

Resource Condition Report for a Significant Western Australian Wetland

Ngallagunda Swamp

2009

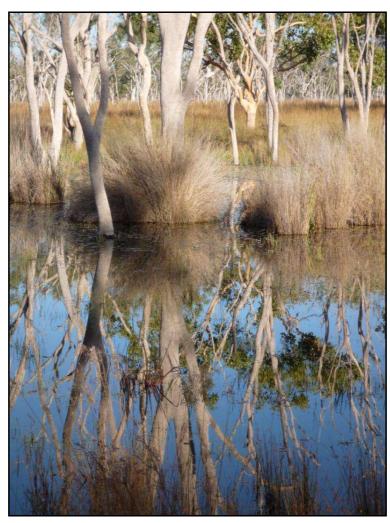


Figure 1 – Vegetation reflected in the water body at Ngallagunda Swamp

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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 Ngallagunda Swamp, a spring-fed permanent, freshwater lake on the Gibb River pastoral lease. Ngallagunda Swamp was selected as a study site for the IAI RCM project because permanent, freshwater bodies are important refuge sites for flora and fauna during periods of drought.

Ngallagunda Swamp does not have an official name. It is referred to here as Ngallagunda Swamp due to its proximity to the Ngallagunda Community.

1.1. Site Code

Inland Aquatic Integrity Resource Condition Monitoring Project: RCM010.

Transect Code: RCM010-R1 RCM010-A1

1.2. Purpose of Resource Condition Report

The objective of the RCR is to summarise all available ecological information relevant to Ngallagunda Swamp and describe the 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

The following is a summary of international agreements and key pieces of legislation that are relevant to the management of Ngallagunda Swamp.

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 Ngallagunda Swamp. 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. Two of these are relevant to Ngallagunda Swamp:

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

Western Australian legislation

Wildlife Conservation Act 1950

This Act provides for the protection of wildlife. All fauna (animals native to Australia) in Western Australia are 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 Affairs Planning Authority Act 1972 (AAPA Act)

The AAPA Act repealed earlier Indigenous welfare legislation. It governs most Indigenous land related matters and vests reserves in the Aboriginal Affairs Planning Authority, which promotes the well-being and economic advancement of Indigenous Australians. A visitor should always seek and gain permission to enter an Aboriginal community, and in the case of Aboriginal Reserve land, must do so by obtaining an entry permit. Under the AAPA Act, transit permits are required for any person visiting or passing through an Aboriginal reserve, unless he/she is:

- · a person of Aboriginal descent;
- a member of either House of Parliament of the State or of the Commonwealth;
- a person exercising a function under the AAPA Act 1972 or otherwise acting in pursuance of a duty imposed by law; or
- a person authorised under the regulations of the AAPA Act 1972.

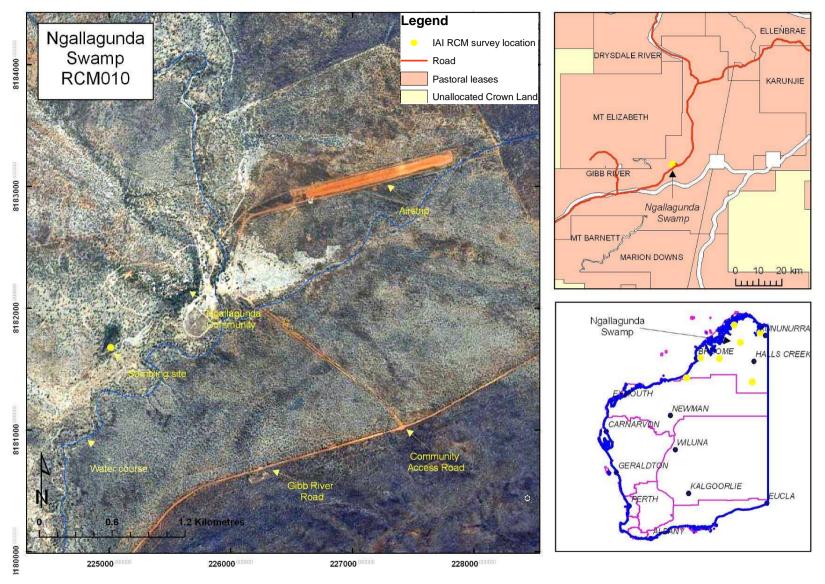


Figure 2 – Satellite imagery showing the location of Ngallagunda Swamp relative to Ngallagunda community. The upper insert shows local cadastral information. The lower insert shows the location of the lake in WA, with DEC regional boundaries in pink

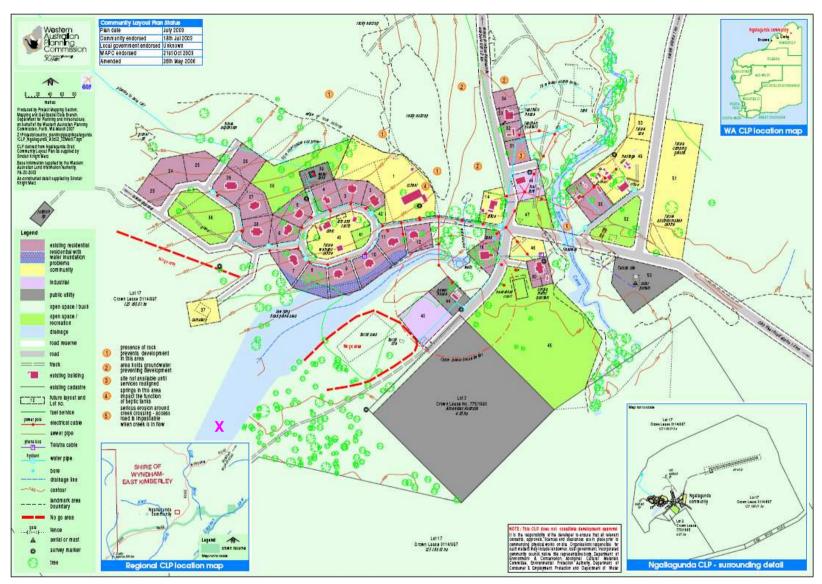


Figure 3 – Planning document showing current layout of Ngallagunda Community and proposed extensions (DPI 2007); the approximate location of the RCM survey site is marked with an 'X'

2. Overview of Ngallagunda Swamp

2.1. Location and Cadastral Information

Ngallagunda Swamp is located approximately 250 km west-southwest of Kununurra (Figure 2), on the Gibb River pastoral lease. The Gibb River lease is owned and operated by Ngallagunda Community and is home to about 80 people (DIA 2005).

Gibb River is an active pastoral lease and cattle pastoralism is the main activity. Plans are also being developed to provide facilities for tourists (Figure 3). This will diversify the income base of the community, but may also place additional pressure on the natural environment.

2.2. Wetland Type

Ngallagunda Swamp would be described as a permanent, freshwater pond (<8 ha), marsh or swamp on inorganic soil; with emergent vegetation waterlogged for at least most of the growing season (type B9) according to the classification system employed by the *Directory of Important Wetlands in Australia* (Environment Australia 2001).

2.3. IBRA Region

Ngallagunda Swamp lies within the Pentecost subregion of the Central Kimberley Interim Bio-Regionalisation of Australia (IBRA) region. In this subregion, parallel siliceous ranges of Proterozoic sedimentary rocks give rise to hilly to mountainous terrain. In flat areas, skeletal sandy soils support *Triodia* spp. hummock grasses with scattered trees. In the valleys, loamy soils derived from Proterozoic volcanic rocks support ribbon grass (*Chrysopogon* spp.) with scattered trees. Open forests of river red gum (*Eucalyptus camaldulensis*) and *Pandanus* spp. occur along drainage lines (Graham 2001).

2.4. Climate

The nearest Bureau of Meteorology weather station to Ngallagunda is at Mt Elizabeth, approximately 20 km to the northwest. However, long-term records are not available for that site. The nearest site for which long-term records are available is Doongan, located approximately 115 km north of Ngallagunda (Bureau of Meteorology 2009).

Doongan averages 1,152 mm of rain per year, the vast majority of which falls between November and March. Temperatures peak in October, when the mean maximum is 37° C and the mean minimum is 21.4° C. The coolest month is July when the mean maximum is 29.7° C and the mean minimum is 10.7° C (Figure 4). Based on the short term data (1993 to the present) available, Mt Elizabeth receives around 15% less rainfall than Doongan, but conditions are otherwise similar.

Ngallagunda Swamp was surveyed by the IAI RCM project on the 19th of May 2008. In the twelve months preceding the survey, Mt Elizabeth received 1120 mm of rain, with almost all falling between November and March (Figure 5). The last rainfall prior to the survey was 7 mm, received on the 5th of April.

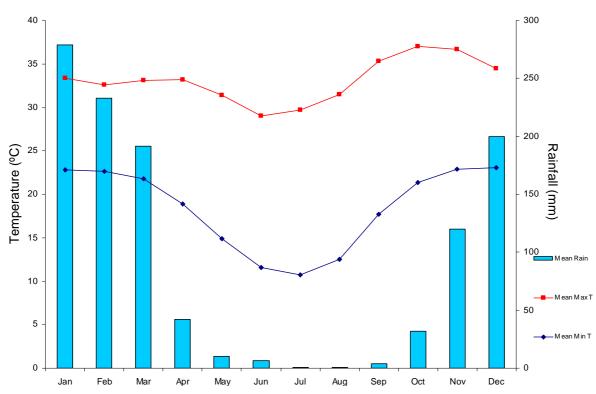


Figure 4 – Climatic averages for Doongan, approximately 115 km north of Ngallagunda Swamp

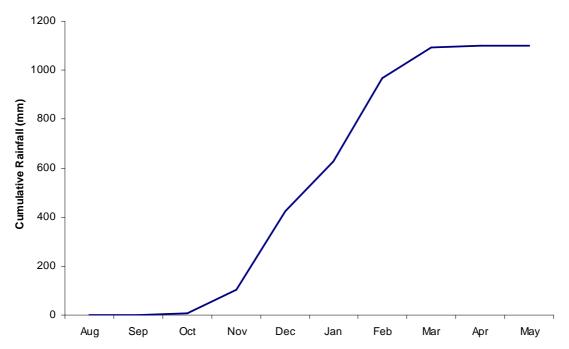


Figure 5 – Cumulative rainfall in 2007/8 at the Mt Elizabeth weather station, approximately 20 km northwest of Ngallagunda Swamp

2.5. Values of Ngallagunda Swamp

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. As such, 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'. It is not known whether local people make any consumptive use of Ngallagunda Swamp.

b. Productive use

Productive use values are derived from market transactions involving products derived from the natural environment. The same firewood that is collected for personal use may be exchanged for money or another commodity. The use of Ngallagunda Swamp as a source of fresh water and fodder for stock is a productive use value. In this instance, the wetland is valued for its contribution to the productivity of a commercial 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. Ngallagunda Swamp 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. Ngallagunda Swamp has very high invertebrate species richness, making it important for biodiversity.

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 Ngallagunda Swamp, 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. Ngallagunda Swamp 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. It is not known whether any recreational usage is made of Ngallagunda Swamp.

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. Standing water is of cultural significance to the local Aboriginal people as it is considered to be the resting place of spirits associated with the world's creation (Yuco Pty Ltd 2003). Permanent, fresh water in an otherwise arid region is an important resource, meaning the swamp and its surrounds are likely to have been utilised by Aboriginal people historically.

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, Ngallagunda Swamp 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 Ngallagunda Swamp

The primary objective of the Ngallagunda Swamp Resource Condition Report (RCR) is to identify, describe and quantify the drivers of the wetland's natural environment. These are the components and processes that 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 Ngallagunda Swamp's 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 of any previous studies conducted on the wetland.

Table 1 – Summary of critical ecosystem components at Ngallagunda Swamp

Component	Summary description					
Geomorphology	Small, shallow depression (200 m x 100 m)					
Hydrology	Fed by spring near Ngallagunda community					
Water Quality	Fresh (48 mS/m), neutral pH (7.49), generally low nutrients and chlorophyll					
Benthic Plants	Dominated by sedges and floating aquatics					
Littoral Vegetation	Dominated by sedges and grasses					
Invertebrates	Very high species richness: 71 species, 29 families					
Fish	None seen					
Waterbirds	Four species, one migratory bird protected under CAMBA					
Terrestrial Vertebrates	Twenty-eight species of frog					

3.1. Geology and Soils

Ngallagunda Swamp is within the greater Kimberley Plateau soil landscape province (Tille 2006). The province comprises undulating plains interspersed with hills, ranges and plateau over the sedimentary and volcanic rocks of the Kimberley Basin. Sandy, stony soils dominate the rugged sandstone terrain. Yellow deep sands, yellow sandy earths and yellow loamy earths are found on the sandstone and shale lowlands and plateau surface. Red loamy earths, red sandy earths and shallow gravels are often associated with basalt uplands and lowlands, while the volcanic hills have stony soils and loamy earths.

The substrate of the survey location was a mixture of silt, sand and gravel with a significant organic component.

3.2. Hydrology

Ngallagunda Swamp is a shallow clear-water sedge swamp, approximately 200 m x 100 m in size. It has areas of open water and dense pond weed and *Chara* sp. Its maximum water depth at the time of the survey was approximately 20 cm. The wetland is fed by a spring near the Ngallagunda Community.

3.3. Water Quality

Ngallagunda Swamp had very high water quality at the time of survey. It was very fresh, clear and had generally low nutrient and chlorophyll concentrations, although phosphorus was above the default trigger range (10 to 50 μ g/L) suggested for tropical wetlands in the ANZECC/ANZECC (2000) guidelines. Total nitrogen concentrations were well below the guideline's trigger range of 350 to 1200 μ g/L).

Table 2 – Water quality parameters of Ngallagunda Swamp

	RCM010
	May 2008
рН	7.49
Alkalinity (mg/L)	10
TDS (g/L)	0.036
Turbidity (NTU)	1.7
Colour (TCU)	14
Total nitrogen (ug/L)	200
Total phosphorus (ug/L)	100
Total soluble nitrogen (ug/L)	60
Total soluble phosphorus (ug/L)	30
Chlorophyll (ug/L)	2
Na (mg/L)	4.9
Mg (mg/L)	1.1
Ca (mg/L)	1.2
K (mg/L)	0.5
CI (mg/L)	7
SO ₄ (mg/L)	6.5
HCO₃ (mg/L)	12
CO ₃ (mg/L)	0.5

3.4. Vegetation

Ngallagunda Swamp is located in the central Kimberley Plateau province, which is dominated by tall grass savannah woodlands (Tille 2006). There is currently no broad-scale vegetation mapping available for the Ngallagunda area.

A littoral vegetation transect was established by the RCM survey in the riparian zone of the wetland (Figure 6). A number of plants could not be accurately identified due to a lack of flowering material. Seven species were found along the littoral transect (Table 3).



Figure 6 - Riparian vegetation RCM010-R1 transect at Ngallagunda Swamp

Table 3 – Vegetation composition of the riparian transect established at Ngallagunda Swamp

Species/Description		Quadrat (m) / % layer cover							
Species/Description	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	
Glyceria sp.	3	3	0	0	0	0	0	0	
Grass with branched brackets	3	10	20	15	0	0	0	0	
Juncus sp.	75	77	75	80	63	30	30	50	
Cyperus sp.	3	0	0	0	0	0	0	0	
Chara sp.	10	10	5	5	30	65	60	50	
Typha sp.	0	0	0	0	2	0	0	0	
Eleocharis sp.	3	5	5	5	5	10	10	10	
Open water	10	10	5	5	30	65	70	50	

An aquatic transect was also established at Ngallagunda Swamp, with six species present (Figure 7). A further three species were collected off transect. These were *Nymphoides indica*, *Schoenoplectus subulatus* and *Glyceria* sp.

Table 4 – Vegetation composition of the aquatic transect at Ngallagunda Swamp

Species/Description	Quadrat (m) / % layer cover									
Species/Description	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50
Potamogeton sp.	20	20	10	10	40	40	40	40	20	20
Typha sp.	10	10	0	0	0	0	0	0	0	5
Emergent sedge	30	30	20	20	15	15	10	10	40	40
Cyperus sp.	0	0	5	5	5	5	5	5	0	0
Scrophulaceae sp.	0	0	5	5	0	0	0	0	0	0
Eleocharis sphacelata	0	0	5	5	10	10	0	0	0	0
Open water	80	80	80	80	80	80	50	50	70	70



Figure 7 - Aquatic vegetation transect RCM010-A1 at Ngallagunda Swamp

3.5. Aquatic Invertebrates

Macroinvertebrate species richness was very high, with seventy-one species belonging to twenty-nine families collected in the IAI RCM survey (Table 5). The fauna includes some possibly undescribed species (e.g. *Anisops* hemipterans). This high richness and broad taxonomic representation suggest the wetland was in good condition. However, there were some major groups missing from the fauna, possibly because the wetland was sampled on just one occasion. These include conchostracans (which frequently occur in temporary swamps but might have already completed their life cycle prior to sampling) and annelids. The diversity of water mites was also lower than expected for this type of wetland.

Table 5 – Aquatic invertebrates collected from Ngallagunda Swamp by the RCM survey

Class	Order	Family	Lowest ID	Sample*
Gastropoda	Basommatophora	Lymnaeidae	Austropeplea sp.	2
		Planorbidae	Gyraulus sp.	1,2,3
			Ameriana sp. P1 (PSW)	2
			Ameriana sp. P2 (PSW)	3
			Ameriana sp. P3 (cf bonushenricus) (PSW)	1
Arachnida	Acariformes	Unionicolidae	Unionicolidae	1
		Arrenuridae	Arrenurus anbangbang	2
			Arrenurus tricornutus	1,2
			Arrenurus sp. 24 (PRP)	1
	Acariformes	-	Oribatida	1,2,3
Insecta	Coleoptera	Haliplidae	Haliplus sp.	3
		Noteridae	Canthydrus ephemeralis	3
		Dytiscidae	Laccophilus clarki	2
			Hydrovatus fasciatus	2
			Hydrovatus opacus	2
			Hydrovatus ovalis	2
			Hydrovatus c.f. rufoniger	2
			Sternopriscus alligatorensis	1
			Onychohydrus atratus	2
			Onychohydrus sp.	3
		Hydrophilidae	Berosus sp.	1,2,3
			Paracymus pygmaeus	3
		Hydrochidae	Hydrochus sp.K1	3
	Diptera	Culicidae	Aedeomyia catasticta	1
		Ceratopogonidae	Bezzia sp.	1,2,3
			Nilobezzia sp.	1,3
		Tabanidae	Tabanidae	1,3
		Chironomidae	Clinotanypus crux	1
			Procladius paludicola	1,3
			Procladius paludicola P1 (no U-claws)	1,3
			Ablabesmyia notabilis	1
			Paramerina sp. A (parva?) (SAP)	3
			Thienemannimyia sp.	2
			Larsia albiceps	1,3
			Pentaneurini sp. K1 (RCM)	2
			Pentaneurini sp. K2 (RCM)	1
			Riethia sp.	2
			Cladotanytarsus sp. A (SAP)	2
			Tanytarsus barbitarsis	1,2
			Tanytarsus fuscithorax/semibarbitarsus	2
			Chironomus occidentalis	2

Class	Order	Family	Lowest ID	Sample*
Insecta	Diptera	Chironomidae	Chironomus aff. alternans (V24) (CB)	2
			Dicrotendipes sp. K4 (RCM)	1,2,3
			Polypedilum leei	2
			Zavreliella marmorata	1,2,3
			Polypedilum convexum	2,3
			Conochironomus cygnus	3
			Harnischia K1 (PSW)	1
			Chironomini genus K2 sp. 1	1
	Ephemeroptera	Baetidae	Cloeon sp.	2,3
			Offadens (ex genus 1) soror (ex WA sp. 1) (PSW)	2,3
		Caenidae	Tasmanocoenis arcuata	1,2
			Tasmanocoenis sp. P (PSW)	1
	Hemiptera	Gerridae	Limnogonus fossarum gilguy	1
		Corixidae	Micronecta lansburyi	1
		Notonectidae	Enithares Ioria	2
			Anisops elstoni	2
			Anisops nasuta	3
			Anisops semitus	1,2,3
			Anisops nsp. K1	3
		Belostomatidae	Diplonychus rusticus	2
		Pleidae	Paraplea sp. K1	2
	Lepidoptera	Pyralidae	Pyralidae nr sp. 36 of JHH (RCM)	2,3
	Odonata	Coenagrionidae	Austroagrion watsoni	1,3
		Protoneuridae	Nososticta Pilbara sp. K1 (RCM)	1
	Odonata	Aeshnidae	Hemianax papuensis	3
		Libellulidae	Neurothemis stigmatizans stigmatizans	1,3
			Orthetrum caledonicum	1,3
			Orthetrum villosovittatum villosovittatum	3
			Trapezostigma loewii	1,3
	Trichoptera	Hydroptilidae	Orthotrichia sp.	2
		Ecnomidae	Ecnomus sp. K1 (RCM)	1
		Leptoceridae	Oecetis sp.	1
			Triplectides ciuskus seductus variant AV19 (RCM)	3

^{*} Numbers relate to the three habitats sampled:

3.6. Fish

No fish were observed during the RCM survey.

Ngallagunda Swamp is located within the Timor Sea Drainage Division. This is one of the richest areas in Australia for freshwater fishes, with nearly 100 species recorded (Allen et al. 2002).

Open water with sparse Characeae
Dense mixed macrophytes over Characeae

^{3.} Sedges

3.7. Waterbirds

Four species of waterbird were observed at Ngallagunda Swamp during the RCM Survey. These included a White-browed Crake, a Spotless Crake, a Painted Snipe and two Pacific Black Ducks. Painted Snipes are protected under CAMBA (see section 1.3).

3.8. Terrestrial Vertebrates

Twenty-eight species of frog were collected from a 390 km transect between Derby and Gibb River Station in February 1985 (Tyler *et al.* 1987). This represented 74% of the frog fauna known from the Kimberley Division. The survey included a "recently-filled billabong adjacent to the homestead" and surrounds. This is likely the same as Ngallagunda Swamp. Thirteen frog species were recorded from this site and these are listed below. There are no records of other terrestrial vertebrates at Ngallagunda Swamp.

Table 6 – Frogs collected from Ngallagunda Swamp by Tyler et al. (1987)

Latin name	Common name/s
Crinia bilingua	Bilingual Froglet
Cyclorana australis	Giant Frog; Northern Snapping Frog
Cyclorana longipes	Long-footed Frog
Litoria caerulea	Common Green Tree Frog
Litoria inermis	Bumpy Rocketfrog; Floodplain Frog; Peter's Frog
Litoria nasuta	Striped Rocketfrog; Rocket Frog
Litoria rothii	Northern Laughing Treefrog; Roth's Tree Frog
Litoria rubella	Ruddy Treefrog; Red Tree Frog; Desert Tree Frog
Litoria tornieri	Tornier's Frog
Limnodynastes convexiusculus	Marbled Frog
Limnodynastes ornatus	Ornate Burrowing Frog
Notaden weigela *	Weigel's Toad
Uperoleia lithomoda	Stonemason Gungan; Stonemason Toadlet

4. Threats to the Ecology of Ngallagunda Swamp

* This species was undescribed at the time of the survey and recorded as "Notaden sp. nov."

The ambition for management at Ngallagunda Swamp is to maintain those elements of the ecology that make it an excellent example of a freshwater wetland. The critical components of the ecology are the geomorphologic, hydrologic and water quality factors that make the lake an important habitat for aquatic fauna, including invertebrates and birds, and a drought refuge for migratory and domestic waterbirds. These factors are the primary determinants of the lake's ecological character. They are influenced by, and exert an influence on, the vegetation communities that surround the water body, the aquatic invertebrate and benthic vegetation communities that inhabit it and the threatening processes that face all of these. Also of importance are the elements of the system that contribute to its cultural and scientific 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 Ngallagunda Swamp must be considered in relation to their likelihood of causing the failure of the above management goal for the wetland. 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 Table 7. In summary, failure to achieve the management goal for Ngallagunda Swamp is most likely to result from the impacts of cattle pastoralism. Alteration to natural fire regimes and weeds are also significant threats, whilst the impacts of planned development, drought and eutrophication of the water body should also be considered.

The greatest threat to Ngallagunda Swamp is the impact of cattle on the site. At the time of the site visit, there were cattle grazing at the swamp. Although the impacts seemed minor, the resulting disturbance may still create an opportunity for weed species to become established, with cattle also acting as a vector for the transport of plant propagules. Soil disturbance increases the likelihood of erosion and increases the turbidity of the water body. Cattle also introduce additional nutrients to the water body, potentially leading to the development of eutrophic conditions. Preventing the impact of cattle at the site is achievable with stock exclusion fencing.

Altered fire regimes are a major threat to biodiversity across the Kimberley region. The Environmental Protection Authority released an issues paper that details the current and future impacts of changes to the natural frequency and intensity of wildfire in that region (Russell-Smith 2005). That paper found that the season of burning has changed during the period of European occupation of the region. Most Aboriginal burning in the Kimberley occurred through the dry season, whereas today, most fires occur at the end of the dry season. Late dry season fires in the Kimberley today have major impacts across all land use and industry sectors. In particular, firesensitive vegetation in the Kimberley is being severely impacted by intense late dry season fires. It is likely that fires in recent times have had a major impact on small to medium sized animals such as bandicoots. Together with the effects of grazing on grass species and seed availability, fires may be a major impact on many birds. Late dry season fires can also have significant impacts on soil loss, loss of nitrogen in smoke, increased greenhouse gas emissions, and impacts on air quality and human health

In the context of Ngallagunda Swamp, 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. It is very difficult to manage fire in a setting such as the Gibb River area. 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.

Wetlands are highly productive environments, but are also easily disturbed. 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 are introduced via 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 usually make chemical weed control inappropriate. Mechanical control is often complicated by difficulty in accessing infestations.

Fortunately, there is currently little evidence of weed invasion at Ngallagunda Swamp. Although some exotic species were identified at the site, these did not appear to be impacting heavily. The potential for weed propagules to be introduced to the site remains a concern however, particularly as cattle are accessing the water body. Cattle exclusion and appropriate fire management are the best tools available to prevent future weed outbreaks.

Cane toads, introduced into Australia as a biological control, have since become a major pest and are still spreading across Australia. The cane toad is poisonous and adult cane toads can produce venom from glands over their upper surface, but especially from bulging glands on their shoulders – these glands exude the venom when the toad is provoked. While some birds and a few other native predators have learned to avoid the poison glands of adult toads, almost anything that eats the toad dies rapidly from heart failure. Cane toads may also eat native animals, having a heavy impact on some species, particularly those that are already threatened. Adult cane toads may compete with native animals for food (particularly insects) and shelter, for example under rocks and logs. Cane toads may also out-compete native frogs for breeding sites, and their tadpoles may out-compete native tadpoles because they are produced in such large numbers (DEH 2004). Cane toads have now crossed the Western Australian border and are expected to impact on the Kimberley in the near future. It is unclear what effect this will have on the ecology of Ngallagunda Swamp.

The CSIRO predicts that climate change will make the Kimberley 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. As Ngallagunda Swamp is spring fed, it should be spared from the impacts of these changes. However, it is possible that increasing aridity may decrease the flow of the spring, and so, impact on the swamp. Determining the likelihood that this should happen would require a detailed study of the hydrology of the area.

Table 7 – Threat assessment for Ngallagunda Swamp

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 Ngallagunda Swamp, thus ensuring it remains an important habitat for aquatic fauna, and a drought refuge for migratory and domestic waterbirds, and that it retains its cultural and scientific values.

Threat category	Management issue	Probability (%) that threat will cause goal failure with:		Assumptions underlying initial probability assessment and	
Timeat category	Management Issue	Existing management	Extra management	explanatory notes	
Altered biogeochemical processes	Hydrological processes, particularly salinity	0	0	Ngallagunda Swamp is fed by a freshwater spring. The hydrology of that spring is not known. However, the lack of development in the area makes it unlikely that there will be any future hydrological alteration. The planned expansion of the community does not affect the expression of the spring.	
	Carbon cycle and climate change	0	0	Changes to rainfall are expected to be fairly minor in the Kimberley, perhaps as little as 1% over the next 50 years (CSIRO Undated). These are unlikely to affect the swamp, as it is spring fed.	
Impacts of introduced plants and animals	Environmental weeds	10	5	Weeds are identified as one of the primary threats to the ecology of the Pentecost IBRA subregion (Graham 2001). Although Ngallagunda Swamp does not currently appear to be heavily impacted by weeds, its perennial nature and the ongoing grazing activities make it highly susceptible to weed invasion.	
	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. Overgrazing has similar impacts. This threat is readily addressed by fencing the lake to exclude cattle.	
	Predation, competition and other harmful effects from introduced fauna	?	?	Cane toads will pose a significant threat to the fauna of Ngallagunda Swamp. They eat small animals, poison their predators and compete with other animals. It is unclear what the potential impacts of cane toads are, as more information is required on the fauna composition at the site. Cane toads may affect waterbirds, including migratory birds.	
Impacts of problem native species	Overgrazing by native species	0	0	No impacts evident.	
Impacts of disease	Plant pathogens	0	0	No impacts evident.	

Threat category	Management issue	Probability (%) that threat will cause goal failure with:		Assumptions underlying initial probability assessment and		
Timeat category	Management 133de	Existing management	Extra management	explanatory notes		
Detrimental regimes of physical disturbance events	Fire regimes	20	10	Increasing frequency and intensity of late season wildfires are 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 sites.		
	Drought	5	5	Rainfall projections for the Kimberley show that climate change may result in longer periods of drought (CSIRO Undated). It is not known whether a prolonged drought could affect the Ngallagunda Spring.		
	Flood	0	0	Flooding occurs regularly in this area and natural systems are adapted to its influence.		
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 broad scale cropping is practiced in the catchment.		
Impacts of competing land	Recreation management	1	0	There does not appear to be any active recreation usage of this site.		
uses	Nutrient enrichment of water body	5	0	It is likely that cattle accessing the swamp 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	10	0	The area of the spring and swamp is to be avoided in the planned expansion of Ngallagunda Community. Plans show the area as prone to flooding and too low lying to be built on.		
	Consumptive uses	0	0	Any consumptive use of the swamp that is occurring 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	Ngallagunda Swamp is well connected to extensive areas of natural or near- natural environment. Populations are likely to self-supporting in this setting.		

5. Knowledge Gaps and Recommendations for Future Monitoring

There is relatively little knowledge about wetlands of the Kimberley region. The remoteness of the area has resulted in a lack of survey effort. Ngallagunda Swamp appears to be an important wetland site which has been overlooked in wetland studies to date. While the IAI RCM survey has provided a 'snapshot' of the ecological character of Ngallagunda Swamp, repeated surveys are required to provide a better understanding of the ecosystem and to determine trends in the condition of components. The need for long-term monitoring is highlighted by the expansion of the community. Survey work conducted prior to development would provide a good idea of baseline condition. This could then be used to determine if changes are occurring to the ecosystem as a result of development.

Aside from a single frog survey in 1985, there have been no previous studies of Ngallagunda Swamp. Therefore, there are significant knowledge gaps in all aspects of the swamp's ecology. Vegetation surveys would be of particular benefit; unfortunately the samples collected as part of this survey were damaged and identification to species level was not possible in most cases. The aquatic macroinvertebrate fauna included some possibly undescribed species that warrant further investigation. There were also some major groups missing from the fauna, and the diversity of water mites was also lower than expected for this type of wetland. Repeated surveys are required to determine if this was a result of sampling methods (such as the time of year) or if this was caused by other factors.

A large diversity of frogs were found at Ngallagunda Swamp by Tyler *et al.* (1987). The survey was conducted some time ago and so further surveys are required to update this information. This may be useful information considering cane toads are expected to invade the Kimberley in the near future. A comprehensive fauna inventory of Ngallagunda Swamp would be beneficial to determine the impacts cane toads may have.

Repeated waterbird surveys are also required. Only four species of waterbird were observed at the swamp during the IAI RCM survey. Considering the wetland's outstanding water quality, very high aquatic invertebrate richness, dense vegetation cover and remote location, it is highly likely that many more species occur here. Of the four species observed during the IAI RCM survey, one was a CAMBA listed waterbird (see section 1.3). It is possible that this is a significant migration stop-over and refuge for other migratory birds. However, repeated surveys would be required to determine this.

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