Department of
Environment and Conservation

Our environment, our future

Resource Condition Report for a Significant Western Australian Wetland

Lake MacLeod System

2009

Figure 1 – The 'Northern Ponds' at Lake MacLeod.

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Contents

1. Introduction

This Resource Condition Report (RCR) was prepared by the Inland Aquatic Integrity Resource Condition Monitoring (IAI RCM) project. It discusses the ecological character and condition of Lake MacLeod, an expansive and complex wetland system in the Gascoyne region. The Lake MacLeod system incorporates a number of different wetland types, including sinkholes, channels, lakes and marshes that are permanently inundated due to a subterranean connection with the ocean. The main lake bed is primarily fed by surface water and inundated only following heavy rain in the catchment. This association of wetland types is unique in Australia.

The Lake MacLeod System was selected as a study site for the IAI RCM project because it is proposed for listing under the Ramsar International Convention on Wetlands as a Wetland of International Importance. Lake MacLeod is currently recognised as nationally significant and is listed in the Directory of Important Wetlands in Australia (DIWA) (Environment Australia 2001). DIWA recognises Lake MacLeod as 'an outstanding example of a major coastal lake that is episodically inundated by fresh water, and includes permanent saline wetlands and inland mangrove swamps that are maintained by subterranean waterways'. The lake is also a major migration stop-over and drought refuge area for shorebirds. Finally, the area supports Australia's largest inland community of mangroves and associated fauna.

The current report considers two sites within the Lake MacLeod System: Jacks Vent and Goat Bay. These are both areas where 'vents' maintain a subterranean connection between the ocean and the lake. They are within the northern part of the system, known as the 'Northern Ponds' (Figure 2).

1.1. Site Code

Directory of Important Wetlands in Australia: WA009.

Register of the National Estate Place ID: 10784.

Inland Aquatic Integrity Resource Condition Monitoring Project (DEC):

Jacks Vent - RCM029A;

Goat Bay – RCM029B.

Carnarvon Basin Survey (DEC):

Jacks Vent – CBS079;

Goat Bay – CBS076.

1.2. Purpose of a Resource Condition Report

The objective of this RCR is to supplement the Lake MacLeod Ecological Character Description (ECD) (unpublished) by providing the results of a survey conduced at the site in October 2008. While a brief overview of the entire wetland system is provided in this report, the survey results will concentrate on Jacks Vent and Goat Bay. It is recommended the reader refer to the Lake MacLeod ECD for more detailed information on the system and for data collected in previous surveys.

1.3. Relevant Legislation and Policy

The following is a summary of legislation and policy that may be relevant to the management of the Lake MacLeod System.

International

Migratory bird bilateral agreements and international conventions

Australia is party to a number of bilateral agreements, initiatives and conventions for the conservation of migratory birds and wetlands that are relevant to the Lake MacLeod System. The bilateral agreements are:

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

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

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

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

Convention on Wetlands (Ramsar) - Australia a signatory to the Ramsar Convention, an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. The Lake MacLeod System, in particular the northern ponds, is proposed for listing under the Ramsar Convention so this convention may have further relevance in the future.

National legislation

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

The EPBC Act is the Australian Government's principal 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. Of these, one applies at Lake MacLeod: migratory species listed under international treaties JAMBA, CAMBA and CMS.

The northern portion of the Lake MacLeod System is also a proposed Ramsar site (Figure 3). If this listing is achieved, the site will be further protected under the EPBC Act as a wetland of international significance.

Western Australian state legislation

Wildlife Conservation Act 1950

The Wildlife Conservation Act provides for the protection of flora and fauna in Western Australia. All fauna are protected under section 14 and all flora are protected under section 23 of the Act. The Act establishes licensing frameworks for the taking and possession of protected fauna, and establishes offences and penalties for interactions with fauna.

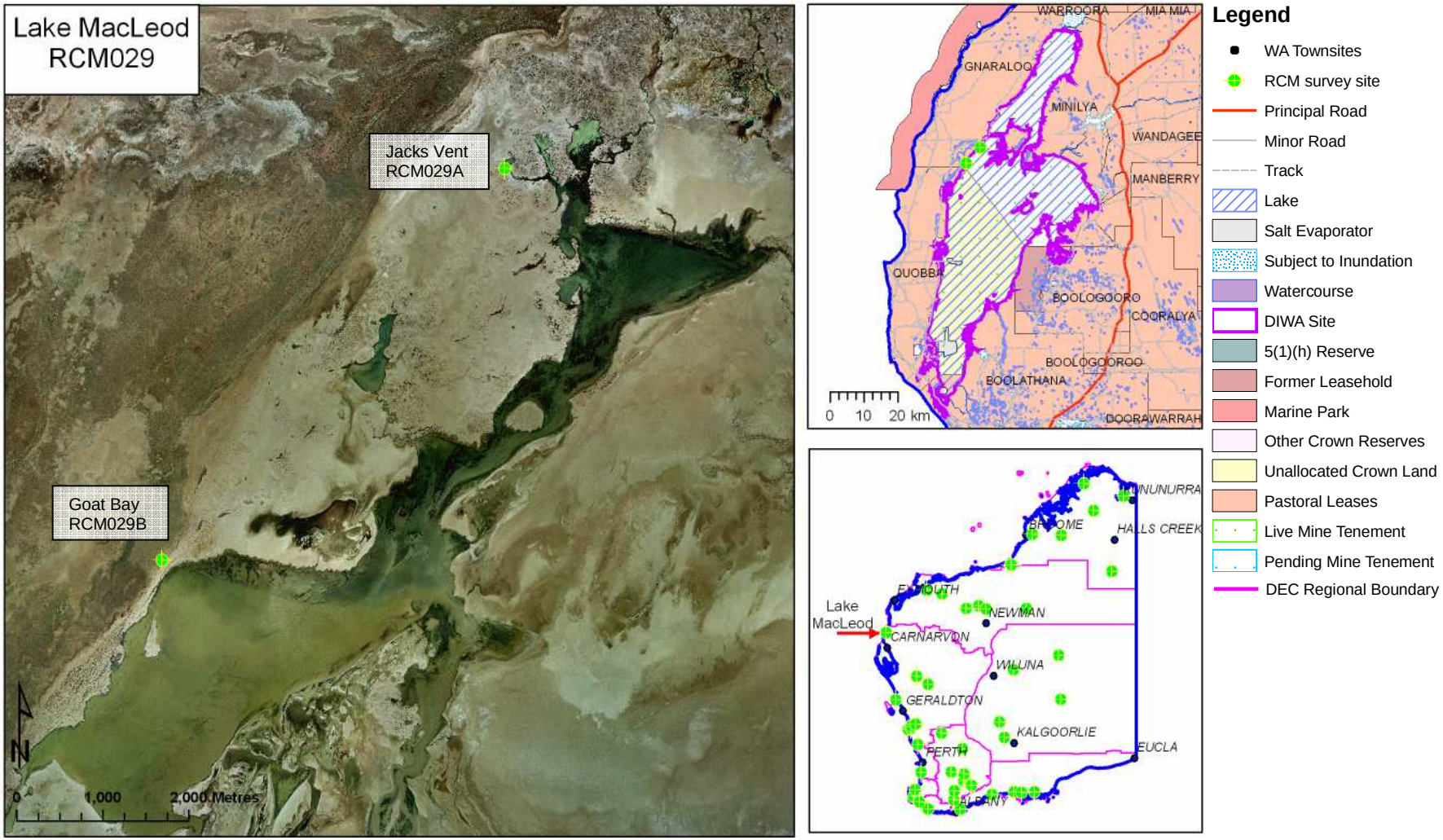

Figure 2 – Aerial photograph showing the survey locations at Lake MacLeod. The upper insert provides cadastral information about the lake and its surrounds. The lower insert shows the location of the lake in Western Australia and its proximity to other RCM survey sites.

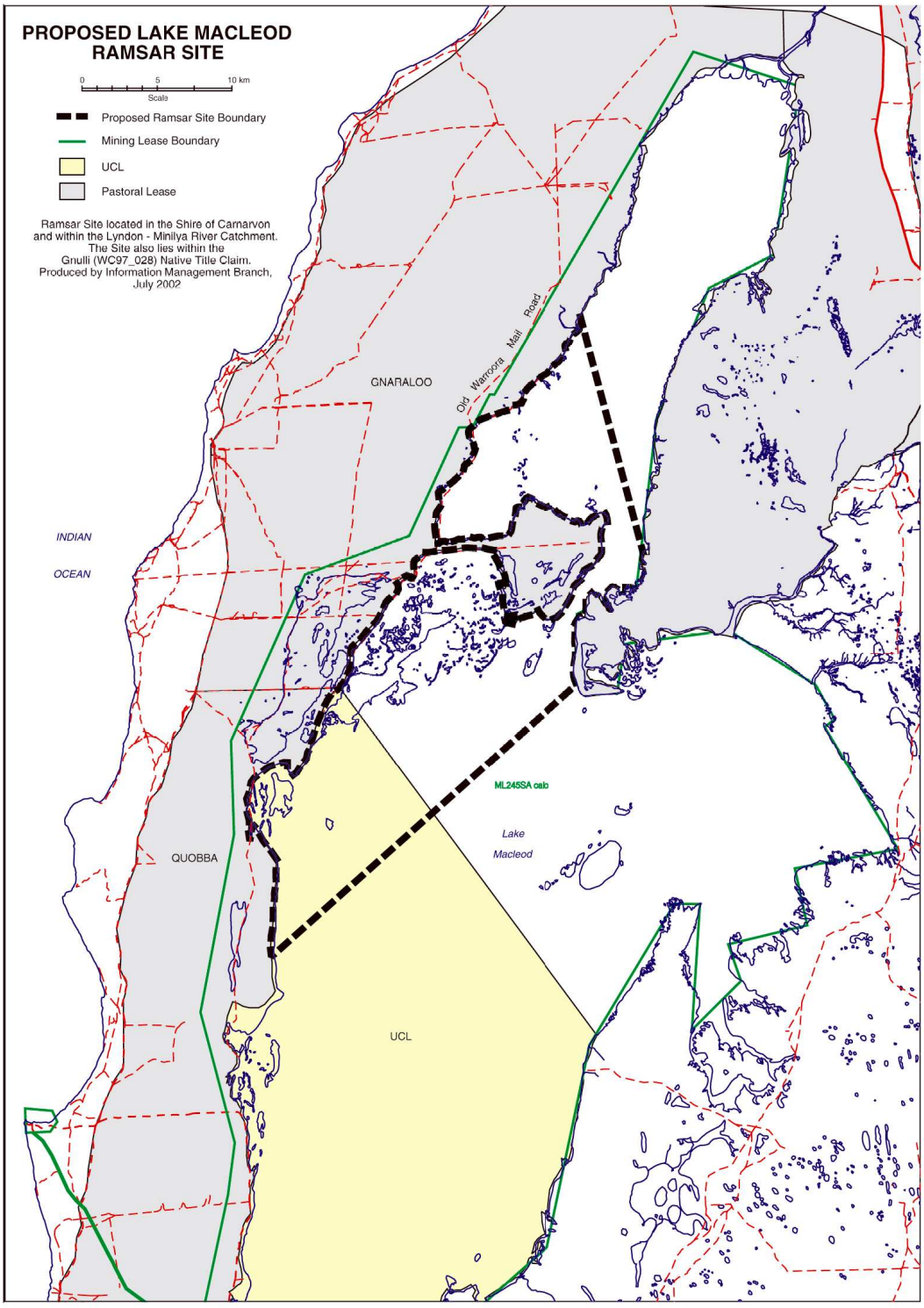

Figure 3 – The Lake MacLeod System, showing the proposed Ramsar site.

2. Overview of the Lake MacLeod System

2.1. Location and Cadastral Information

The Lake MacLeod system includes distinct 'inner wetlands' (sinkholes, channels, lakes, marshes) in the west and 'floodout marshes' at river mouths in the north east, as well as the lake bed (Jaensch, 1992). The southern extent of the system is approximately 30 km north northwest of Carnarvon and, from here, the main lake body runs parallel to the coast for approximately 120 km. The total area covered by the wetland system is approximately 2,000 km^2.

The Lake MacLeod System straddles the Gnaraloo, Minilya, Quobba, Boologoora and Boolathana pastoral leases. The southern half of the lake floor is Unallocated Crown Land, while the northern half is a 'water feature' that is not vested in any management authority. Dampier Salt Pty Ltd holds a live mining tenement over the entire system and runs a salt mine at the southern end of the lake bed. There is also a small aquaculture venture in that area, farming the alga *Dunaliella salina.*

2.2. IBRA Region

The Lake MacLeod System lies at the north west of the Carnarvon Interim Biogeographic Regionalisation of Australia (IBRA) region. The Carnarvon subregion consists of quaternary alluvial, aeolian and marine sediments overlying Cretaceous strata. Vegetation of the subregion includes mosaics of saline alluvial plants with samphire and saltbush low shrublands; Bowgada low woodland on sandy ridges and plains; snake wood shrubs on clay flats; and tree to shrub steppe over hummock grasslands on red sand dune fields. Limestone strata with *Acacia startii/bivenosa* shrublands outcrop in the north of the subregion, with extensive tidal flats in sheltered embayments.

2.3. Climate

The nearest Bureau of Meteorology weather station to Lake MacLeod is at Carnarvon Airport, approximately 50 km to the south (Bureau of Meteorology 2009). Carnarvon experiences a semi-arid climate, with a mean annual rainfall of 228 mm. Rainfall is most reliably received between May and July, but summer storms can occur in association with the passage of tropical lows or cyclones. Temperatures peak in February with mean maxima/minima of 32.5 ºC/23.3 ºC and fall to 22.2 ºC/11 ºC in July (Figure 4). Mean annual evaporation is 3,212 mm. In the twelve months preceding the IAI RCM survey of the Lake MacLeod System, Carnarvon Airport received 228.2 mm of rain.

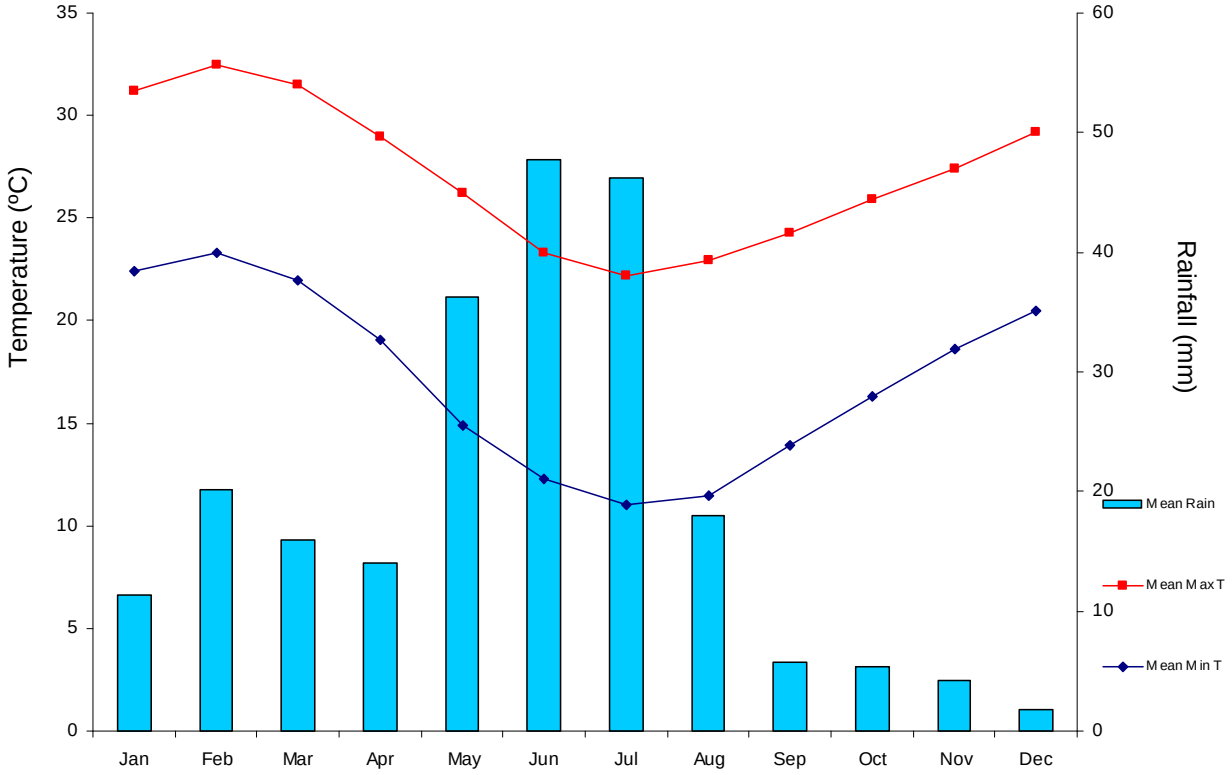

Figure 4 – Climatic means for Carnarvon Airport, 50 km south of Lake MacLeod.

2.4. Wetland Type

The Directory of Important Wetlands in Australia (Environment Australia 2001) describes the Lake MacLeod System as comprising eight main wetland types:

- Permanent saline/brackish lakes (type B7).
- Seasonal/intermittent saline lakes (type B8).
- Inland sub-terrain karst wetlands (type B19).
- Salt exploitation, salt pans, saline (type B4).
- Permanent saline/brackish marshes (type B11).
- Seasonal saline marches (type B12).
- Seasonal/intermittent freshwater ponds and marches on inorganic soils; includes sloughs, potholes; seasonal flooded meadows, sedge marshes (type B10).
- Intertidal forested wetlands; includes mangrove swamps, nipa swamps, tidal freshwater swamp forests (type A9).

The northern pools, where surveys for this report were conducted, comprise intermittently inundated, brackish to saline flats surrounding a series of saline springs and associated permanent saline channels and lagoons.

2.5. Directory of Important Wetlands in Australia Criteria

The Lake MacLeod System is currently identified as a wetland of national importance under criteria 1, 2, 3, 4 and 6 of the Directory of Important Wetlands in Australia (DIWA). These criteria are as follows:

1. It is a good example of a wetland type occurring within a biogeographic region in Australia.

   The Lake MacLeod System is an outstanding example of a major coastal lake that is episodically inundated by fresh water, which includes permanent saline wetlands and inland mangrove swamps that are maintained by subterranean waterways - a unique assemblage of wetland types in Australia.

2. It is a wetland that plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex.

3. It is a wetland that is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail.

   *The Lake MacLeod system is a major migration stop-over and drought refuge area for shorebirds, including Banded Stilt (*Caldorhynchus leucocephalus*), Curlew Sandpiper (*Calidris ferruginea*) and Red-necked Stint (*Calidris rufilcollis*). It also supports Australia's largest inland community of mangroves and associated fauna.*

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

   Surveys at Lake MacLeod have recorded as many as 111,600 shorebirds and 114,956 waterbirds belonging to fifty-eight different species. The system supports more than 1% of the national population of the following shorebirds:

   - *Banded Stilt (*Cladorhynchus leucocephalus*);*
   - *Curlew Sandpiper (*Calidris ferruginea*);*
   - *Red-necked Stint (*Calidris ruficollis*);*
   - *Red Knot (*Calidris canutus*);*
   - *Pied Cormorant (*Phalacrocorax melanoleucos);
   - *Red-necked Avocet (*Recurvirostra novaehollandiae*);*
   - *Red -capped Plover (*Charadrius ruficapillus*); and*
   - *Australian Pelican (*Pelecanus conspicillatus*).*

6. The wetland is of outstanding historical or cultural significance.

3. Results of the IAI RCM Survey at Lake MacLeod

Lake MacLeod was surveyed by the IAI RCM project on 11th October 2008. The objective of the survey was to document the vegetation, water chemistry, aquatic fauna and impacts of threatening processes at Jacks Vent and Goat Bay. The results this survey discussed below.

3.1. Water Chemistry

The chemical properties of water in the Lake Macleod System are strongly influenced by the hydrological influxes to the system. There are two main sources of water for the lake: subterranean vents that connect with the ocean and rivers that arise in the Gascoyne. Water from each of these sources has properties that are quite different from the other.

Along the north western margin of the main lake are several ‘vents’ that provide a subterranean connection to the ocean. These vents are lower than sea level, allowing water to flow through fractures in the bedrock into the lake under hydrostatic pressure. The areas surrounding these vents are permanently

inundated by water with very similar chemical properties to seawater. Water flows away from the vents into the body of the main lake, where salts and other chemicals are concentrated by evaporation.

The other major input of water to the Lake MacLeod System is relatively fresh water inflow from a number of creeks and rivers on the lake's eastern side. The Minilya and Lyndon River catchments drain into Lake MacLeod following heavy rainfall events, usually associated with the passage of tropical cyclones. This water is relatively fresh but may be somewhat nutrient enriched.

The two locations surveyed by the IAI RCM project are both within the area of marine influence. Jack's Vent is located directly at a vent and the water here was very similar in composition to seawater (pH 9.79, TDS 39 gL^{-1}). Goat Bay is nearby, in an area where ions in the water are evapoconcentrated as water moves from the vents onto the main lake floor. Water chemistry here reflected this process of evapoconcentration (pH 7.97, TDS 50 gL^{-1}). Nutrient concentrations at both locations were low (Table 1), reflecting the lack of recent river flow (Table 1).

Table 1 – Water chemistry parameters recorded during the Carnarvon Basin Surveys (CBS) and Inland Aquatic Integrity Resource Condition Monitoring project survey (RCM) at Lake MacLeod.

	CBS076 Aug 1994	CBS076 Mar 1995	RCM029B Oct 2008	CBS079 Oct 1994	CBS079 Mar 1995	RCM029A Oct 2008
pH	8.2	7.9	7.97	7.3	7.2	9.79
Alkalinity (mg/L)			130			130
TDS (g/L)	46	53	50	41	40	39
Turbidity (NTU)	0.26	3.6	1	0.05	0.6	0.25
Colour (TCU)	9	13	8	12	17	3
Total nitrogen (ug/L)			470			460
Total phosphorus (ug/L)			5			5
Total soluble nitrogen (ug/L)	510	550	380	480	280	270
Total soluble phosphorus (ug/L)	10	10	5	5	5	5
Chlorophyll (ug/L)	42	2	2	0	0	2
Na (mg/L)			15,800			12,300
Mg (mg/L)			1,890			1,480
Ca (mg/L)			638			487
K (mg/L)			580			447
Cl (mg/L)			26,600			21,300
SO4 (mg/L)			4,140			3,150
HCO3 (mg/L)			159			159
CO3 (mg/L)			0.5			0.5

3.2. Benthic Plants

Aquatic plants were not collected at either survey location. Algal mats were observed at both Jacks Vent and Goat Bay, but the species of algae was not identified.

3.3. Littoral Vegetation

There were three vegetation transects established: one adjacent to Jacks Vent, the other two at Goat Bay. The location and attributes of these transects are summarised in Table 2 and expanded on in the following subsections.

Table 2 –Attributes of the vegetation transects established at Lake MacLeod by the Inland Aquatic Integrity Resource Condition Monitoring project.

Transect name		RCM029A-R1 (Jack's Vent 1)	RCM029B-R1 (Goat Bay 1)	RCM029B-R2 (Goat Bay 2)
Datum		WGS84	WGS84	WGS84
Zone		49	49	49
Easting		769671	765672	765718
Northing		7352191	7347644	7347607
Length		30 m	30 m	50 m
Bearing		0	210	210
Wetland state		Full	Full	Full
Soil state (%)	Dry	0	100	0
	Waterlogged	100	0	100
	Inundated	0	0	0
Substrate (%)	Bare	5	60	95
	Rock	0	0	0
	Cryptogam	0	0	0
	Litter	1	2	0
	Trash	1	0	0
	Logs	0	0	0
Time since last fire		no evidence	no evidence	no evidence
Community condition		Natural	Natural	Natural
Upper Stratum	Cover (%)	4.43333	-	2.83773
	Height (m)	1	-	1.5
Mid Stratum	Cover (%)	89.8333	39.2333	2.36
	Height (m)	<0.5	<0.5	<0.4
Ground Cover	Cover (%)	-	-	-
	Height (m)	-	-	-

Jacks Vent Transect RCM029A-R1

This transect was established in vegetation on the margins of Jacks Vent, a pool where seawater enters the lake system (Figure 4). The clay soils were waterlogged at the time of survey. The tallest vegetative stratum was *Avicennia marina* low sparse mangrove shrubland (4.4% cover, 1 m tall). However, vegetation along the transect was dominated by *Tecticornia peltata*, *T. pruinosa*, *T. pergranulata* low closed samphire shrubland (89.8% cover, <0.5 m tall). Table 3 provides a complete list of taxa recorded along the transect RCM029A-R1.

The mangroves on the transect were all young plants no taller than 1 m. Dead mangroves, which are up to 3 m tall, were abundant near the water's edge (Figure 5). These deaths were caused by a flooding event in February/March 2000 (D. Bauer pers. comm.). This disturbance is part of the natural ecology of the lake, and so, the overall community condition was considered 'natural' (Table 9).

Further back from Jacks Vent the mudflats were largely devoid of vegetation, with occasional clumps of samphires and mangroves.

Figure 4 – Samphire shrubland along vegetation transect RCM029A at Jack's Vent.

Figure 5 – Mangrove deaths near vegetation transect RCM029A-R1.

Table 3 – Plant taxa recorded on the Jacks Vent vegetation transect RCM029A-R1 (in order of stratum then dominance).

Genus	Species	Height (m)	Stratum[1]	Form
Avicennia	*marina*	2	U1	Shrub
Tecticornia	*peltata*	0.4	M1	Chenopod
Tecticornia	*pruinosa*	0.4	M1	Chenopod
Tecticornia	*?pergranulata*	0.4	M1	Chenopod
Muellerolimon	*salicorniaceum*	0.2	M1	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 (ESCAVI 2003).

? Limited confidence in identification.

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

U1 ^*Avicennia marina*\shrub (mangrove)\3\r; M1+ ^*Tecticornia peltata*, *T. pruinosa*, *T. ?pergranulata*, *Muellerolimon salicorniaceum*\samphire shrub, shrub\1\d.

Goat Bay Transect RCM029B-R1

This transect was established approximately 80 m from the water's edge at Goats Bay to the west of the main lake. The soil was waterlogged at the time of survey. Vegetation was dominated by *Tecticornia halocnemoides*, *T.* sp., M*uellerolimon salicorniaceum* low open shrubland (39.2% cover, <0.5 m tall). Table 4 provides a complete list of taxa recorded along the transect RCM029B-R1.

Despite the presence of stock and feral goats in the area, no significant degradation of the vegetation was evident. The overall community condition was considered 'natural' (Table 9).

The landscape surrounding Goat Bay is generally flat and samphire-dominated vegetation covers large expanses (Figure 6). Further from the water's edge at Goat Bay, low shrubland continues but samphires become less dominant. Shrubs common to this area include *Atriplex vesicaria*, *A. amnicola*, *Frankenia pauciflora*, *F. cinerea*, *Neobassia astrocarpa* and *Maireana appressa*. The grasses *Eragrostis dielsii* and *E. pergracilis* were also abundant. *Acacia synchronicia* forms a taller shrub layer nearby dune tops.

Figure 6 – Samphire-dominated vegetation along vegetation transect RCM029B-R1.

Table 4 – Plant taxa recorded along Goats Bay vegetation transect RCM029B-R1 (in order of dominance).

Genus	Species	Height (m)	Stratum[1]	Form
Tecticornia	*halocnemoides*	0.4	M1	Chenopod
Tecticornia	sp.	0.4	M1	Chenopod
Muellerolimon	*salicorniaceum*	0.3	M1	Shrub
Tecticornia	*auriculata*	0.3	M1	Chenopod

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 (ESCAVI 2003).

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

M1+ ^Tecticornia halocnemoides, T. sp., Muellerolimon salicorniaceum\samphire shrub, shrub\1\i.

Transect RCM029B-R2

The second transect at Goats Bay was established approximately 20 m from the water's edge (Figure 7). The substrate was waterlogged at the time of survey. Vegetation at this site was very sparse and dominated by *Avicennia marina* mid-high sparse shrubs (2.8% cover, 1.5 m tall) over low isolated clumps of *Tecticornia halocnemoides* and *T. auriculata* (2.4% cover, <0.4 m tall). No further taxa were recorded along the transect (Table 5).

As with the mangroves at Jacks Vent, most large individuals around the area (some up to 4 m tall) had been killed by the flooding event in the year 2000. Despite this impact, the overall community condition was considered 'natural' (Table 9).

Figure 7 – Goats Bay vegetation transect RCM029B-R2.

Table 5 – Plant taxa recorded along Goats Bay vegetation transect RCM029B-R2 (in order of stratum then dominance).

Genus	Species	Height (m)	Stratum[1]	Form
Avicennia	*Marina*	1.5	U1	Shrub
Tecticornia	*Halocnemoides*	0.4	M1	Chenopod
Tecticornia	*auriculata*	0.3	M1	Chenopod

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 (ESCAVI 2003).

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

NVIS

U1+ ^*Avicennia marina*\shrub (mangrove)\3\r; M1 ^*Tecticornia halocnemoides*, *T. auriculata*\samphire shrub\1\bc.

3.4. Aquatic Invertebrates

Several locations in the Lake MacLeod System were surveyed for aquatic invertebrates during the Carnarvon Basin Survey (Halse *et al*.2000). Site CBS076 is located within a few hundred metres of RCM029B in the same embayment. CBS079 ("Blue Holes"), if not Jack's Vent, is certainly very close to it and is the same type of habitat. Samples were also collected from two other locations (CBS077 and CBS078) in the lake by Halse *et al*. (2000). For both of the IAI RCM survey locations, macroinvertebrate family and species richness (Table 6) are similar to those recorded by Halse *et al*. (2000), but show greater polychaete diversity (Table 7).

Specimens collected during the Carnarvon Basin Survey were not available to compare with specimens collected during the IAI RCM project. This means that some species of invertebrates listed below may be duplicates, particularly for molluscs. This may explain the inconsistency in mollusc species between projects. Excluding this uncertainty, forty-four taxa have been recorded from these locations. The fauna is dominated by crustaceans and polychaetes and is largely marine in taxonomic affinity. Thus, many species belong to marine families and genera, and some are probably marine species, particularly the crustaceans, molluscs and polychaetes. *Neocyclops petovskii* is the only species of the *Neocyclops* genus known from Australian inland waters and the Lake MacLeod System the only locality where this species has been recorded. There are some species of this genus known from inland salt lakes elsewhere, including insects such as the rotifer *Keratella australis*, copepod *Onychocamptus bengalensis* and chironomid *Kiefferulus longilobus* (though the latter two tend to be coastal species). *Kiefferulus longilobus* is a relatively uncommon species.

Table 6 – Summary of the findings of surveys of aquatic invertebrate richness conducted at Lake MacLeod by the Carnarvon Basin Survey and Inland Aquatic Integrity Resource Condition monitoring project.

Diversity measure	Carnarvon Basin Survey		RCM Survey	Carnarvon Basin Survey		RCM Survey
	Goat Bay		Goat Bay	Jacks Vent?		Jacks Vent
	Aug 1994	Mar 1995	Oct 2008	Oct 1994	Mar 1995	Oct 2008
Total invertebrate species richness	14	16		17	21	
Macroinvertebrate species richness	5	8	5	11	10	18
Total invertebrate family richness	12	16		17	19	
Macroinvertebrate family richness	5	8	11	11		17

Table 7 – Aquatic invertebrates recorded during the Carnarvon Basin Surveys (CBS) and Inland Aquatic Integrity Resource Condition Monitoring project survey (RCM) at Lake MacLeod.

Class	Order	Family	Lowest ID	CBS076 Aug 1994	CBS076 Mar 1995	CBS079 Oct 1994	CBS079 Mar 1995	RCM029A Oct 2008	RCM029B Oct 2008
Nematoda			Nematoda	+	+		+		
Rotifera	Ploimida	Brachionidae	*Keratella australis*			+			
Gastropoda	Neotaeniglossa	Bithynidae	*Gabbia* sp. B (CB)		+				
		Truncattidae	*Truncatella* cf. *guerinii* (CB)				+		
		Marginellidae	Marginellidae		+	+	+		
	Opisthobranchia	Scaphandridae	*Arcteocina* sp.	+	+	+	+		
		Diaphanidae	Diaphanidae		+	+			
		Ituminoeidae	*Liloa brevis*					1,2,3	
	-	-	Gastropoda sp.1					1,2,3	
			Gastropoda sp.2					1,2,3	
Bivalvia	Veneroida	Laternulidae	*Laternula* cf. *anatina* (CB)			+			
	-	-	Bivalvia	+			+		
Polychaeta	-	Nereidae	Nereidae			+	+,2		2
		Capitellidae	Capitellidae				+,2,3	1,2,3	2,3
		Orbiniidae	Orbiniidae		+	+	+		1,2,3
		Syllidae	Syllidae				+,3		
		Eunicidae	Eunicidae					1,3	1,3
		Polynoidae	Polynoidae		+		2		2,3
Arachnida	Parasitiformes	-	Mesostigmata					1,2	
Crustacea	Decapoda	-	*Decapoda* sp.			+		3	2,3
	Ostracoda	Candonidae	*Phlyctenophora* cf. *zealandia* (CB)	+	+	+	+		
		Trachyleberididae	*Actinocythereis scutigera*	+	+				
		Paradoxostomidae	*Paradoxostoma* sp. 429 (CB)		+		+		
		Pectocytheridae	*Mckenzieartia portjacksonensis* (CB)				+		
Crustacea	Copepoda	Acartidae	*Acartia* sp. 357 (CB)	+	+		+		
		Cyclopidae	*Neocyclops petovskii*	+	+	+	+		
		Canthocamptidae	*Nannomesochra arupinensis*				+		

Class	Order	Family	Lowest ID	CBS076 Aug 1994	CBS076 Mar 1995	CBS079 Oct 1994	CBS079 Mar 1995	RCM029A Oct 2008	RCM029B Oct 2008
		Laophontidae	*Onychocamptus bengalensis*	+	+		+		
		Diosaccidae	*Robertsonia mourei*	+	+		+		
			Robertsonia propinqua	+		+	+		
			Amphiascoides subdelis	+					
			Amonardia sp. n. (CB)				+		
		Ameiridae	*Ameira* sp. 308 (CB)			+	+		
		Lourinidae	*Lourinia armata*	+					
		Tisbidae	*Tisbella timsae*		+				
		-	*Harpacticoida* sp 415 (CB)			+			
	Amphipoda	Paracalliopiidae	Paracalliopidae	+	+	+	+	1	2,3
		Tanaidacea	Tanaidacea RCM sp.1					1,2,3	1,2,3
		Paramelitidae	Paramelitidae	+		+	+		
Insecta	Coleoptera	Hydrophilidae	*Enochrus elongatus*			+			
			Hydrophilidae				+		
	Diptera	Ceratopogonidae	Ceratopogonidae				+		
		Stratiomyidae	Stratiomyidae				+	1,3	3
		Ephydridae	Ephydridae					1,3	1
		Chironomidae	*Tanytarsus barbitarsis*					3	3
			Kiefferulus longilobus					3	
	Hemiptera	Saldidae	*Pentacora* sp.			+			

Shading indicates microinvertebrate species not identified for the RCM project.
+ indicates presence in Carnarvon Basin Survey samples, numbers indicate presence in samples 1, 2 or 3 of the RCM sampling.
The CB (Carnarvon Basin Survey) samples each consisted of a 50 m benthic sweep using a net with 250 µm mesh plus a 50 m plankton sample using a net with 50 µm mesh.
The three RCM samples (samples 1, 2 and 3 in the RCM columns) were replicate 15 m benthic sweeps (bare sediment) using a net with 250 µm mesh.

3.5. Waterbirds

Waterbirds were not counted as part of the IAI RCM survey at Jacks Vent and Goat Bay.

3.6. Other Fauna

Fish were observed at both Jacks Vent (Halse *et al.* 2000) and Goat Bay (Figure 8). The species of fish were not formally identified, but are believed to be Flag Tail Grunter (*Amniataba caudovittata*), Mangrove Jack (*Lutjanus argentimaculatus*) and a species of mullet (possibly *Mugil cephalus*).

There was no evidence of other terrestrial vertebrate fauna within the wetland.

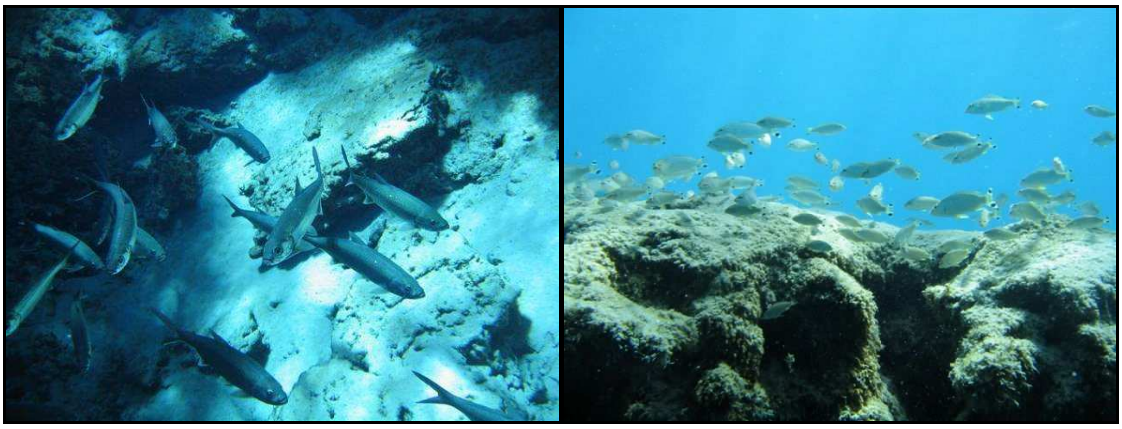

Figure 8 –Fish observed at Jacks Vent within the Lake MacLeod System. The image on the left shows the species thought to be *Mugil cephalus* and the one on the right shows the species thought to be Flag Tail Grunter (*Amniataba caudovittata*).

4. Threats to Ecology of the Lake MacLeod System

An analysis of threats to the ecology of Lake MacLeod was completed in 2008. Disturbance from human visits was identified as the most significant threat to the system, followed by introduced fish, predation of waterbirds by carnivores, livestock and feral animal grazing, increased turbidity and extraction of salt and gypsum. A number of more minor threats were also discussed.

Based on the findings of the IAI RCM project, the threat analysis overstates the threat posed by human visitation of the northern vents. It seems unlikely that significant numbers of visitors will travel the difficult access road because the lake has very limited recreational appeal in comparison to the nearby coastline.

It is possible that the threat posed by the introduced fish tilapia (*Oreochromis mossambica*) has also been exaggerated. Although its absence from the lake cannot be confirmed, it has never been credibly recorded there and was not observed during two visits be the IAI RCM project. Tilapia are known to occur in the Gascoyne catchment and there is an ongoing risk they may become established in the lake.

The result of prioritising the threats posed by human visitors and feral fish is that the threat posed by mining has been deemphasised. The southern end of Lake MacLeod has been used by Dampier Salt Ltd for commercial salt production since 1978. In 1997, Dampier Salt also began mining gypsum adjacent to the salt mine, although the gypsum operation is currently suspended. To date, salt production has involved pumping groundwater onto the lake surface, allowing it to evaporate and then collecting the crystallised salt. This carries a minor risk of disturbing the hydrology of the system. However, Dampier salt is currently considering increasing production by mining the profile beneath the lake bed (Chris McQuade pers. comm.). Doing so will require dewatering the profile, with potentially far more serious consequences than current water extraction.

Pastoral leases surround Lake MacLeod (Jaensch 1992). Goats and sheep were seen in the paddocks adjacent to both Jacks Vent and Goat Bay. However, little evidence of grazing was observed and the impact of livestock and feral goats on the wetland appeared minimal.

Mangrove deaths near the water's edge were evident at both Jacks Vent and Goats Bay. These were caused by a flooding event in February/March 2000 (D. Bauer pers. comm.). Flooding events are part of the natural ecology of the wetland and regeneration appears to be occurring.

Numerous tyre tracks were observed at Jacks Vent. If unmanaged, vehicle access has the potential to caused significant impacts such as erosion, introduction of weeds, and vegetation damage, as well creating permanent tracks that could facilitate greater visitation to the site.

More information on threats to Lake MacLeod is available in the Lake MacLeod Ecological Character Description and Lake MacLeod Management Plan. Both of these documents are currently in draft.

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Appendix - Vegetation Data

Plant specimens submitted to the WA Herbarium:

Tecticornia auriculata (RCM029b-R1-01)

Table 8 – Herbarium Records for Lake MacLeod.

Search Coordinates: NW corner: 23.4996°S, 113.448° E; SE corner: 24.5471°S, 114.0083°E

Family	Species	Alien	Cons. Status
Acanthaceae	*Dicladanthera forrestii*		
	Dipteracanthus australasicus subsp. *australasicus*		
Acarosporaceae	*Acarospora* sp.		
Aizoaceae	*Tetragonia diptera*		
Amaranthaceae	*Alternanthera nodiflora*		
	Hemichroa diandra		
	Ptilotus alexandri		P2
	Ptilotus chamaecladus		
	Ptilotus divaricatus		
	Ptilotus exaltatus var. *exaltatus*		
	Ptilotus gomphrenoides var. *conglomeratus*		
	Ptilotus macrocephalus		
	Ptilotus obovatus		
	Ptilotus obovatus var. *obovatus*		
	Ptilotus polakii		
Anthericaceae	*Arthropodium* sp.		
	Corynotheca pungens		
	Murchisonia sp.		
	Murchisonia volubilis		
	Thysanotus speckii		
Apiaceae	*Neosciadium glochidiatum*		
	Trachymene elachocarpa		
Asclepiadaceae	*Marsdenia australis*		
	Marsdenia graniticola		
	Rhyncharrhena linearis		
Asphodelaceae	*Asphodelus fistulosus*	Y	
Asteraceae	*Angianthus acrohyalinus*		
	Angianthus milnei		
	Angianthus tomentosus		
	Brachyscome cheilocarpa		
	Brachyscome latisquamea		
	Brachyscome oncocarpa		
	Calocephalus francisii		
	Calocephalus multiflorus		

Family	Species	Alien	Cons. Status
Asteraceae	*Calotis multicaulis*		
	Centipeda minima subsp. *macrocephala*		
	Centipeda thespidioides		
	Chondropyxis halophila		
	Chthonocephalus spathulatus		P1
	Chthonocephalus tomentellus		P2
	Cratystylis subspinescens		
	Decazesia hecatocephala		
	Flaveria australasica		
	Gnephosis arachnoidea		
	Gnephosis brevifolia		
	Gnephosis eriocephala		
	Gnephosis gynotricha		
	Gnephosis tenuissima		
	Helipterum craspedioides		
	Hypochaeris glabra	Y	
	Millotia myosotidifolia		
	Myriocephalus gascoynensis		
	Myriocephalus oldfieldii		
	Olearia dampieri subsp. *dampieri*		
	Pembertonia latisquamea		
	Pluchea rubelliflora		
	Podolepis canescens		
	Podolepis microcephala		
	Podotheca angustifolia		
	Rhodanthe chlorocephala subsp. *splendida*		
	Rhodanthe citrina		
	Rhodanthe humboldtiana		
	Rhodanthe maryonii		
	Rhodanthe psammophila		
	Rhodanthe stricta		
	Schoenia ayersii		
	Senecio conferruminatus		
	Streptoglossa liatroides		
Avicenniaceae	*Avicennia marina*		
Boraginaceae	*Heliotropium crispatum*		
	Trichodesma zeylanicum		
Brassicaceae	*Brassica tournefortii*	Y	
	Lepidium linifolium		
	Lepidium phlebopetalum		
	Stenopetalum pedicellare		
Caesalpiniaceae	*Labichea cassioides*		

Family	Species	Alien	Cons. Status
Caesalpiniaceae	*Senna artemisioides* subsp. aff. *helmsii*		
	Senna artemisioides subsp. *helmsii*		
	Senna glutinosa subsp. *chatelainiana*		
	Senna notabilis		
Campanulaceae	*Wahlenbergia* sp.		
	Wahlenbergia tumidifructa		
Ceramiaceae	*Nitella* sp.		
Chenopodiaceae	*Atriplex amnicola*		
	Atriplex codonocarpa		
	Atriplex holocarpa		
	Atriplex paludosa		
	Atriplex semilunaris		
	Chenopodium curvispicatum		
	Chenopodium gaudichaudianum		
	Chenopodium melanocarpum		
	Didymanthus roei		
	Dissocarpus paradoxus		
	Dysphania plantaginella		
	Enchylaena tomentosa var. *tomentosa*		
	Maireana aff. *amoena*		
	Maireana appressa		
	Maireana lanosa		
	Maireana pentagona		
	Maireana planifolia		
	Maireana tomentosa		
	Neobassia astrocarpa		
	Rhagodia latifolia subsp. *latifolia*		
	Sclerolaena eurotioides		
	Sclerolaena gardneri		
	Sclerolaena recurvicuspis		
	Sclerolaena tridens		
	Tecticornia disarticulata		
	Tecticornia doleiformis		
	Tecticornia halocnemoides		
	Tecticornia indica subsp bidens		
	Tecticornia indica subsp. *leiostachya*		
	Tecticornia peltata		
	Tecticornia pruinosa		
	Tecticornia pterygosperma subsp. *denticulata*		
	Threlkeldia diffusa		
Chloanthaceae	*Pityrodia paniculata*		
Cladophoraceae	*Chaetomorpha* sp.		

Family	Species	Alien	Cons. Status
Convolvulaceae	*Convolvulus angustissimus* subsp. *angustissimus*		
	Duperreya sericea		
	Porana sericea		
Cymodoceaceae	*Halodule uninervis*		
Cyperaceae	*Cyperus bifax*		
	Cyperus bulbosus		
	Eleocharis pallens		
Dasypogonaceae	*Acanthocarpus humilis*		
	Acanthocarpus verticillatus		
Euphorbiaceae	*Euphorbia australis*		
	Euphorbia drummondii subsp. *drummondii*		
	Phyllanthus fuernrohrii		
	Phyllanthus sp. Coastal North West (J.Z. Weber 4919)		
Frankeniaceae	*Frankenia cinerea*		
	Frankenia pauciflora		
	Frankenia sp.		
Goodeniaceae	*Dampiera incana* var. *incana*		
	Goodenia corynocarpa		
	Goodenia ochracea		
	Scaevola crassifolia		
	Scaevola cunninghamii		
	Scaevola sericophylla		
	Scaevola spicigera		
	Scaevola spinescens		
	Scaevola thesioides		
Gyrostemonaceae	*Gyrostemon ramulosus*		
Haloragaceae	*Haloragis gossei* var. *inflata*		
	Haloragis gossei var. *gossei*		
Lauraceae	*Cassytha aurea*		
	Cassytha aurea var. *aurea*		
	Cassytha capillaris		
Lobeliaceae	*Lobelia heterophylla*		
Lythraceae	*Lythrum wilsonii*		
Malvaceae	*Abutilon cunninghamii*		
	Abutilon otocarpum		
	Abutilon oxycarpum		
	Abutilon pritzelianum		
	Abutilon sp. Hamelin (A.M. Ashby 2196)		P2
	Alyogyne pinoniana		
	Hibiscus gardneri		
	Hibiscus sturtii		
	Lawrencia densiflora		

Family	Species	Alien	Cons. Status
Malvaceae	*Lawrencia viridigrisea*		
	Sida fibulifera		
	Sida kingii		
	Sida sp. Carnarvon (P.S. Short 2492)		
Meliaceae	*Owenia acidula*		P3
Mimosaceae	*Acacia ?* sp. Ripon Hills (B.R. Maslin 8460)		
	Acacia chartacea		
	Acacia coriacea subsp. *coriacea*		
	Acacia cuspidifolia		
	Acacia gregorii		
	Acacia ligulata		
	Acacia murrayana		
	Acacia ramulosa var. *linophylla*		
	Acacia ramulosa var. *ramulosa*		
	Acacia rostellifera		
	Acacia sclerosperma subsp. *sclerosperma*		
	Acacia spathulifolia		
	Acacia synchronicia		
	Acacia tetragonophylla		
	Acacia xiphophylla		
Myoporaceae	*Eremophila forrestii* subsp. *forrestii*		
	Eremophila mackinlayi subsp. *mackinlayi*		
	Eremophila maitlandii		
	Eremophila setacea		
Myrtaceae	*Calothamnus ? borealis*		
	Calothamnus borealis		
	Calytrix truncatifolia		
	Eucalyptus ? sp. Giralia Range (M.E. French 195)		
	Eucalyptus aff. *obtusiflora*		
	Eucalyptus dongarraensis		
	Eucalyptus eudesmioides		
	Eucalyptus fruticosa		
	Eucalyptus obtusiflora		
	Eucalyptus repullulans		
	Eucalyptus victrix		
	Malleostemon minilyaensis		
	Melaleuca cardiophylla		
	Melaleuca eleuterostachya		
	Melaleuca stereophloia		
	Pileanthus limacis		
	Pileanthus peduncularis subsp. *pilifer*		
	Thryptomene baeckeacea		

Family	Species	Alien	Cons. Status
Myrtaceae	*Verticordia forrestii*		
Najaceae	*Najas marina*		
Nyctaginaceae	*Commicarpus australis*		
Oleaceae	*Jasminum calcarium*		
Ophioglossaceae	*Ophioglossum lusitanicum*		
Papilionaceae	*Chorizema racemosum*		
	Cullen cinereum		
	Cullen lachnostachys		
	Daviesia benthamii subsp. *benthamii*		
	Daviesia hakeoides		
	Glycine canescens		
	Indigofera brevidens		
	Indigofera chamaeclada		
	Indigofera colutea		
	Leptosema macrocarpum		
	Lotus cruentus		
	Rhynchosia minima		
	Swainsona kingii		
	Swainsona pterostylis		
	Tephrosia gardneri		
Pertusariaceae	*? Pertusaria* sp.		
Physciaceae	*? Dirinaria* sp.		
	Buellia sp.		
	Dirinaria sp.		
	Physcia jackii		
	Pyxine petricola		
Pittosporaceae	*Pittosporum phylliraeoides*		
Poaceae	*Aristida holathera*		
	Aristida holathera var. *holathera*		
	Austrostipa crinita		
	Austrostipa elegantissima		
	Austrostipa nitida		
	Chloris virgata	Y	
	Cymbopogon obtectus		
	Enneapogon avenaceus		
	Eragrostis cumingii		
	Eragrostis dielsii		
	Eragrostis eriopoda		
	Eragrostis lanipes		
	Eragrostis pergracilis		
	Eragrostis setifolia		
	Eragrostis sp.		

Family	Species	Alien	Cons. Status
Poaceae	*Eragrostis xerophila*		
	Eriachne aristidea		
	Eriachne benthamii		
	Eriachne gardneri		
	Eriachne helmsii		
	Eriachne pulchella		
	Eriochloa pseudoacrotricha		
	Eulalia aurea		
	Iseilema eremaeum		
	Leptochloa fusca subsp. *muelleri*		
	Paractaenum novae-hollandiae		
	Paractaenum refractum		
	Setaria dielsii		
	Sporobolus mitchellii		
	Tragus australianus		
	Triodia basedowii		
	Triodia epactia		
	Triodia pungens		
	Triraphis mollis		
Polygonaceae	*Emex australis*	Y	
Portulacaceae	*Calandrinia disperma*		
	Calandrinia eremaea		
	Calandrinia sp.		
	Calandrinia sp. Truncate capsules (A. Markey & S. Dillon 3474)		
Primulaceae	*Muellerolimon salicorniaceum*		
	Samolus junceus		
Proteaceae	*Grevillea eriostachya*		
	Grevillea stenobotrya		
	Grevillea variifolia subsp. *bundera*		
	Grevillea variifolia subsp. *variifolia*		
	Hakea preissii		
Psoraceae	*Psora decipiens*		
Rhamnaceae	*Stenanthemum divaricatum*		P3
Rhodomeliaceae	*Polysiphonia* sp.		
Ruppiaceae	*Ruppia polycarpa*		
Santalaceae	*Exocarpos aphyllus*		
	Exocarpos sparteus		
	Santalum lanceolatum		
	Santalum spicatum		
Sapindaceae	*Alectryon oleifolius* subsp. *oleifolius*		
	Diplopeltis eriocarpa		

Family	Species	Alien	Cons. Status
Sapindaceae	*Diplopeltis intermedia*		
Solanaceae	*Anthocercis littorea*		
	Anthocercis sp. Shark Bay (T.E.H. Aplin 3335)		
	Datura leichhardtii	Y	
	Nicotiana occidentalis subsp. *obliqua*		
	Nicotiana sp.		
	Solanum ellipticum		
	Solanum lasiophyllum		
Stackhousiaceae	*Stackhousia clementii*		P1
Sterculiaceae	*Commersonia gaudichaudii*		
	Hannafordia quadrivalvis subsp. *recurva*		
	Hannafordia quadrivalvis subsp. *quadrivalvis*		
Surianaceae	*Stylobasium spathulatum*		
Teloschistiaceae	*Xanthoria parietina*		
Thelotremataceae	*Diploschistes* sp.		
Thymelaeaceae	*Pimelea microcephala*		
Tiliaceae	*Corchorus crozophorifolius*		
Tiliaceae	*Corchorus walcottii*		
Verrucariaceae	*Endocarpon* sp.		
Zygophyllaceae	*Tribulus forrestii*		
	Tribulus occidentalis		
	Zygophyllum compressum		
	Zygophyllum eremaeum		
	Zygophyllum fruticulosum		
	Zygophyllum retivalve		
	Zygophyllum simile		

Table 9 – Overall Vegetation Community Condition Rating as adapted from (Thackway and Lesslie 2005). Shading indicates the condition of Lake MacLeod.

Overall Community Condition Rating					
	0	**1**	**2**	**3**	**4**
	RESIDUAL BARE	**NATURAL**	**IMPACTED**	**DEGRADED**	**REMOVED / REPLACED**
Community Condition Class	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