Department of
Environment and Conservation
Our environment, our future

Resource Condition Report for a Significant Western Australian Wetland

Lake Goorly

2008

Figure 1 – A view along the shore of Lake Goorly.

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Contents

1. Introduction

This Resource Condition Report (RCR) was prepared by the Inland Aquatic Integrity Resource Condition Monitoring project (IAI RCM). It considers the ecological character and condition of Lake Goorly, an intermittent saline lake in the Yarra-Monger Catchment.

The main body of Lake Goorly is an irregularly shaped basin, approximately 20 km in length. It is surrounded by a number of claypans and smaller saline lakes that are hydrolgically linked to the main lake. The IAI RCM survey was conducted in one of these peripheral lakes, at the southern end of the system.

1.1. Site Code

Inland Aquatic Integrity Resource Condition Monitoring Project: RCM022.

Salinity Action Plan Wetland Biological Survey: SPS144.

South West Wetlands Monitoring Program: SWWMP_GOOR.

1.2. Purpose of Resource Condition Report

This RCR provides a summary of information relevant to the ecology of Lake Goorly. This information is then used to describe the drivers of, and threats to, the wetland ecosystem. The resultant 'snapshot' of ecological character will provide context for future monitoring of the lake and assist with assessing the effectiveness of management planning and actions on the property.

2. Overview of Lake Goorly

2.1. Location and Cadastral Information

Lake Goorly is in the Shire of Dalwallinu, approximately 30 km north-northwest of Kalannie (Figure 2). The lake is located on Unallocated Crown Land and surrounded by freehold land. The predominant land uses in the area are wheat cropping and grazing sheep. A gypsum mine is located in the north-western part of the lake.

2.2. IBRA Region

Lake Goorly lies within the Western subregion (AW2) of the Avon Wheatbelt Interim Bioregionalisation of Australia (IBRA) region. This region is a dissected plateau of tertiary laterite on the Yilgarn Craton. The western subregion comprises gently undulating rises to low hills with abrupt breakaways. The vegetation consists primarily of proteaceous scrubheaths, rich in endemic species (Beecham 2003).

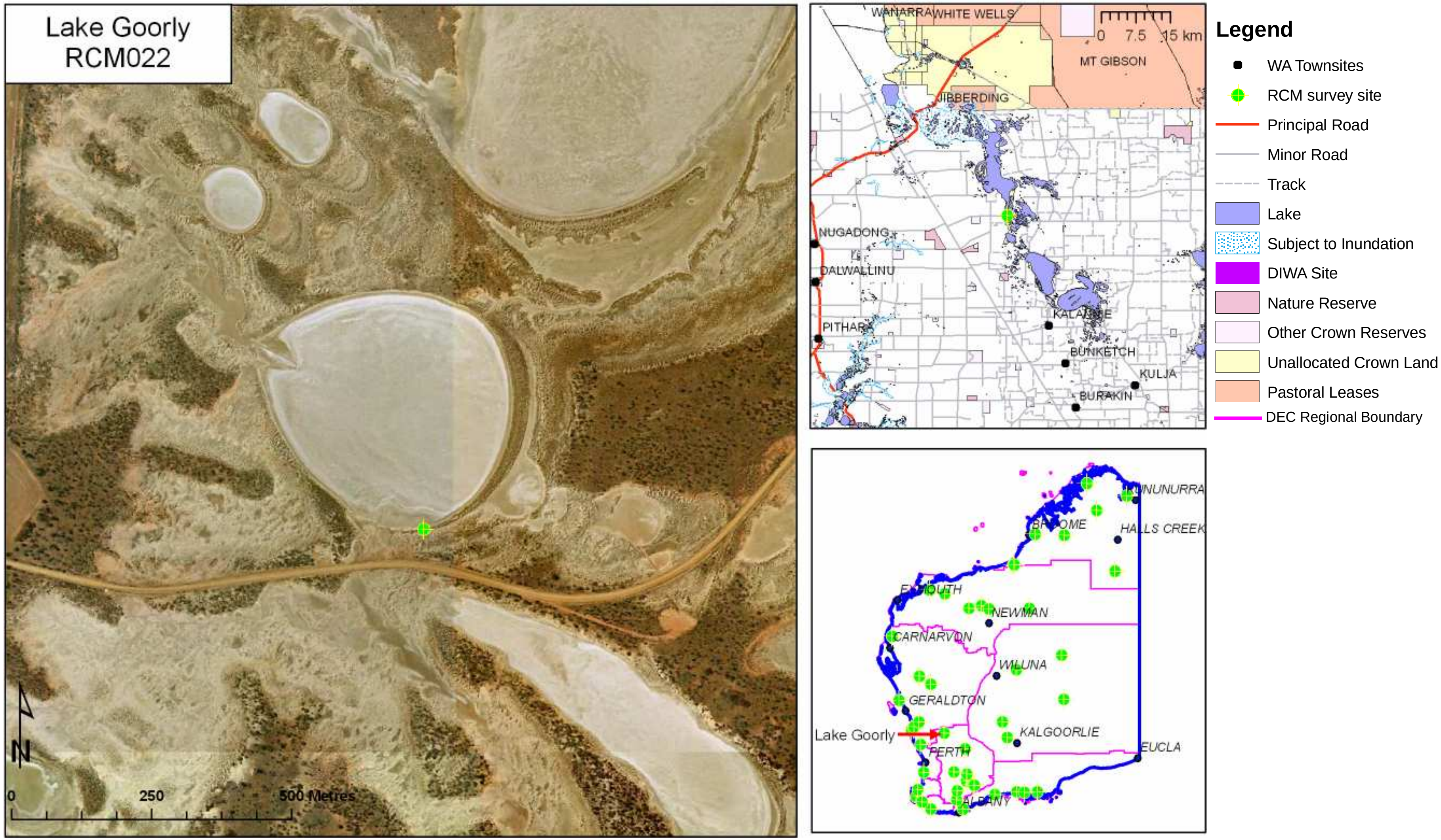

Figure 2 – Aerial photograph showing the survey location at Lake Goorly. The upper insert shows the location of the survey site relative to the surrounding lake system. The lower insert shows the location of the lake in Western Australia and in relation to the remaining RCM survey sites.

2.3. Climate

The nearest Bureau of Meteorology weather station to Lake Goorly is at Dalwallinu (Bureau of Meteorology 2009), where records have been kept since 1912. Climatic conditions at Lake Goorly would not differ appreciably from those at Dalwallinu.

Dalwallinu experiences a semi-arid, warm Mediterranean climate. It receives a mean annual rainfall of 357.3 mm with 60% of this falling between May and August (Figure 3). Annual evaporation at Dalwallinu is approximately 2,400 mm.

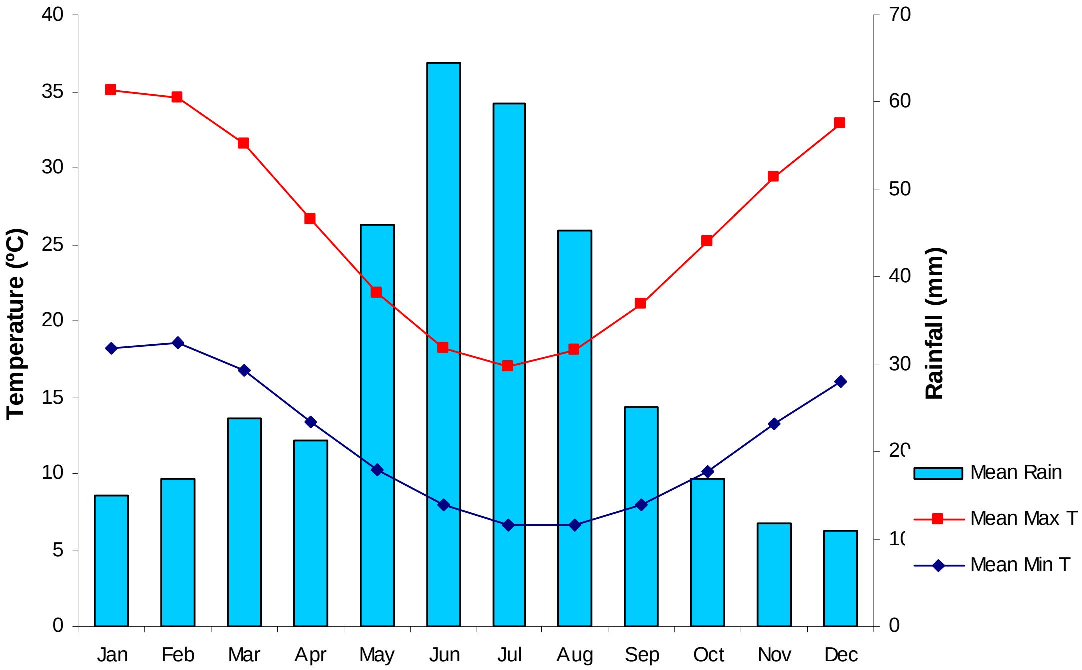

Figure 3 – Climatic means for Dalwallinu, approximately 40 km southwest of Lake Goorly.

Lake Goorly was surveyed by the IAI RCM project on the 25^{th} of August 2008. In the six months preceding the survey, Dalwallinu received 236.2 mm of rain. The majority of this fell in July (97.4 mm), February (51.6 mm) and April (43.8 mm) with 2.2 mm falling in the first 25 days of August.

2.4. Wetland Type

Lake Goorly is a large, irregular basin wetland. It is saline and intermittent. The floor of the lake is composed of gypsum.

2.5. Values of Lake Goorly

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

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

a. Consumptive use

Consumptive use is gaining benefit from products derived from the natural environment, without these products going through a market place. For example, the collection and personal use of firewood or 'bushtucker'. There are no known contemporary consumptive uses of Lake Goorly.

b. Productive use

Productive use values are derived from market transactions involving products derived from the natural environment. For example, firewood may be collected and sold or exchanged for another commodity or commercial cattle may be grazed on native grasses. Lake Goorly Gypsum Mine extracts up to 70,000 tonnes of gypsum per annum from the lake floor. In this context, the wetland is valued because it contributes to the productivity of a commercial enterprise.

c. 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 Goorly, in itself, would make a relatively small contribution to the ecosystem services delivered by the region's natural biodiversity. That said, given the parlous state of the global environment, every small contribution is important.

d. Amenity

Amenity describes features of the natural environment that make life more pleasant for people. For instance, pleasant views, shade or wind shelter provided by a stand of trees. It is difficult to quantify the amenity value of a site such as Lake Goorly, but it is likely valued by the local community for the amenity it provides.

e. 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 may also be considered 'control' sites that allow us to benchmark other, altered habitats. Lake Goorly is a characteristic degraded primarily saline system with altered hydrology. As such, it presents opportunities for education and scientific research on the topics of wetland management and rehabilitation.

f. 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 Goorly may be used by the local community as a passive recreation site for activities such as bird watching.

g. Spiritual/philosophical values

People's spiritual and philosophical reasons for valuing the natural environment are numerous and diverse. One commonly cited is the 'sense of place' that people derive from elements of their environment. This is evident in many Aboriginal and rural Australians, who strongly identify themselves with their natural environment. Many people also believe that nature has inherent value or a right to exist that is independent of any benefit delivered to humans. A sense of spiritual well-being may be derived from the knowledge of healthy environments, even if the individual has no contact with them. Lake Goorly is part of the Mongers Lake Waterway, which has been recognised as a mythological site by the Department of Indigenous Affairs (DIA 2009).

h. 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. Any taxa or ecosystem that is lost represents lost opportunities.

The intent of nature conservation is usually to maintain the ecosystem services, scientific and educational uses and opportunities for future uses at a given site. Doing so is likely to have positive effects on the amenity, recreational potential 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 Goorly is certainly highly valued by the owners and operators of Lake Goorly Gypsum Mine 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 Goorly

The objective of the Lake Goorly RCR is to compile information relevant to the ecology of the wetland's ecosystem. By doing so, it is possible to identify the critical components and drivers of the wetland. These components and processes determine the site's ecological character and are the variables that should be assessed 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 its hydrological regime. Position and hydrology, in turn, exert a strong influence on the physiochemical properties of the water column and the biota that utilise it.

A summary of Lake Goorly's critical ecosystem components is presented in Table 1. This is followed by a description of the results of the IAI RCM 2008 survey. Some data from previous studies of the site are also presented.

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

Component	Summary description
Geomorphology	Irregular saline basin situated in the Yilgarn Craton with lacustrine deposits (clay and silt)
Hydrology	One of an extensive chain of lakes in the Yarra Monger Catchment; uncoordinated drainage
Water Quality	Saline: TDS 120 gL^{-1} at the time of survey; high nitrogen, phosphorous and chlorophyll levels
Benthic Plants	None
Littoral Vegetation	Samphire-dominated (*Tecticornia* spp.)
Invertebrates	15 species from 12 families known; all common and widespread taxa
Fish	None
Waterbirds	Eleven species recorded, including Hooded Plover

3.1. Geology and Soils

Lake Goorly lies on Quaternary salt lake deposits of lacustrine silt and clay. Soils surrounding the lake consist of alluvial and colluvial deposits (transported clay, sand, lithic fragments) and residual deposits (sand, clay, duricrust). The Yarra Yarra Catchment, within which the lake lies, is a basin that is rimmed with granitic outcrop (Fordyce 2005).

Gradients are extremely low throughout the region, and the distinction between valley floor and valley sides is not always obvious. There is only about 40 m fall along the Lake Goorly salt lake chain (Fordyce 2005).

3.2. Hydrology

Lake Goorly is located in the Yarra Monger Catchment within the Yarra Yarra Drainage Basin. It is part of a chain of several thousand ephemeral saltlakes, playas and samphire-covered claypans, that stretch for approximately 300 km and cover an area of 250,000 ha. The major lakes in the system include Nullewa Lake, Weelhamby Lake, Mongers Lake, Lake DeCourey, Lake Hillman and Yarra Yarra Lake, which is the terminal point of the system (Fordyce 2005).

Due to the flat terrain of the Yarra Yarra system, drainage is generally uncoordinated and each lake has its own internal drainage system (Fordyce 2005; NACC 2005). In wet years, the lakes overflow along a broad drainage line, ending in Yarra Yarra Lake (NACC 2005). However, in most years surface water does not flow through the system. Instead, it ponds in waterlogged depressions or poorly defined drainage lines, and eventually infiltrates to the groundwater. The system's drainage lines, along with the broad valley floors that host them, are becoming progressively saltier as saline groundwater nears the surface. Across much of the subregion, groundwater is currently within 1-2 m of the surface (Fordyce 2005).

It is uncertain if there is a surface or groundwater connection between Yarra Yarra Lake and the Coonderoo River, a tributary of the Moore River. It is believed that during the Eocene Epoch (40 million years ago) the system drained southwards, along the Darling Fault, to discharge through the Brockman River Valley (NACC 2005).

3.3. Water Quality

Lake Goorly is saline and gypsum dominated. Salinity varies substantially with the volume of water in the lake. In 1991, the lake was 30 cm deep and had a salinity of 50 g/L whereas in 2008 it was shallower and more saline (120 g/L). The concentration of nutrients and chlorophyll in the water (Table 2) were high and indicate nutrient enrichment from surrounding agricultural lands. This is supported by the moderately high chlorophyll concentration in 1991. High salinity probably prevented such algal growth in 2008.

Table 2 – Water quality data recorded in Lake Goorly by DEC surveys in 1991 and 2008.

	SPS144 Aug 1991	**RCM022 Aug 2008**
pH	9.69	8.22
Alkalinity (mg/L)	60	70
TDS (g/L)	52	120
Turbidity (NTU)	7.6	44
Colour (TCU)	8	5
Total nitrogen (μg/L)	-	4,200
Total phosphorus (μg /L)	-	280
Total soluble nitrogen (μg /L)	1,400	1,900
Total soluble phosphorus (μg /L)	30	5
Chlorophyll (μg /L)	56	6.5
Na (mg/L)	16,700	53,200
Mg (mg/L)	1,060	4,860
Ca (mg/L)	420	1,400
K (mg/L)	406	1,110
Cl (mg/L)	29,000	77,200
SO_4 (mg/L)	2,040	9,380
HCO_3 (mg/L)	73	85
CO_3 (mg/L)	1	0.5

3.4. Benthic Plants

Lake Goorly is too saline to support benthic plants.

3.5. Littoral Vegetation

Two transects were established in the fringing vegetation on the southern side of Lake Goorly on the 25th August 2008 (Table 3). These sites were representative of the samphire-dominated vegetation communities surrounding Lake Goorly.

Table 3 – Site attributes of the Lake Goorly vegetation transects.

Transect		R1	R2
Datum		WGS84	WGS84
Zone		50	50
Easting		503500	503508
Northing		6664776	6664761
Length		30 m	50 m
Bearing		60	60
Wetland state		Full	Full
Soil state (%)	Dry	100	100
	Waterlogged	0	0
	Inundated	0	0
Substrate (%)	Bare	60	70
	Rock	0	0
	Cryptogam	0	1
	Litter	2	1
	Trash	0	0
	Logs	0	0
Time since last fire		fire unlikely here	fire unlikely here
Community condition		Natural	Impacted
Upper Stratum	Cover (%)	-	-
	Height (m)	-	-
Mid Stratum	Cover (%)	19.6	11.56
	Height (m)	<0.5	<0.5
Ground Cover	Cover (%)	6.43	23.92
	Height (m)	<0.3	<0.1

Transect RCM022-R1

Transect R1 was established within 10 m of the water's edge (Figure 4). The sandy soil was dry at the surface. Vegetation was dominated by *Tecticornia halocnemoides*, *T. peltata* low open chenopod shrubland (19.6% cover, <0.5 m tall) over low sparse herbs and grasses (Table 4).

Recruitment of samphires was evident with seedlings abundant across this transect. No weeds were recorded along this transect. The overall community condition was considered 'natural' (Table 11 in Appendix 1).

Podotheca uniseta is a species of conservation significance, with a limited range southeast of Geraldton, currently listed as 'Priority Three' (Atkins 2008). Isolated plants of this species were scattered along this transect.

Figure 4 – Lake Goorly vegetation transect RCM022-R1.

Table 4 – Plant taxa recorded along vegetation transect RCM022-R1 (in order of stratum then dominance).

Genus	Species	Height (m)	Stratum[1]	Form
Tecticornia	*halocnemoides*	0.5	M1	Chenopod
Tecticornia	*peltata*	0.4	M1	Chenopod
Senecio	*pinnatifolius*	0.4	M1	Forb
Lawrencia	*squamata*	0.02	M1	Shrub
Stenopetalum	*salicola*	0.3	G1	Forb
Podotheca	sp.	0.1	G1	Forb
Wurmbea	*tenella*	0.1	G1	Forb
Gnephosis	*acicularis*	0.15	G1	Forb
Eragrostis	*?pergracilis*	0.01	G1	Grass
Podotheca	*uniseta* (P3)	0.1	G1	Forb
?Pogonolepis	*stricta*	0.03	G1	Forb
Triglochin	*calcitrapa*	0.05	G1	Forb
Disphyma	*crassifolium* subsp. *clavellatum*	0.05	G1	Shrub

1 In an NVIS description, ‘U’ denotes the upper storey, ‘M’ the mid storey and ‘G’ the under storey (ground cover). Numerals to denote substrata from tallest to smallest (ESCAVI 2003).
? Limited confidence in identification

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

M1+ ^*Tecticornia halocnemoides*, *T. peltata*\samphire shrub\1\i; G1 ^*Stenopetalum salicola*, *Podotheca* sp., *Wurmbea tenella*, *Gnephosis acicularis*, *Eragrostis ?pergracilis*\ forb, tussock grass\1\r.

Transect RCM022-R2

This transect was established approximately 30 m from the water’s edge (Figure 5). The soil was white sand, which was dry at the time of survey. Vegetation was dominated by low *Tecticornia halocnemoides*, *Lawrencia squamata*, *T. peltata* open chenopod shrubland (11.6% cover, <0.5 m tall) over a mixed open ground cover (Table 5).

Recruitment of samphires was evident with seedlings abundant. No weeds were recorded along this transect. The overall community condition was considered ‘natural’ despite erosion evident across a small portion of the site (Table 11 in Appendix 1).

Figure 5 – Lake Goorly vegetation transect RCM022-R2.

Table 5 – Plant taxa recorded along vegetation transect RCM022-R2 (in order of stratum then dominance).

Genus	Species	Height (m)	Stratum[1]	Form
Tecticornia	*halocnemoides*	0.4	M1	Chenopod
Lawrencia	*squamata*	0.3	M1	Shrub
Tecticornia	*peltata*	0.5	M1	Chenopod
Maireana	*atkinsoniana* (pictured below)	0.4	M1	Chenopod
Sclerolaena	*eurotioides*	0.3	M1	Chenopod
Didymanthus	*roei*	0.4	M1	Chenopod
Senecio	*pinnatifolius*	0.3	M1	Forb
Disphyma	*crassifolium* subsp. *clavellatum*	0.1	G1	Shrub
Atriplex	*vesicaria*	0.2	G1	Chenopod
Eragrostis	*?pergracilis*	0.02	G1	Grass
?Pogonolepis	*stricta*	0.05	G1	Forb
Stenopetalum	*salicola*	0.2	G1	Forb
Drosera	*zigzagia*	0.1	G1	Forb
Frankenia	sp.	0.15	G1	Shrub
Podotheca	sp.	0.05	G1	Forb
Wurmbea	*?dioica*	0.05	G1	Forb
Dithyrostegia	*amplexicaulis*	0.1	G1	Forb
Triglochin	*calcitrapa*	0.05	G1	Forb

1 In an NVIS description, ‘U’ denotes the upper storey, ‘M’ the mid storey and ‘G’ the under storey (ground cover). Numerals to denote substrata from tallest to smallest (ESCAVI 2003).
? Limited confidence in identification

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

M1+ ^*Tecticornia halocnemoides*, *Lawrencia squamata*, *Tecticornia peltata*, *Maireana atkinsoniana*\samphire shrub, shrub, chenopod shrub\1\c; G1 ^*Disphyma crassifolium* subsp. *clavellatum*, *Atriplex vesicaria*, *Eragrostis ?pergracilis*\shrub, chenopod shrub, tussock grass\1\i.

Figure 6 – *Maireana atkinsoniana* at Lake Goorly.

3.6. Aquatic Invertebrates

This lake was coded SPS144 during the Biological Survey of the Western Australian Agricultural Zone by Pinder et al. (2004). Primary salt lakes such as this one have naturally low diversity. The decrease in macroinvertebrate family richness from 7 to 4 between 1991 and 2008 (Table 6) is entirely explainable by the higher salinity in 2008 (120 g/L compared to 50 g/L in 1991). The higher salinity is due to shallower depth (18 cm) in 2008 compared to 1991 (30 cm). All species recorded from the Lake Goorly are widespread species (Table 7).

Table 6 – Summary of findings of aquatic invertebrate surveys of Lake Goorly in 1991 and 2008.

Diversity measure	**SPS144 Aug 1991**	**RCM022 Aug 2008**
Total invertebrate species richness	15	-
Macroinvertebrate species richness	9	-
Total invertebrate family richness	12	-
Macroinvertebrate family richness	7	4

Table 7 – Aquatic invertebrate species identified from Lake Goorly in 1991 and 2008. Time constraints on the 2008 survey prevented species level identification.

Class	Order	Family	Lowest ID	SPS144 Aug 1991	RCM022 Aug 2008
Crustacea	Anostraca	Branchiopodidae	*Parartemia informis*	✓	▪
			Parartemia sp.	▪	✓
	Cladocera	Chydoridae	Chydoridae	✓	▪
		Daphniidae	*Daphniopsis truncata*	✓	▪
	Ostracoda	Cyprididae	*Australocypris insularis*	✓	▪
			Diacypris compacta	✓	▪
			Platycypris baueri	✓	▪
	Copepoda	Cyclopidae	*Meridiecyclops baylyi*	✓	▪
Crustacea	Isopoda	Oniscidae	*Haloniscus searlei*	✓	▪
Insecta	Coleoptera	Dytiscidae	*Necterosoma penicillatus*	✓	▪
		Hydrophilidae	*Berosus munitipennis*	✓	▪
		Staphylinidae	Staphylinidae	▪	✓
	Diptera		unidentified Diptera	✓	▪
		Ceratopogonidae	*Monohelea* sp. 3 (SAP)	✓	▪
		Tabanidae	Tabanidae	✓	▪
		Ephydridae	Ephydridae	▪	✓
		Chironomidae	Chironomidae	▪	✓
			Procladius paludicola	✓	▪
			Tanytarsus fuscithorax/ semibarbitarsus	✓	▪

3.7. Fish

Fish were not observed during the IAI RCM survey and there are no previous records of fish in Lake Goorly.

3.8. Waterbirds

Two species of waterbird were observed at Lake Goorly during the IAI RCM survey: Red-necked Avocet and Banded Stilt. Both of these species have been recorded previously at the site by the Salinity Action Plan Wetland Biological Survey. That project recorded eleven species of waterbird at the site, none of which are protected by international migratory treaties (Table 8).

The low waterbird species diversity at Lake Goorly may partly be attributed to meagre survey effort at the site. Another important factor is likely to be the lack of upper storey vegetation. The littoral vegetation is primarily composed of chenopod shrubland, so there is little diversity of roosting and breeding habitat for waterbirds.

The Hooded Plover is a significant species as it is classified as 'near threatened' on the IUCN Red List with its population declining (IUCN 2009). The species is endemic to Australia with 3,000 individuals of the eastern subspecies, *rubricollis*, and 4,000 individuals of the *tregellasi* subspecies. Predation by foxes is probably the main threat to Hooded Plovers in Western Australia, but it is not known whether this constrains the population. Pollution of lakes may also affect the western population (IUCN 2009).

Table 8 – Waterbirds observed at Lake Goorly (numbers indicate abundance).

	Survey code and date	SPS	RCM
Common name	**Latin name**	**18/08/1999**	**25/08/2008**
Australasian Shoveler	*Anas rhynchotis*	1	
Australian Shelduck	*Tadorna tadornoides*	25	
Banded Stilt	*Cladorhynchus leucocephalus*	671	410
Grey Teal	*Anas gracilis*	24	
Gull-billed Tern	*Gelochelidon nilotica*	38	
Hooded Plover	*Thinornis rubricollis*	1	
Red-capped Plover	*Charadrius ruficapillus*	36	
Red-necked Avocet	*Recurvirostra novaehollandiae*	235	50
Silver Gull	*Larus novaehollandiae*	1	
White-faced Heron	*Egretta novaehollandiae*	3	
Whiskered Tern	*Chlidonias hybridus*	1	

3.9. Terrestrial Vertebrates

No evidence of other fauna was observed during the IAI RCM survey. There are also no WA Museum fauna records within 5 km of Lake Goorly.

4. Interactions between Ecological Components at Lake Goorly

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. Table 9 summarises the interactions between key components and processes at Lake Goorly. The table lists the components that are directly responsible for the provision of each service or benefit of the wetland and the biotic and abiotic factors that support or impact these components. Also listed, are the key threats that may affect the components or processes. This information assists in the identification of the primary determinants of ecological character.

Table 9 – The relationship between the services and benefits delivered by Lake Goorly and the key components and processes that support them.

Benefit or Service	Component	Factors Influencing Component		Threats and Threatening Activities
		Biotic	Abiotic	
Productive Value Gypsum mine	Gypsum/lake floor	None	Geomorphology Sediments	Increased inundation due to groundwater rise
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	Alteration to hydrology due to climate change, groundwater extraction or catchment perturbation Overexploitation by gypsum mine Grazing by stock and introduced pest animals Weeds
Recreational Value Bird watching Picnicking Bush walking Photography	Landscape amenity Waterbird populations Vegetation communities Significant flora Significant fauna	Aquatic invertebrates Vegetation communities	Hydrology Water quality Habitat extent and distribution Soils and sediments	Alteration to hydrology due to climate change, groundwater extraction or catchment perturbation Overexploitation by gypsum mine Grazing by cattle and introduced pest animals Weeds Predation by introduced fauna Lack of native vegetation in surrounding area Grazing by stock and introduced pests Pugging by stock Excessive nutrient inputs from stock or mine Loss of migratory bird populations due to offsite factors
Spiritual/Cultural Value The wetland is of outstanding historical or cultural significance	Mongers Lake Waterway	Fauna communities Vegetation communities	Geomorphology Hydrology Soils and sediments Water quality Habitat extent and distribution	Alteration to hydrology due to climate change, groundwater extraction or catchment perturbation Overexploitation by gypsum mine Grazing by cattle and introduced pest animals Weeds Predation by introduced fauna Lack of native vegetation in surrounding area Grazing by stock and introduced pests Pugging by stock Excessive nutrient inputs from stock or mine Loss of migratory bird populations due to offsite factors

5. Threats to the Ecology of Lake Goorly

The ambition for management at Lake Goorly is to maintain the primary determinants of the site's ecological character. These are the geomorphologic, hydrologic and water quality factors that make the lake a suitable habitat for domestic waterbirds and priority plant species. The primary determinants of ecological character are influenced by, and exert an influence on, the plant 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 values.

Threats to Lake Goorly must be considered in relation to their likelihood of causing failure of the above management goal for the lake. An assessment was 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 10. In summary, failure to achieve the management goal for Lake Goorly is most likely to result due to the effects of land clearing in the catchment, leading to altered hydrology and salinisation. The impacts of mining on the lake floor and pollution from the surrounding agricultural land are also significant threats.

Altered hydrology and secondary salinity

Secondary salinisation is the greatest threat to wetlands of the Western Australian Wheatbelt (George *et al.* 1995; Williams 1999; Halse *et al.* 2003). It occurs when the water table rises in response to increased water infiltration and reduced evapotranspiration following the clearing of native vegetation. Rising groundwater dissolves salt that was previously stored in the soil above the water table and transports it to the soil surface. The combination of soil waterlogging and high concentrations of salt causes a number of impacts, including the death of vegetation and disruption of soil structure (Mulcahy 1978; Ruprecht and Schofield 1991; George *et al.* 1995; Halse *et al.* 2003).

Lake Goorly is a primarily saline wetland and so, under a natural water regime, is often highly saline. Secondary salinisation of such 'salt lakes' results in an increase in the extent and period of inundation. The resultant soil waterlogging kills vegetation. Disruption of the natural cycle of wetting and drying, and associated changes to water chemistry, disrupt the life cycle of aquatic invertebrate taxa. In these ways, secondary salinisation is highly damaging to primary saline wetlands.

Barriers to the flow of surface water or groundwater can exacerbate the effects of water table rise. For example, roads block the flow of water through the landscape, causing inundation of upstream land. This can be seen at the Lake Goorly survey location, where Glamoff Road impedes water drainage and upstream vegetation has been killed by waterlogging.

Salinisation and waterlogging have been recognised as significant threats region-wide by the Yarra Yarra Catchment Management Group. One strategy proposed to address these issues is to drain excess water from the landscape through a network of deep drains that empty into the salt-lake system. The drainage lines would then be revegetated (Fordyce 2005). Salinisation and waterlogging will then be prevented from redeveloping by:

(i) maintaining the deep-drainage network;

(ii) managing groundwater recharge through surface-water management plans and by encouraging revegetation in the sandy, upland areas; and

(iii) setting up a hydrological monitoring system of wells, piezometers and flow meters.

It is hoped biodiversity values would be enhanced by draining threatened patches of remnant vegetation, increasing the total vegetated area of the landscape and connecting isolated remnants by constructing environmental corridors (Fordyce 2005). However, such deep drainage carries risks such as the exposure of acid sulphate soils and the degradation of down stream ecosystems. Its effectiveness as a solution to regional water table rise is also unproven.

Mining

Gypsum is mined from the bed of Lake Goorly. An assessment by the Environmental Protection Agency (EPA) concluded there are no significant emissions or discharges associated with the mine, and that the mine is of low environmental risk.

Mining alters the geomorphology of the lake, the impacts of which are unknown. There is also a risk of minor dust emissions, which could affect nearby vegetation. Noise from the site might be disruptive to birds. No discharges to the lake are authorised; however, the risk of accidental discharge always exists.

Climate change

Climate change modelling conducted by the CSIRO predicts that rainfall received by the southwest of WA will decline by as much as 20% by 2030 and 60% by 2070, relative to 1990 figures (EPA 2007). The impacts of this on the Lake Goorly ecosystem are difficult to predict and should be monitored. It is likely that climate change may lead to alteration in wetland extent and hydrology. Given the current impacts of excess water in the system, decreased rainfall could yield some benefits.

Table 10 – Threat assessment for Lake Goorly.

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 Goorly, thus ensuring it remains a suitable habitat for waterbirds and priority flora, 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	60	20	The hydrology of Lake Goorly is being affected by historic land clearing and it is evident water tables are rising. This has caused waterlogging of soils and likely prolonged inundation.
	Carbon cycle and climate change	5	5	CSIRO modelling predicts that rainfall received by the southwest of WA will decline by as much as 20% by 2030 and 60% by 2070, relative to 1990 figures (EPA 2007). However, without a detailed knowledge of the hydrology of Lake Goorly, it is difficult to predict how climate change may affect the wetland.
Impacts of introduced plants and animals	Environmental weeds	1	0	No weeds were recorded from Lake Goorly. However, given the highly cleared surrounding, Lake Goorly is susceptible to future weed invasions and this should be monitored.
	Herbivory, wallowing and trampling by introduced species	5	1	Land surrounding Lake Goorly appears to be primarily used for cropping, rather than keeping stock. Rabbits are likely present in the area and may graze on the vegetation.
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	0	0	The vegetation is not susceptible to fire.
	Drought	0	0	Due to the ephemeral & seasonal nature of Lake Goorly, most species would be considered naturally adapted to these prolonged periods.
	Flood	5	5	Alteration to rainfall and hydrological fluxes, associated with global climate change may impact on the vegetation of Lake Goorly. The nature of the impacts is not clear and should be monitored.
Impacts of pollution	Herbicide, pesticide or fertiliser use and direct impacts	10	5	Extensive clearing of the native vegetation surrounding Lake Goorly has resulted in increased runoff from surrounding agriculture. This has likely resulted in elevated nutrient levels within the wetland.

Threat category	Management issue	Probability (%) that threat will cause goal failure with:		Assumptions underlying initial probability assessment and explanatory notes
		Existing management	Extra management	
Impacts of competing land uses	Recreation management	1	0	Any recreational usage of Lake Goorly is low impact and is not having any deleterious impacts.
	Nutrient enrichment of water body	5	0	It is likely that stock accessing the lake will result in nutrient enrichment of the waterbody.
	Urban and industrial development	0	0	There are no plans of development in the foreseeable future.
	Consumptive uses	0	0	There is no evidence of consumptive use of Lake Goorly.
	Illegal activities	0	0	No evidence of any threat.
	Mines and quarries	20	5	The Lake Goorly Gypsum Mine may be affecting the condition of the wetland. Although the EPA has assessed the mine to be of low environmental risk, the EPA's assessment did not consider the affect mining activities have on visiting waterbirds, particularly the shore nesting, near-threatened Hooded Plover.
Insufficient ecological resources to maintain viable populations	Habitat, genetic exchange	5	1	Lake Goorly is located within a largely cleared landscape. It is connected to Lake Moore in the Ninghan catchment by the 'Goodlands Environmental Link', an initiative of the Goodlands Landcare Conservation District, which has been functioning as a wildlife corridor since 1997. Populations are likely to self-supporting in this setting.

6. Knowledge Gaps and Recommendations for Future Monitoring

Vegetation clearing in the catchment of Lake Goorly has almost certainly caused alteration to the hydrology of the system. The gypsum mine on the lake bed may also be influencing the local hydrology. The relative magnitude of these changes and their implications cannot be quantified as no detailed studies of the hydrology of the lake have been conducted.

Aquatic invertebrates and waterbirds have been surveyed twice at Lake Goorly: by the RCM and SPS surveys. Vegetation was also surveyed by the RCM project. While these surveys provide some indication of the biodiversity and condition of the lake, there are not enough data to detect any trends in condition. These two surveys are also unlikely to have described the full suite of species present. Therefore, further surveys would be of benefit, particularly to capture seasonal variations.

On a subregional scale, data gaps include (Beecham 2003):

- vegetation and regional ecosystem mapping, including soil-landscape unit mapping;
- ecological and life history data, systematic fauna surveys for birds, small terrestrial mammals, reptiles and select invertebrate groups across the landscape; also measures of various habitat and landscape variables; and
- a knowledge of fire regimes and histories for reserves and areas of remnant vegetation, and data on the effects of fire on flora and fauna based on their life history attributes.

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Appendix 1 – Vegetation Condition

Table 11 – Overall Vegetation Community Condition Rating as adapted from Thackway and Lesslie (2005). Shading indicates the condition of Hutt Lagoon.

Overall Community Condition Rating					
	0	**1**	**2**	**3**	**4**
Community Condition Class	**RESIDUAL BARE**	**NATURAL**	**IMPACTED**	**DEGRADED**	**REMOVED/REPLACED**
	Areas where native vegetation does not naturally persist	Native vegetation community structure, composition and regenerative capacity intact - no significant perturbation from land management practices	Native vegetation community structure, composition and regenerative capacity intact but perturbed by land management practices	Native vegetation community structure, composition and regenerative capacity significantly altered by land management practices	Species present are alien to the locality and either spontaneous in occurrence or cultivated. Alternatively, vegetation may have been removed entirely
Regenerative Capacity	Natural regenerative capacity unmodified - ephemerals and lower plants	Regenerative capacity intact. All species expected to show regeneration are doing so	Natural regenerative capacity somewhat reduced, but endures under current/past land management practices	Natural regenerative capacity limited and at risk due to land management practices. Rehabilitation and restoration possible through removal of threats	Regenerative potential of native vegetation has been suppressed by ongoing disturbances. There is little potential for restoration
Vegetation Structure	Nil or minimal	Structural integrity of native vegetation is very high. All expected strata, growth forms and age classes are present	Structure is altered but persists, i.e. some elements of a stratum are missing	Structure of native vegetation is significantly altered, i.e. one or more strata are missing entirely	All structural elements of native vegetation are missing or highly degraded
Vegetation Composition	Nil or minimal	Compositional integrity of native vegetation is very high. All species expected at the site are present	Composition of native vegetation is altered. All major species are present, although proportions may have changed. Some minor species may be missing	Significant species are missing from the site and may have been replaced by opportunistic species. Loss of species affects structure of vegetation	Native vegetation removed entirely +/- replaced with introduced species

Appendix 2 – Herbarium Plant Records

Plant specimens submitted to the Western Australian Herbarium:

Drosera zigzagia (RCM022-R2-16)
Podotheca uniseta (RCM022-R1-07)

Table 12 – Herbarium Records for Lake Goorly.

Search Coordinates: NW corner 30.1023°S, 117.0083° E; SE corner 30.1701°S, 117.0712°E

Family	Species	Alien	Cons. Status
Aizoaceae	*Disphyma crassifolium*		
	Gunniopsis glabra		
Asteraceae	*Cotula cotuloides*		
	Podotheca pritzelii		P2
	Trichanthodium exile		
Brassicaceae	*Stenopetalum salicola*		
Caryophyllaceae	*Spergularia* sp. 1 Mollerin		
Chenopodiaceae	*Sclerolaena eurotioides*		
	Tecticornia disarticulata		
	Tecticornia halocnemoides		
	Tecticornia peltata		
	Roycea spinescens		
	Sarcocornia globosa		
	Tecticornia undulata		
Frankeniaceae	*Frankenia* aff. *laxiflora*		
Gyrostemonaceae	*Gyrostemon ramulosus*		
Mimosaceae	*Acacia coolgardiensis*		
	Acacia sp. Wubin (B.R. Maslin 4131)		
Myrtaceae	*Eucalyptus salicola*		
Papilionaceae	*Bossiaea spinescens* Meisn.		
Plumbaginaceae	*Limonium lobatum*	Y	
Ranunculaceae	*Clematis delicata*		
Solanaceae	*Solanum nummularium*		