus balladoniensis*	3
			Arrenurus tricornutus	1,3
	Acariformes	-	Trombidioidea	1
			Oribatida	1,2
	Parasitiformes	-	Mesostigmata	2
Crustacea	Conchostraca	Cyzicidae	*Caenestheriella packardi*	3
Insecta	Coleoptera	Haliplidae	*Haliplus* nsp. P1 "*fortescuensis*"	3
		Noteridae	*Hydrocanthus waterhousei*	1,2
			Neohydrocoptus subfasciatus	1
		Dytiscidae	*Laccophilus sharpi*	1,2
			Laccophilus clarki	1,2
			Hydrovatus rufoniger	1,2
			Hydroglyphus ?balkei	2
			Hydroglyphus ?leai	1
			Hydroglyphus leai	2,3
			Hydroglyphus trilineatus	2
			Paroster sharpi	2
			Megaporus sp.	2
			Bidessini	1
		Hydrophilidae	*Berosus josephenae*	2,3

Class	Order	Family	Lowest ID	Sample*
Insecta	Coleoptera	Hydrophilidae	*Paracymus pygmaeus*	1,2
	Diptera	Culicidae	*Culex* sp.	2
		Ceratopogonidae	*Monohelea* sp.	2
			Forcypomyia sp. P2 (PSW)	1
		Tabanidae	Tabanidae	1,2
		Stratiomyidae	Stratiomyidae	1,2
		Ephydridae	Ephydridae sp. 17 (PSW)	2
		Muscidae	Muscidae sp. M	1
		Chironomidae	*Tanypus* sp.K1	2
			Procladius paludicola	1,2,3
			Procladius paludicola P1 (no U-claws)	3
			Ablabesmyia notabilis	3
			Larsia albiceps	1,2,3
			Tanytarsus fuscithorax/semibarbitarsus	2
			Chironomus occidentalis	2
			Chironomus sp.	1
			Dicrotendipes 'CA1' Pilbara type 1 (was *lindae*) (PSW)	3
	Ephemeroptera	Baetidae	*Cloeon* sp. K1 (PSW)	1
	Hemiptera	Gerridae	*Limnogonus fossarum gilguy*	2
			Limnogonus sp.	1
		Belostomatidae	*Diplonychus eques*	1,2
		Corixidae	*Agraptocorixa halei*	2
			Micronecta lansburyi	3
			Micronecta virgata	3
			Micronecta nsp. P3 (PSW)	1,2,3
			Micronecta sp. K1 RCM	2
			Micronecta nr *lansbury*	2
		Naucoridae	*Naucoris subopacus*	1,3
		Notonectidae	*Anisops nasuta*	3
			Anisops occipitalis	2,3
			Anisops semitus	2,3
		Pleidae	*Paraplea* n. sp. (ANIC 6)	3
			Paraplea n. sp. ('*timmsi*' - Lansbury)	1,2
	Odonata	Coenagrionidae	*Austroagrion watsoni*	1,2,3
		Aeshnidae	*Hemianax papuensis*	1,2,3
		Libellulidae	*Diplacodes bipunctata\trivialis*	1
			Neurothemis stigmatizans stigmatizans	1,2
			Orthetrum caledonicum	2
			Trapezostigma loewii	1,3
		Urothemistidae	*Macrodiplax cora*	1,3

* Numbers refer to samples taken from within: (1) Sedges, (2) Sedges, and (3) Submerged macrophytes
? denotes unconfirmed specie identification

3.6. Fish

No fish were observed during the 2008 IAI RCM survey.

3.7. Waterbirds

A total of sixty-four waterbird species have been recorded across the Roebuck Plains system, including twenty-two species that are listed under treaties. Species known to inhabit the area include thirteen species of herons and allies, eleven species of ducks and allies, five species of rails and twenty-one species of shorebirds.

Significant species recorded at Lake Eda include Painted Snipe (*Rostratula benghalensis*), Freckled Duck (*Stictonetta naevosa*), Garganey (*Anas querquedula*), Pectoral Sandpiper (*Calidris melanotos*) and Long-toed Stint (*C. subminuta).* Occurrences of White-browed Crake (*Poliolimnas cinereus*) and Green Pygmy Goose (*Nettapus pulchella*) at Lake Eda, and Yellow Chat (*Ephthianura crocea*) on the floodplain are the westernmost for these species in north-western Australia.

Seven species have been found breeding at Lake Eda: Black Swan (*Cygnus atratus*), Magpie Goose (*Anseranas semipalmatus*), Masked Lapwing (*Vanellus miles*) and Black-winged Stilt (*Himantopus himantopus*) plus Hardhead (*Aythya australis*), Whiskered Tern (*Chlidonias hybrida*) and Australian Crake (*Porzana fluminea*) on the plain.

The plain is an important migration stopover for at least fourteen shorebird species, and the plains and lakes are an internationally important stopover area for Little Curlews and Oriental Pratincole. It is thought that many of these birds fly direct to China from the site in late March (Jaensch 1992).

3.8. Terrestrial Vertebrates

No other vertebrate fauna were observed during the 2008 IAI RCM survey.

4. Interactions between Ecological Components at Lake Eda

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 Lake Eda are:

- The characteristics that make the site a good example of a wetland type occurring within a biogeographic region in Australia.
- The contribution the site makes to the ecological or hydrological functioning of the wetland system/complex.
- The animal taxa that utilise the site as habitat at a vulnerable stage in their life cycle, or as a refuge when adverse conditions such as drought prevail, and the characteristics of the site that allow it support these populations.
- The plant or animal taxa that have more than 1% of their national populations supported by the site.
- The site's outstanding historical and cultural significance.

Table 6 and Figure 10 summarise the interactions between key components and processes at Lake Eda. 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. The most important element of Lake Eda is the waterbirds that utilise the area. These birds are supported by the vegetation of the lake and the near-permanent fresh water it contains.

Table 6 – The relationship between the services and benefits delivered by Lake Eda, and the key components and processes that support them.

Benefit or Service	Component	Factors Influencing Component		Threats and Threatening Activities
		Biotic	Abiotic	
Consumptive Value Bush tucker and fishing	Palatable plants and animals	Plant pollinators Animal food sources	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 Erosion
Productive Value Beef production	Cattle	Plants palatable to stock	Availability of fresh water Periodic inundation events Groundwater level Water quality (salinity)	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
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 climate change, groundwater extraction or catchment perturbation Inappropriate fire regimes Weeds Predation of fauna
Ecosystem Service Value A good example of a wetland type occurring within a biogeographic region in Australia	A good example of a major freshwater floodplain of the bioregion, lacking substantial riverine inflow (applies to entirety of Roebuck Plains)	Vegetation communities	Hydrological regime	Alteration to hydrology due to climate change, groundwater extraction or catchment perturbation Grazing by cattle or introduced pest animals Erosion and sedimentation

Benefit or Service	Component	Factors Influencing Component		Threats and Threatening Activities
		Biotic	Abiotic	
Ecosystem Service Value Important ecological or hydrological role in the natural functioning of a major wetland system/complex	Lake Eda basin	Vegetation communities	Soils and sediments Hydrological regime	Alteration to hydrology due to climate change, groundwater extraction or catchment perturbation Grazing by cattle or introduced pest animals Erosion and sedimentation
Ecosystem Service Value Habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge hen adverse conditions, such as drought, prevail	Migrating Little Curlew and Oriental Pratincole Other waterbirds that utilise the site as a drought refuge	Invertebrate populations (food source) Phytoplankton (food source) Benthic plant biomass Vegetation contributing to habitat requirements	Soils and sediments Nutrient concentrations Water salinity and pH Groundwater level	Grazing by cattle and introduced pests Pugging by cattle Alteration to hydrology due to climate change, groundwater extraction or catchment perturbation Inappropriate fire regimes Excessive nutrient inputs from stock Weeds Predation of fauna Loss of migratory bird populations due to offsite factors
Ecosystem Service Value Supports 1% or more of the national populations of any native plant or animal taxa	Little Curlew and Oriental Pratincole	Invertebrate populations (food source) Phytoplankton (food source) Benthic plant biomass	Soils and sediments Nutrient concentrations Water salinity and pH Groundwater level	Grazing by cattle and introduced pests Pugging by cattle Alteration to hydrology due to climate change, groundwater extraction or catchment perturbation Inappropriate fire regimes Excessive nutrient inputs from stock Weeds Predation of fauna Loss of migratory bird populations due to offsite factors

Benefit or Service	Component	Factors Influencing Component		Threats and Threatening Activities
		Biotic	Abiotic	
Recreational Value Bird watching Picnicking Kayaking Bush walking Photography	Landscape amenity Waterbird populations Vegetation communities Significant flora Significant fauna	Invertebrate populations (food source) Phytoplankton (food source) Benthic plant biomass	Soils and sediments Nutrient concentrations Water salinity and pH Groundwater level	Grazing by cattle and introduced pests Pugging by cattle Alteration to hydrology due to climate change, groundwater extraction or catchment perturbation Inappropriate fire regimes Excessive nutrient inputs from stock Weeds Predation of fauna Loss of migratory bird populations due to offsite factors
Spiritual Value The wetland is of outstanding historical or cultural significance	Geomorphology of lake and surrounds Native flora and fauna communities Association with early pastoral industry	Flora and fauna populations Pollinators and food sources for above	Soils and sediments Hydrology Water quality	Grazing by cattle and introduced pests Pugging by cattle Alteration to hydrology due to climate change, groundwater extraction or catchment perturbation Inappropriate fire regimes Excessive nutrient inputs from stock Weeds Predation of fauna Erosion

Primary Determinants of Ecological Character

(DIWA criteria for Lake Eda)

The characteristics that make the site a good example of a wetland type occurring within a biogeographic region in Australia. *A good example of a major freshwater floodplain of the bioregion, lacking substantial riverine inflow.*
The contribution the site makes to the ecological or hydrological functioning of the wetland system/complex. *Permanent fresh water on the Roebuck Plain.*
The animal taxa that utilise the site as habitat at a vulnerable stage in their life cycles, or as a refuge when adverse conditions such as drought prevail; and the characteristics of the site that allow it support these populations. *A significant drought refuge area for waterbirds in the bioregion and an internationally important stopover area for Little Curlews and Oriental Pratincole.*
The plant or animal taxa that have more than 1% of their national populations supported by the site (note that this applies to the Roebuck Plains system as a whole, rather than specifically to Lake Eda). *Little Curlew and Oriental Pratincole.*
The site's outstanding historical and cultural significance. *Educational, research, recreational and spiritual values.*

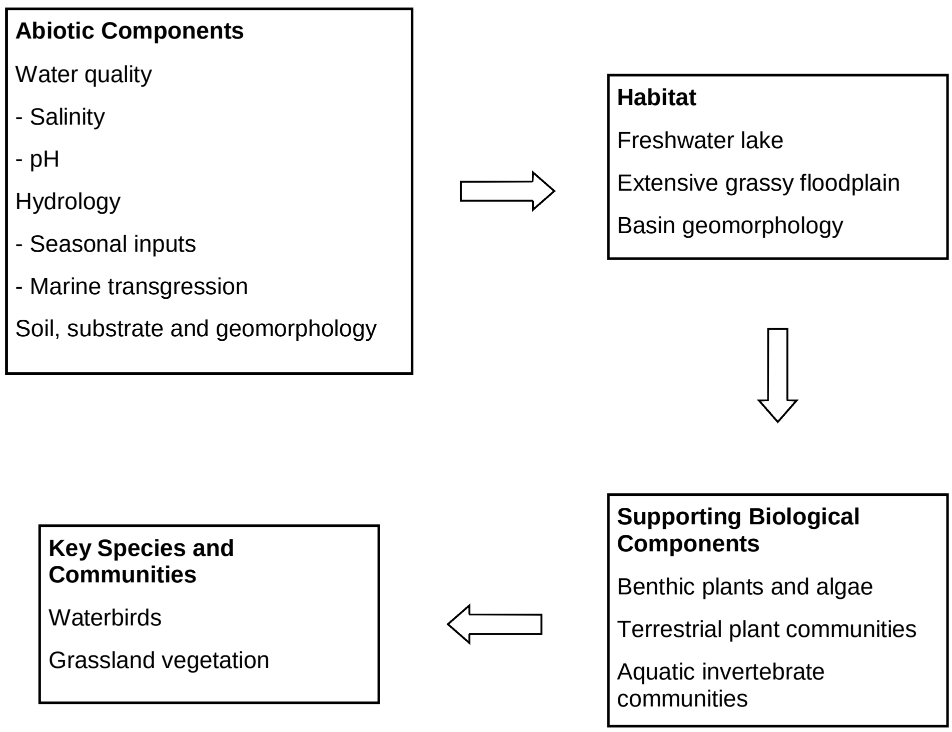

Figure 10 – Schematic depiction of the interactions between critical components of the Lake Eda ecosystem.

5. Threats to the Ecology of Lake Eda

The ambition for conservation management at Lake Eda is to maintain the habitat factors that make the lake a suitable stopover for migratory birds and a refuge site for domestic waterbirds. The most important aspect of Lake Eda's ecology is the nearly permanent presence of fresh water, which shapes the composition of biotic communities at the site. In particular, it supports the vegetation and aquatic invertebrates that waterbirds depend on for food and habitat. Also of importance are the elements of the system that contribute to its cultural and scientific value.

Threats to Lake Eda must be considered in relation to their likelihood of causing the failure of the management goal for the lake. The impacts of each threatening process identified at the site, or potentially acting there, have been quantified in Table 7. Management actions should be prioritised by a combination of the probability of the threat causing goal failure and its potential for mitigation.

In summary, failure to achieve the management goal for Lake Eda is most likely to result due to the impacts of cattle pastoralism and alteration to natural fire regimes. Weeds and climate change are also significant threats, whilst the impacts of drought, flood and eutrophication of the water body should also be considered.

Altered fire regimes are a major threat to biodiversity across the Kimberley region. The Environmental Protection Authority recently released an issues paper that details the current and future impacts of changes to the natural frequency and intensity of wildfire in the region (Russell-Smith 2005). That paper relates that the season of burning has changed during the period of European occupation of the area. Aboriginal burning in the Kimberley was spread through the dry season, whereas today, most fires occur at the end of the dry season. Late dry season fires in the Kimberley have major impacts across all land use and industry sectors. In particular, fire-sensitive vegetation is being severely impacted by the intensity of these fires. It is likely that the altered fire regime has had a major impact on small to medium sized animals such as bandicoots. These fires may also be affecting birds, adding to the effects of grazing on grass species. Late dry season fires cause soil loss by erosion, loss of nitrogen in smoke, increased greenhouse gas emissions and impacts on air quality and human health.

In the context of Lake Eda and the Roebuck Plains system, fire has the potential to facilitate the establishment of weed species, expose soils to erosion, cause the loss of fire sensitive flora and negatively impact on fauna. It is very difficult to manage fire in a setting such as the Roebuck Plains. The dominant vegetation of the area is a community of perennial grasses, meaning that prescribed burning is largely ineffective in establishing buffers to limit the spread of fires. Also, much of the system is inaccessible to vehicles due to waterlogging.

The second major threat to Lake Eda is the impact of cattle on the site. At the time of the site visit, there were no cattle grazing on the lakebed. However, there were large areas of disturbed soil caused by cattle accessing the lake for water and wallowing in its margins. Soil disturbance creates an opportunity for weed species to become established, with cattle also 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. If erosion occurs higher in the catchment (this was not assessed) it may result in sediment deposition in Lake Eda. This is probably the most serious of these potential impacts, as it would permanently alter the geomorphology and hydrology of the lake and so change its character.

Preventing the impact of cattle at the lake is achievable with stock exclusion fencing. There is currently no evidence that upstream management is impacting on Lake Eda. This should be monitored and, if necessary, catchment scale management implemented.

Wetlands are highly productive environments, but also easily damaged. Fires, pest animals, stock and human activities may all disturb native vegetation and create the niche required for exotic plants to become established. Weed propagules may be introduced via inflowing water, grazing stock, exotic animals, visiting waterbirds or wind. Once established, the productivity of the ecosystem 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 usually make chemical weed control inappropriate. Mechanical control is often complicated by difficulty in accessing infestations.

Two weed species are known to be well-established at Lake Eda. *Phyla nodiflora* var. *nodiflora* and *Cynodon dactylon* were significant components of the vegetation at the sampling location. It is not clear what effect this infestation is having on the overall ecology of the system. The potential for new weed species to become established is also a concern however, particularly as cattle are accessing the water body. Cattle exclusion (to the non-fenced portions of Lake Eda) and appropriate fire management are the best tools available to prevent future weed outbreaks.

The CSIRO predicts that climate change will make the Roebuck Plains a significantly warmer and slightly drier place in the future. Periods of aridity are likely to be longer and the rainfall events that end them more extreme (CSIRO Undated). 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, and greater erosion risk in the catchment. Also, global sea levels are expected to rise, making it likely that the marine transgressions of the Roebuck Plains that accompany storm events will be more common, more extensive and more prolonged. Indeed, CSIRO consider the loss of freshwater wetlands due to sea level rise as the greatest climate-related threat to the Kimberley's biodiversity. Marine incursion into Lake Eda would be devastating to the site as it currently a very fresh system. It is not at all clear whether storm surges are likely to carry seawater as far inland as Lake Eda in the future. If this does occur, there is unlikely to be any feasible local-scale management of the threat.

The final noteworthy threat to the ecology of Lake Eda is eutrophication of the water body. This may occur due to the excrement of cattle contributing excessive nutrients to the system. At the time of the site visit, nutrient levels were acceptably low, perhaps due to recent wet season flushing of the system. The continued use of the lake for grazing cattle makes nutrient enrichment a threat to monitor.

Table 7 – Threat assessment for Lake Eda.

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 and hydrology of Lake Eda, 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	Hydrological processes, particularly salinity	0	0	There is no evidence of alteration to the hydrology of the Lake Eda area, nor does there appear to be any likelihood of any alteration in the foreseeable future.
	Carbon cycle and climate change	10	10	Changes to rainfall are expected to be fairly minor in the Kimberley, perhaps as little as 1% over the next 50 years. Predicted rises in global sea levels, combined with more intense storm activity may result in more frequent and more extensive marine transgressions on the Roebuck Plains. This would cause changes to the ecology of Lake Eda. CSIRO consider the loss of freshwater wetlands due to sea level rise to be the primary climate-change related threat to biodiversity in the Kimberley.
Impacts of introduced plants and animals	Environmental weeds	15	5	Weeds are identified as one of the primary threats to the ecology of the Roebuck Plains. Lake Eda's near perenniality and the ongoing grazing activities make it highly susceptible to weed invasion. The lake already has well-established populations of several exotic plants. Alteration to natural fire regimes may facilitate the establishment of more weed species in the area and the spread of existing species. Weed control is required at the site.
	Herbivory, wallowing and trampling by introduced species	30	0	Significant impacts of cattle are already evident. Cattle wallowing around the lake margins kill vegetation and make soil susceptible to erosion. Over-grazing has similar impacts. This threat is readily addressed by fencing the lake to exclude cattle.
Impacts of problem native species	Overgrazing by native species	0	0	No impacts evident.
Impacts of disease	Plant pathogens	0	0	No impacts evident.
Detrimental regimes of physical disturbance events	Fire regimes	30	10	The increasing frequency and intensity of late season wildfires is having deleterious impacts on grasslands across the Kimberley. Such fires facilitate the establishment of exotic grasses and other weeds. They also create the potential for erosion of soils with the next rainfall event. Management of fire in the Kimberley is difficult because of the size and remoteness of the region and the fast return rate of native annuals. However, fire management should be an achievable goal for specific site.

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	5	5	Rainfall projections for the Kimberley show that climate change may result in longer periods of drought, interspersed with severe storms and heavy rainfall. The impacts of this on the ecology and geomorphology of Lake Eda are difficult to predict. It is possible that it may lead to some alteration in the composition of vegetation.
	Flood	5	5	Alteration to rainfall and hydrological fluxes, associated with global climate change may impact on the vegetation of Lake Eda. The nature of the impacts is 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 chemical and, at present, no intensive agriculture or broadscale cropping is practiced in the catchment.
Impacts of competing land uses	Recreation management	1	0	Recreational usage of Lake Eda is low impact and unlikely to have any deleterious impacts.
	Nutrient enrichment of water body	5	0	It is likely that cattle accessing the lake will result in nutrient enrichment of the water body. However, the regular flushing of the system following seasonal rainfall events appears to prevent the development of eutrophic conditions.
	Urban and industrial development	0	0	Roebuck Plains are an inappropriate site for any urban or industrial development due to regular flooding. 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 Lake Eda 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.
	Mines and quarries	0	0	No mineral potential.
Insufficient ecological resources to maintain viable populations	Habitat, genetic exchange	1	1	Lake Eda is well connected to extensive areas of natural or near-natural environment. Populations are likely to 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.

6. Knowledge Gaps and Recommendations for Future Monitoring

There is relatively little knowledge of wetlands of the Kimberley region. The remoteness of this area has historically resulted in a lack of survey effort. While this RCM survey has provided a 'snapshot' of the ecological character of Lake Eda, repeat surveys are required to provide a good understanding of the entire ecosystem and to determine trends over time.

Notable knowledge gaps include a lack of knowledge of the interactions of groundwater with Lake Eda, as well as a lack of documented data on vertebrate fauna other than waterbirds, including fish. As a freshwater wetland within the Kimberley region, frogs are likely to occur at the lake. These may be an important study topic considering cane toads have crossed the Western Australian border and are expected to invade the Kimberley in the near future.

Several aquatic invertebrate taxa were recorded during the current survey did not appear to match known described species and may be new. However, for the present, taxonomic impediments and a lack of survey data for the Kimberley region prevent much further discussion of these. Therefore, repeated surveys of aquatic invertebrates at Lake Eda and the Kimberley region are highly recommended to determine the status of these taxa.

Lake Eda is largely contained within the Roebuck Plains pastoral lease. The eastern portion of the lake is within an unnamed crown reserve that was gazetted for the purpose of a stock route and stock watering place. Given this land use, it is not surprising weeds have been identified as a threatening process affecting Lake Eda. Two weed species are known to be well-established at the lake. It is not clear what effect this infestation is having on the overall ecology of the system. Cattle exclusion and appropriate fire management are the best tools available to prevent future weed outbreaks. Preventing the impact of cattle at the lake is achievable with stock exclusion fencing. Monitoring of the vegetation and weed infestations at Lake Eda is recommended prior to and following any such management actions.

References

Anugraha. (Undated) Rarrdjali Aboriginal Corporation <http://www.broomejobs.com.au/yawuru> Accessed on 02/09/2008.

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

CSIRO. (Undated) Climate Change in the Kimberley Region. CSIRO Marine and Atmospheric Research. <www.sharingknowledge.net.au/files/kimberleyv1_2006.pdf> Accessed on 04/09/2008.

Graham, G. (2001) Dampierland 2 (DL2 Pindanland subregion). In *A Biodiversity Audit of Western Australia's 53 Biogeographic Subregions in 2002*. (McKenzie, N. L., May, J. E., and McKenna, S., eds). Pages 179-187. Department of Environment and Conservation, Perth, Australia.

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. (1992) Roebuck Plains System - WA021. In *Australian Wetlands Database*. Department of Environment, Heritage and the Arts. Accessed on 2 November 2009.

Morton, S. R., Short, J., and Barker, R. D. (Undated) *Refugia for Biological Diversity in Arid and Semi-arid Australia*. Biodiversity Series Paper No. 4. Biodiversity Unit, Department of Environment, Water, Heritage and the Arts, Canberra, Australia.

Russell-Smith, J. (2005) *Fire in the Kimberley and Inland Regions of WA – Issues Paper*. Environmental Protection Authority, Perth, Australia.

Start, T. (Undated) Savannah Explorer. Northern Australian Information Resource. Kimberley Savannah Vegetation. <http://www.savanna.org.au/km/kb_vegetation.html> Accessed on 18 February 2009.

Tille, P. (2006) *Soil Landscapes of Western Australia's Rangelands and Arid Interior*. Resource Management Technical Report 313. Department of Agriculture and Food, Perth, 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.